Level 2 hands-off (L2H-off)

Project overview and results

Presentation in the 17th TF ADAS (19th January 2023)

fka CREATING IDEAS & DRIVING INNOVATIONS

ika RWTH AACHEN UNIVERSITY

Technische Universität München

Project Level 2 hands-off (L2H-off)

The project goal was to generate a **reliable set of data, information and knowledge** by combination of different methods to derive **recommendations for L2H-off in order to address challenges and questions** that have been raised regarding the use of L2H-off functions.

Project team

fka GmbH
Johanna Josten & Philipp Seewald
(Project management)

Institute for Automotive Engineering, RWTH Aachen University
Prof. Dr.-Ing. Lutz Eckstein

fka SV Inc.

Chair of Ergonomics, Technical University of Munich
Prof. Dr. phil. Klaus Bengler

Project assigned by VDA

Milestones of the L2H-off project (as presented in 14th TF ADAS)

Sep 21	*09/2021 Project started*	
Oct		
Nov		11/2021 Data collection concept defined
Dec 21	12/2021 Expert study USA: field data collection (SP 3)	
Jan 22		01/2022 State of the art review completed (SP 1)
Feb		
Mar	03/2022 Data collection FOT DE started (SP 3)	
Apr		04/2022 L2 US user survey started (SP 3)
May	05/2022 FOT DE data collection completed (SP 3)	
Jun	06/2022 Controlled studies on L2 design hypotheses started (Study 1-3; SP 4)	06/2022 Analysis of existing field data completed (SP 2)
Jul		
Aug	08/2022 Data collections completed (SP 3 / SP 4)	08/2022 Anchor study USA - DE (Study 4; SP 4)
Sep		
Oct 22	10/2022 Recommendations derived (SP 5)	*Final Event*

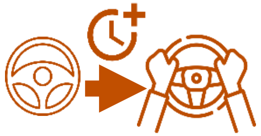
Motivation for the project

Potential Challenges and Questions (CQs)

Challenges and questions potentially related to a hands-free use of L2 functions (focus on interaction behavior):

- **CQ1: Hands-off = mind-off?**
  - There are concerns that a lack of driver involvement in the driving task (exacerbated by the lack of contact with the steering wheel during use of L2H-off functions) will reduce the driver's attention to the driving task.

- **CQ2: Prolonged transition times**
  - There are concerns that hands-on (reaction) times (returning hands to the steering wheel) as well as longer reaction times in general lead to an increased risk of accidents.



- **CQ3: Foreseeable misuse**
  - There are concerns that the use of L2H-off functions will lead to foreseeable misuse or to disuse, particularly with respect to an increased initiation of non-driving related tasks.

- **CQ4: Mode confusion**
  - There are concerns that with the introduction of L2H-off functions drivers are no longer aware of their tasks and roles as drivers and have a lesser understanding of ODD and system functioning, which also makes it difficult to anticipate functional limitations.

- **CQ5: Safety level**
  - There is uncertainty as to what level of safety can be achieved by introducing L2H-off functions.

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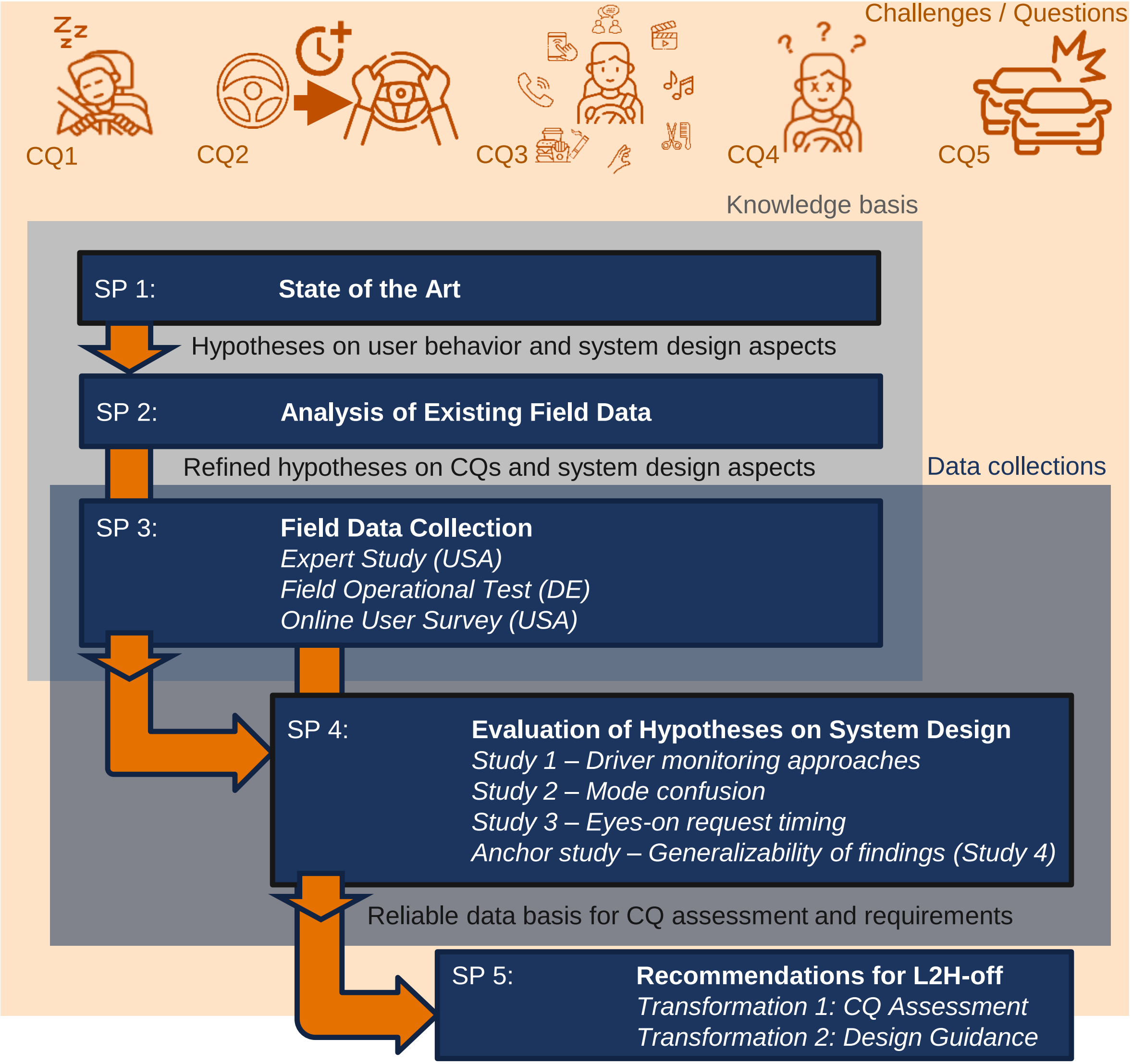

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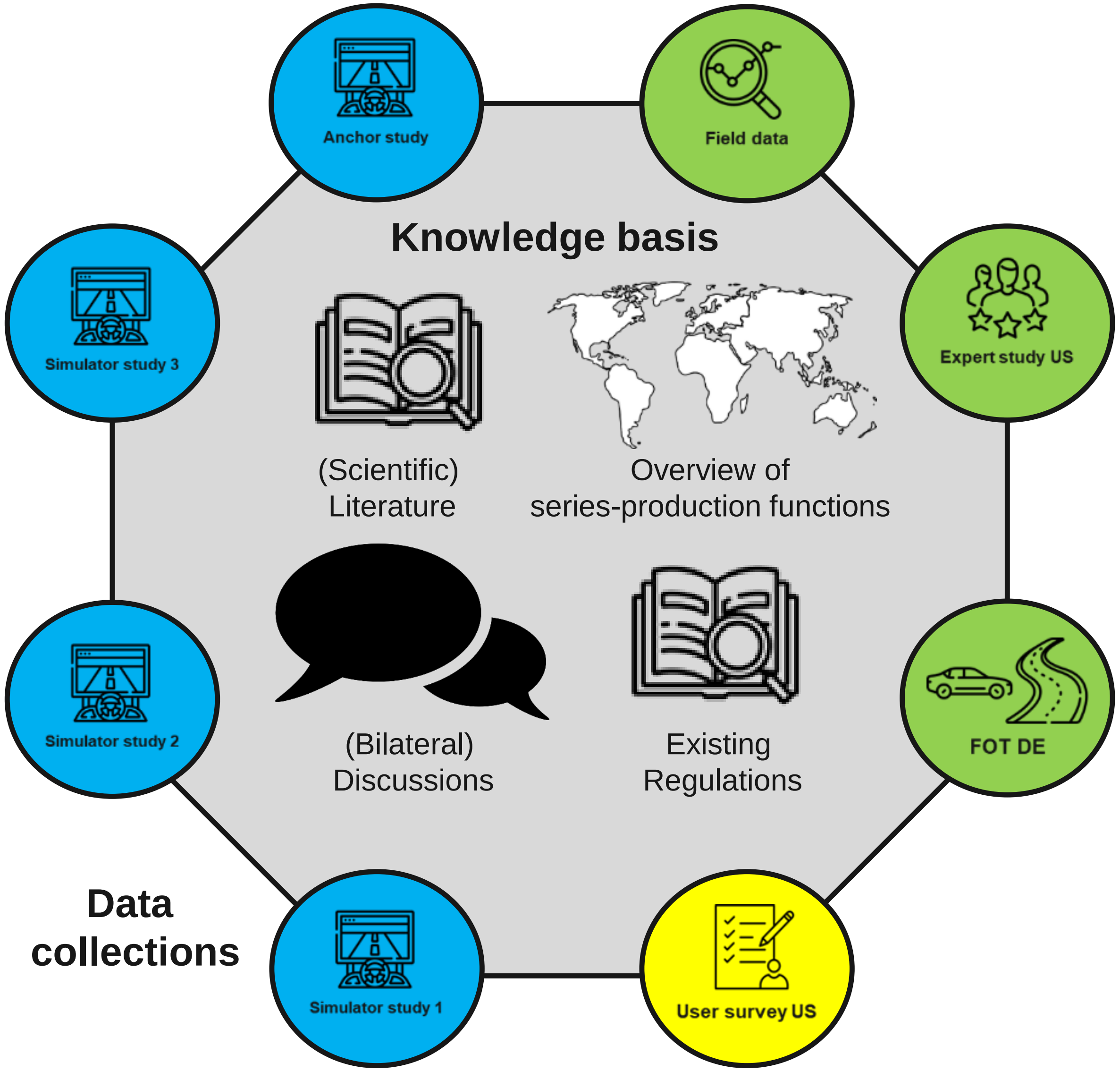
- **Knowledge basis**
  - Considering **existing or prototypical L2H-off functions** and L2H-on functions (as a reference for interactions with L2 driver assistance) within a **defined operational design domain**
  - **Considering existing input to the five CQs**
- **Data collections**
  - Providing new / additional input to answer the five CQs
  - Providing a data basis on prototypical design solutions to compensate potential challenges
- **Derive conclusions and recommendations**
  - with regard to the **five CQs** (Transformation 1).
  - with regard to the **design of L2H-off functions** to address potential challenges (Transformation 2).

Project Overview L2H-off
Agenda

- **Knowledge basis and methods**
- **Transformation 1: CQ Assessment**
  - Highlighted overview on results
- **Transformation 2: Design Guidance**

Methodological approach



- **Knowledge basis provides the starting point for the focus and experimental setup of the simulator studies.**
- Existing technological solutions and recommendations from literature as input for **prototypical function design used in simulator studies**
  - No focus on specific technological solutions (e.g. type of driver monitoring camera)
  - **Goal: Design realistic prototypical L2H-off function** to test behavioral effects when being allowed to monitor hands-free.
- **Aspects for the design of prototypical functions:**
  - Driver Monitoring System (DMS)
  - Human Machine Interface (HMI)
  - Functional design

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Methodological approach
Knowledge basis

Level 2 driver assistance

(Scientific) Literature

Overview of series-production functions

Existing Regulations

Keyword based search and input from

- Literature databases / Google scholar search (journal and conference papers, doctoral theses, reports)
- Experience and accident reports (user forum discussions, news reports, online videos)
- Bilateral discussions including unpublished research

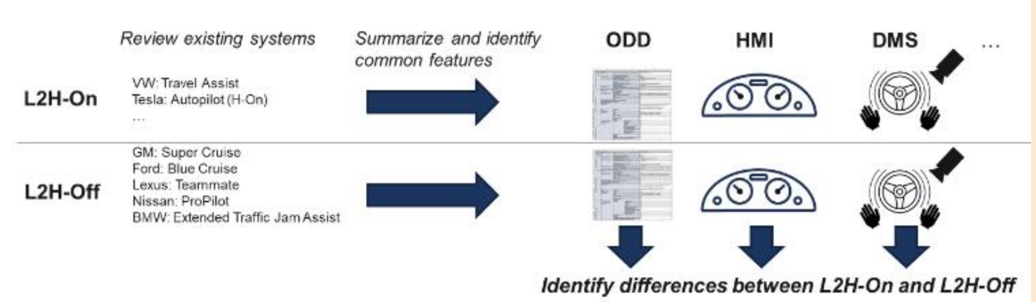
Hands-free specific effects as primary focus

Authors	Year	Title	Investigated Function/Driver Task	Investigated Scenario(s)	Type of Investigation	Investigated Metrics	Key-Findings	Challenges/Questions				
								1	2	3	4	5

(Bilateral) Discussions

Systematic description of

- Operational design domain (ODD) + risk classification
- Human Machine Interface (HMI)
- Driver Monitoring System (DMS)



Primary focus:
Behavioral effects / Interaction behavior **(CQs)**
with and without adapted driver monitoring systems
for hands-free L2 use

Primary focus:
Existing technological solutions
for L2H-on and L2H-off functions
(state of the art)

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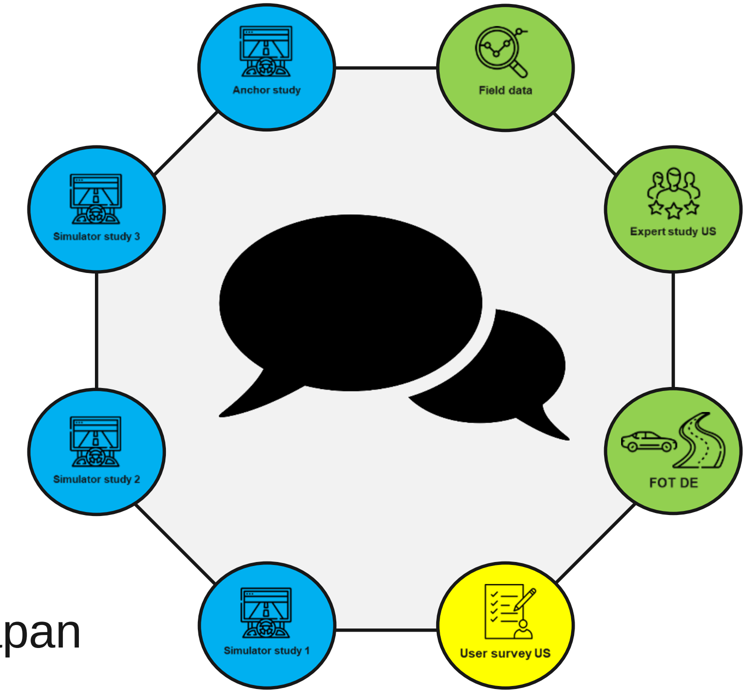
Methodological approach
L2H-off Scientific Advisory Board

International scientific advisory board established with a focus on

- **Methodological aspects of study designs**
- **Relevant aspects for consideration in studies**



- **Marco Dozza**
  Chalmers University of Technology, Sweden
- **Satoshi Kitazaki**
  National Institute of Advanced Industrial Science and Technology (AIST), Japan
- **Eddy Llaneras**
  Virginia Tech Transportation Institute, USA

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Methodological approach
Data basis

Simulator Study 1

- 20 (L0), 20 (L2H-on), 20 (L2H-off)
- 45 minutes simulator driving
- 4 scenarios

Simulator Study 2

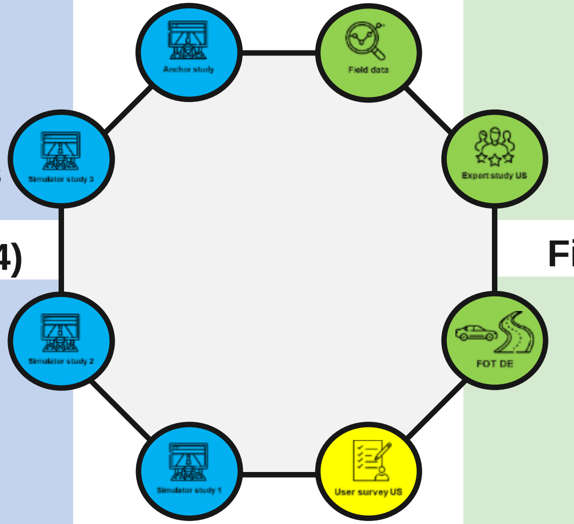
- 20 (L2H-on), 19 (L2H-off A), 19 (L2H-off B)
- 45 minutes simulator driving
- 5 scenarios, two L2H-off system designs

Simulator Study 3

- 21 (L2H-on), 19 (L2H-off A), 19 (L2H-off B)
- 45 minutes simulator driving
- 4 scenarios, two L2H-off DMS implementations

Anchor Study (Simulator Study 4)

- 39 (L2H-on), 37 (L2H-off) with & w/o prior ADAS experience
- 40 minutes simulator driving
- 2 scenarios (repeated once each)



Field Data Analysis

- USA, China, Germany
- L0, L2H-on, L2H-off
- ~610 h analyzed
- Motorway driving (customers and tests)

Field Operational Test (FOT DE)

- 30 (L2H-on + L2H-off), 30 (L2H-off)
- 4 (L2H-on) + 2 (L2H-off)
- 45-minute L2 intervals
- Motorway driving in the area of Munich

User Survey US

- 55 (L2H-on), 57 (L2H-off)
- Series-production functions (L2H-on and L2H-off) available in the US

Expert Study US

- 5 interdisciplinary experts
- 3 series-production vehicles (L2H-on and L2H-off functions)
- > 45 hours recorded
- Various motorways in California

Image source: Flaticon.com

Methodological approach
Data basis: L2 function designs

L2 function analysis: Overview, FOT DE, Expert Study Knowledge basis

- **L2H-off:**
  - ODD: Based on map data; traffic situation / velocity
  - DMS: Head- / eye- / gaze-tracking
- **L2H-on:**
  - ODD: Road type restricted; unrestricted
  - DMS: Torque vs. capacitive hands-off detection
- **HMI and DMS:**
  - HMI: Instrument cluster; head-up display, steering wheel rim
  - L2H-off: Stage 1: 3-5 s / Stage 2: +3-5 s / Stage 3: +2-5 s
  - L2H-on: Stage 1: 5-15 s / Stage 2: +4-15 s / Stage 3: +5-30 s
  - Visual, acoustic and haptic (seat vibrations; electric recuperation)

L2 functions applied in driving simulator studies Data collections

- **HMI: Regular instrument cluster (no head-up display)**
- **L2H-off:**
  - DMS based on automated live tracking of (head and) eyes
  - DMS stage 1: First inattention warning after 5 s (Study 3: 3 s)
- **L2H-on:**
  - DMS: Capacitive steering wheel
  - DMS stage 1: First hands-off warning after 15 s hands-free driving
- **Assistance modes:**
  - Clear-cut (L0 or L2) (Study 1, Study 2, Study 3)
  - Multi-step approach (L0 or L1 or L2) (Study 2, Study 4)
    - Fallback to L1 at function direct control request (FDCR)

H-off	**Driver Monitoring Cascade**					
	1. Warning Stage		**2. Warning Stage**		**3. Warning Stage**	
HMI	3-5 s	Eyes-on Request (visual + acoustic alert) **"Stay attentive!"**	+3 s	Hands-on Request (visual + acoustic alert) **"Stay attentive! Hands on steering wheel!"**	+5 s	Direct Control Request (DCR) (visual + acoustic alert; braking to standstill) **"Vehicle stops. Please take over!"**
Termination of requests		Eyes on road		Eyes on road + hands on wheel		Take direct control

H-on	**Driver Monitoring Cascade**					
	1. Warning Stage		**2. Warning Stage**		**3. Warning Stage**	
HMI	15 s	Hands-on Request (visual alert + acoustic alert) **„Hands off wheel detected. Stay attentive!" / "Hands on steering wheel"**	+5 s	Hands-on Request (visual + acoustic alert) **„Hands off wheel detected. Stay attentive!" / "Hands on steering wheel"**	+5 s	Direct Control Request (DCR) (visual + acoustic alert; braking to standstill) **"Vehicle stops. Please take over!"**
Termination of requests		Hands on wheel		Hands on wheel		Take direct control

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Methodological approach
Data basis: Data collection procedures

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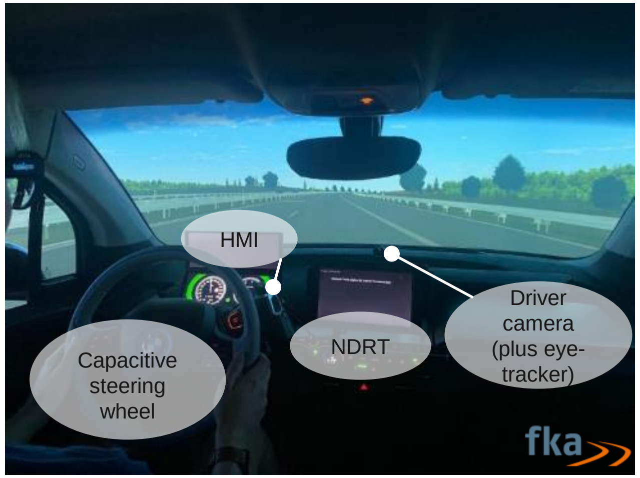
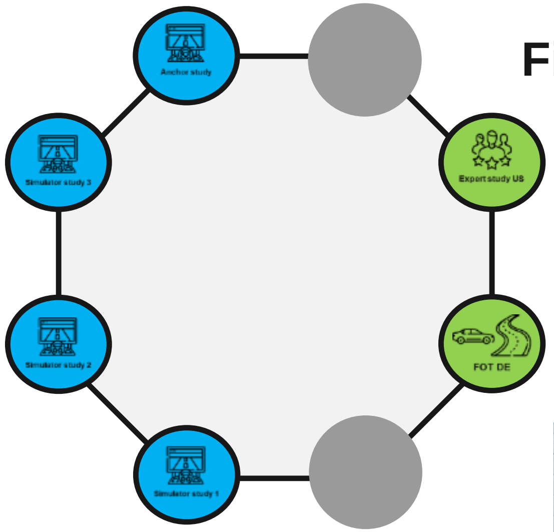
Simulator studies

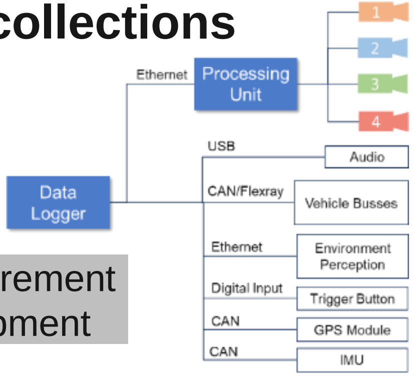


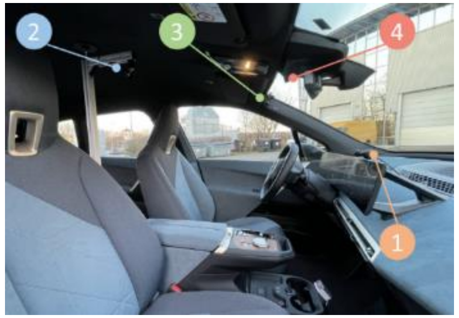


https://www.fka-sv.com/solutions/driver-simulator.html

Field data collections

Measurement Equipment





1 – driver face / gaze
2 – driver body posture
3 – steering wheel
4 – instrument cluster
5 – environment (LiDAR)

FOT Vehicles

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Methodological approach
Data basis: Analyzed scenarios

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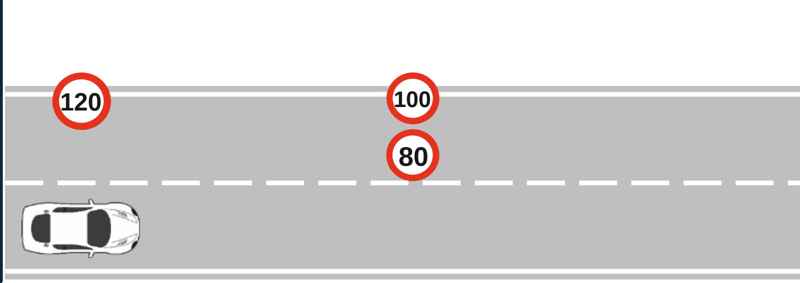
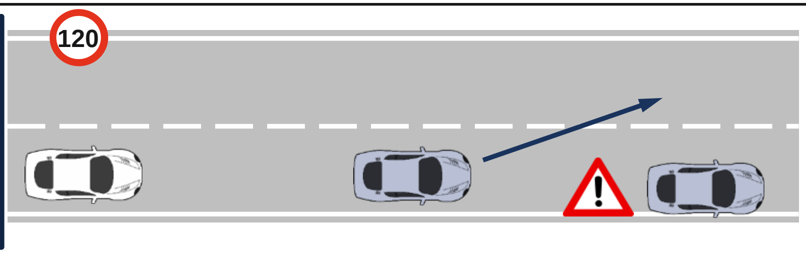
Speed limit



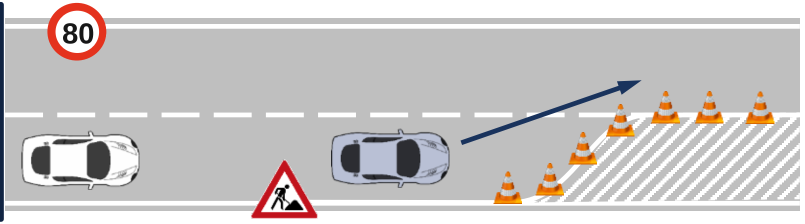
- Detection failure of new limit (100 km/h or 80 km/h)
- **Study 1+3: No FDCR***

Cut-out



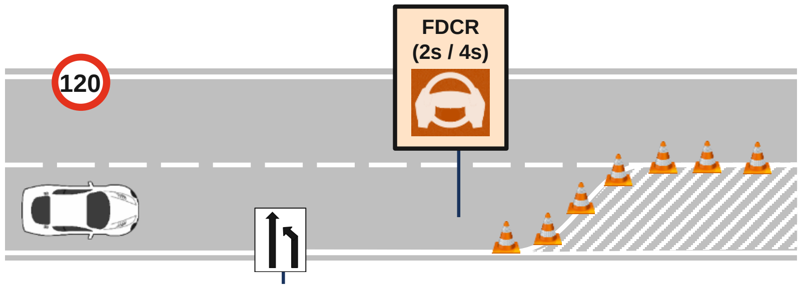
- Cut-out (**occluded** by traffic)
- **Unpredictable** (obstacle)
- **Study 1+2: No FDCR***
- **Study 3: With FDCR***

Roadworks



- **Predictable** (signs)
- **Occluded** by lead vehicle
- **Study 1: No FDCR***
- **Study 3: With FDCR***

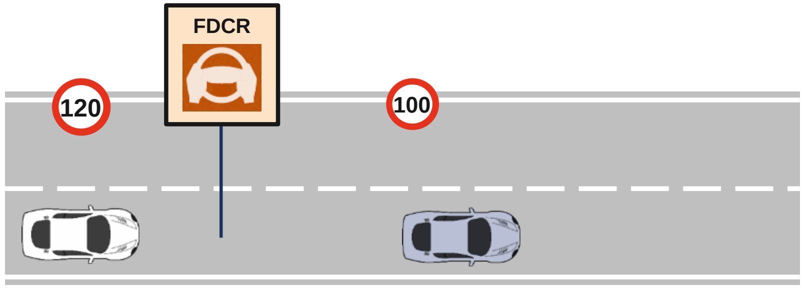
Lane end



- **Predictable** (signs)
- No lead vehicle (**no occlusion**)
- **FDCR* at 2 s or 4 s**
- Study 4

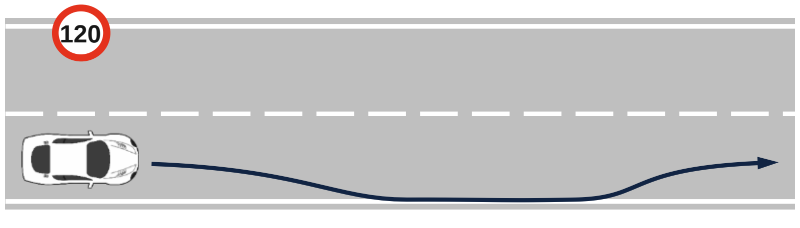
*FDCR = function direct control request

End of ODD



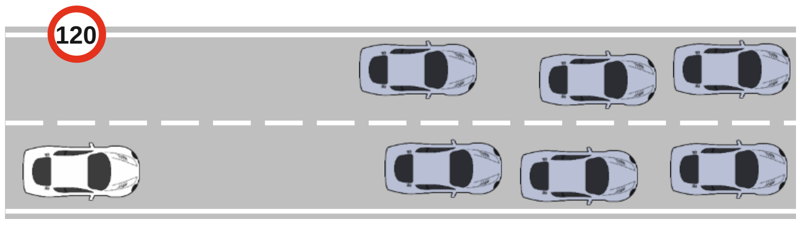
- Vehicle leaves ODD
- New limit ahead (not detected)
- With or without lead vehicle
- **With FDCR***
- Study 2

Silent Failure



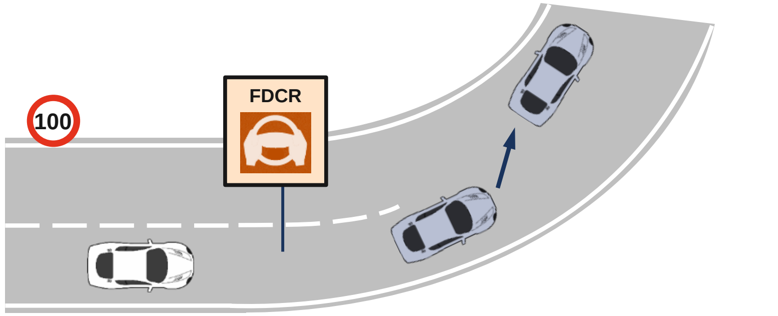
- **Unpredictable** lane drift (0.2 m/s; 0.6 m/s)
- **No FDCR***
- Study 4

Traffic jam



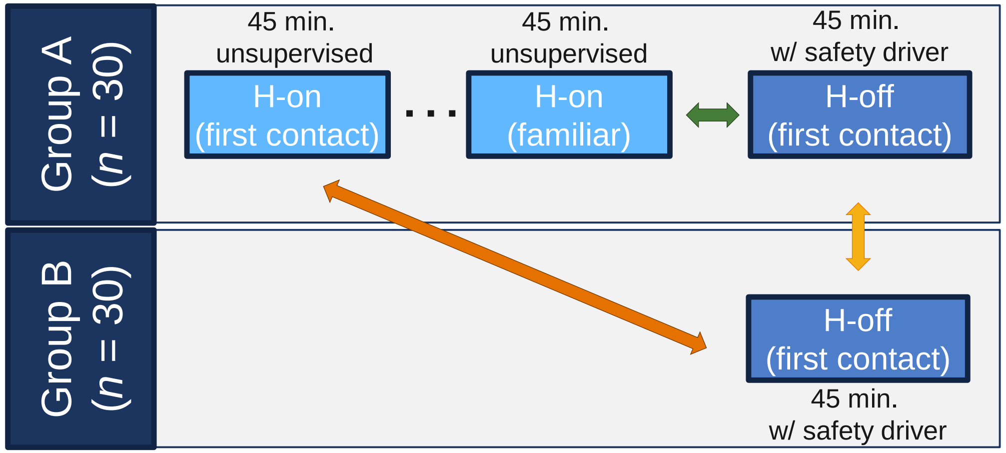
- Traffic jam ahead
- **Occluded** by lead vehicle
- **No FDCR***
- Study 2

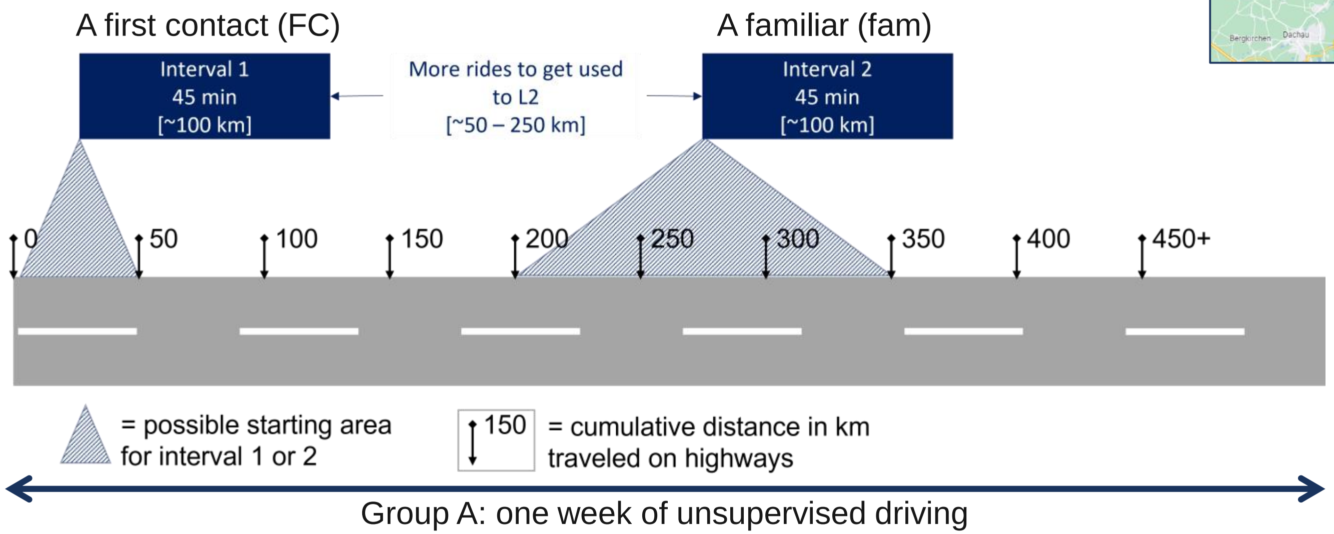
Curve

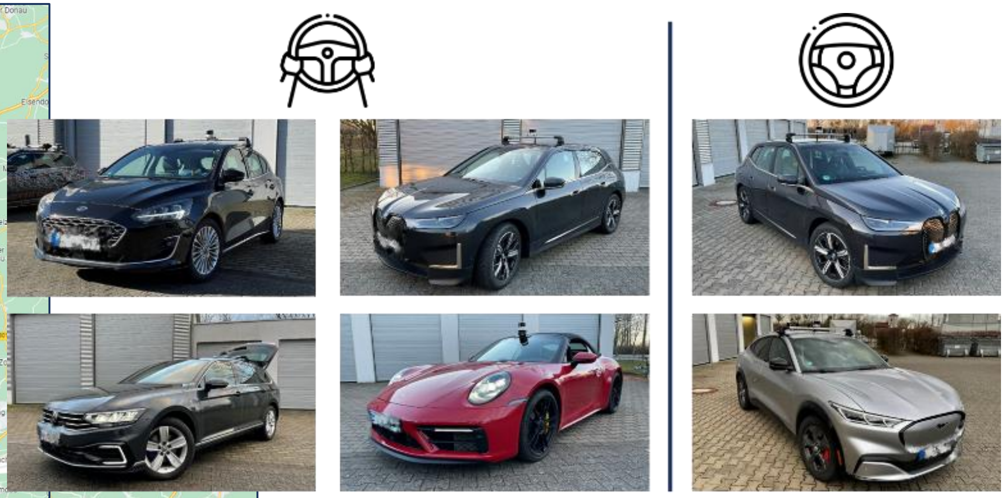


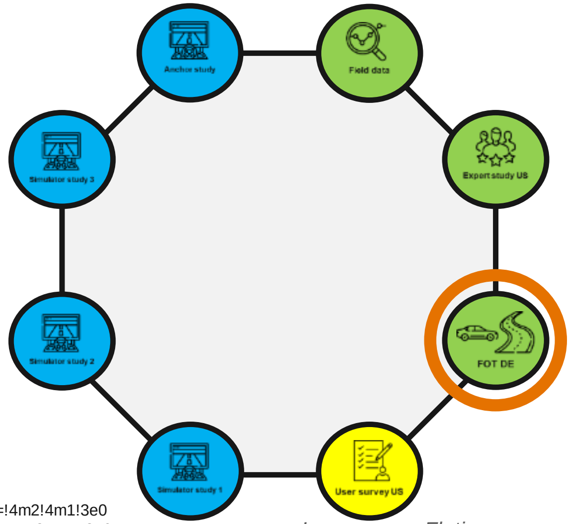
- Curve w/o lane markings (**unpredictable**) + reduction of speed limit
- Vehicle in front changing lane
- **With FDCR***
- Study 2

Methodological approach
Data basis: FOT DE









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Methodological approach
Data basis: User survey

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Group description:

L2H-on with HOD ⇦ **RQ** ⇨ **L2H-off with EOD**

HOD: Hands-on Detection, EOD: Eyes-on Detection

Survey link active between April 6th and August 31st 2022

Link shared via social media, recruiting agencies, personal contacts and forums for automated driving topics

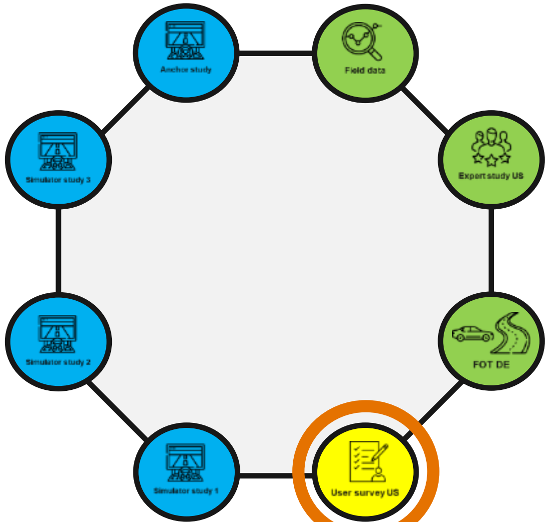
Sample description:

System	Sample size	Gender	Age	L2 experience	Miles driven in the last 12 months on highways
Overall	*n* = 112	18 Women 92 Men 2 Other	*M* = 41 years *SD* = 13.03	*M* = 17.5 months *SD* = 17.89 *(excl. n = 16 less than a month)*	*M* = 11,462 miles *SD* = 10,624.2 miles range: 3-60,000 miles
L2H-on	*n* = 55	9 Women 45 Men 1 Other	*M* = 39 years *SD* = 12.23	*M* = 28 months *SD* = 18.79 *(excl. n = 6 less than a month)*	*M* = 11,986 miles *SD* = 11,998.2 miles range: 3-60,000 miles
L2H-off	*n* = 57	9 Women 47 Men 1 Other	*M* = 44 years *SD* = 13.41	*M* = 12 months *SD* = 16.85 *(excl. n = 10 less than a month)*	*M* = 10,956 miles *SD* = 9,186.22 miles range: 3-60,000 miles

Sample structure / focus:

- Introduction / Informed consent
- Experience with L2 (max. 10 q.)
- Sample characteristics (max. 6 q.)
- (Foreseeable) Misuse
- NDRT (max. 13 q.)
- Situations of use (max. 6 q.)
- L2 driver role (max. 7 q.)
- Changes in usage behavior (max. 4 q.)

NDRT = non-driving related tasks
q. = Question



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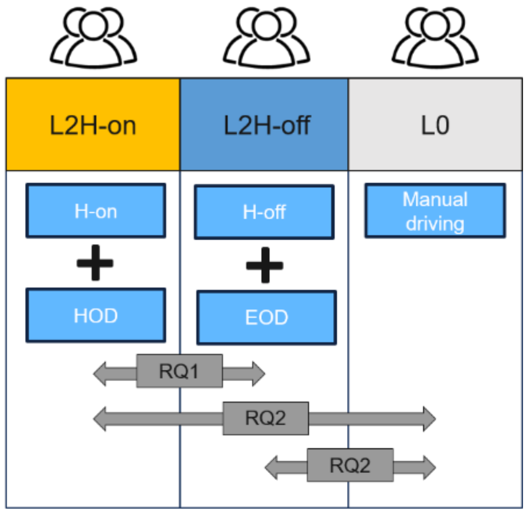
Methodological approach
Data basis: Simulator study 1

Group description:

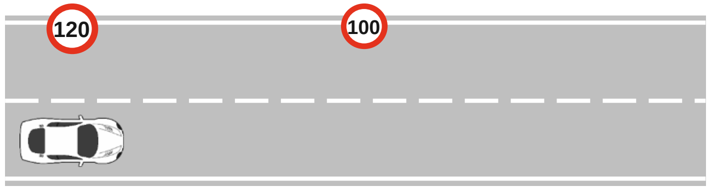


HOD: hands-on detection; EOD: eyes-on detection

Sample description:

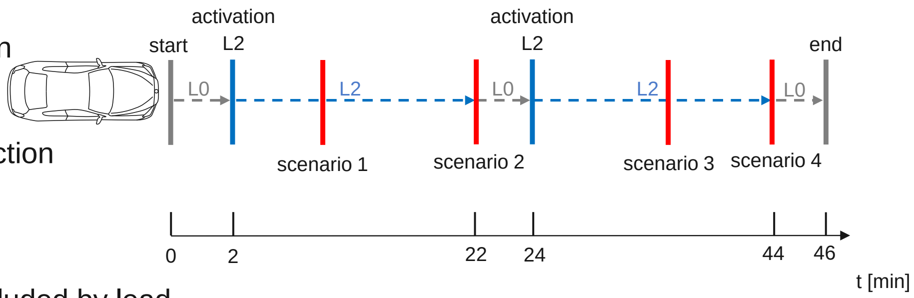
L2H-on	*n* = 20	7 Women 13 Men	*M (SD)* = 15.75 (12.05) years Range = 5 – 42 years
L2H-off	*n* = 20	7 Women 13 Men	*M (SD)* = 14.95 (16.39) years Range = 5 – 56 years
L0	*n* = 20	7 Women 13 Men	*M (SD)* = 16.10 (13.23) years Range = 5 – 52 years

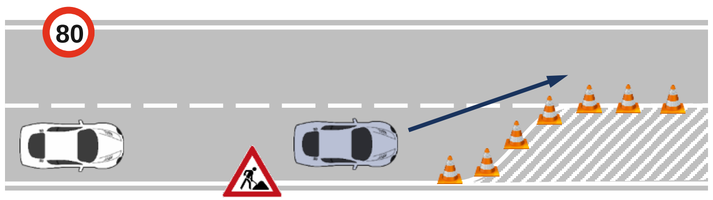
Scenario description:



Scenario 1 and 3:

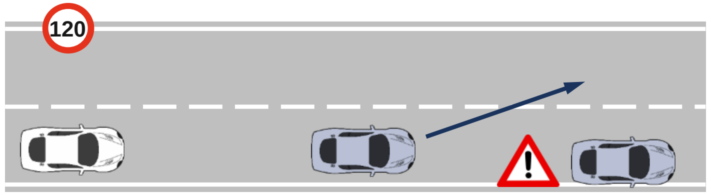
- Speed limit reduction ahead (120 → 100 km/h)
- Not detected by function
- **No FDCR**





Scenario 2:

- Roadworks ahead
- Predictable, but occluded by lead vehicle
- **No FDCR**
- Braking maneuver if no driver reaction within 5 s



Scenario 4:

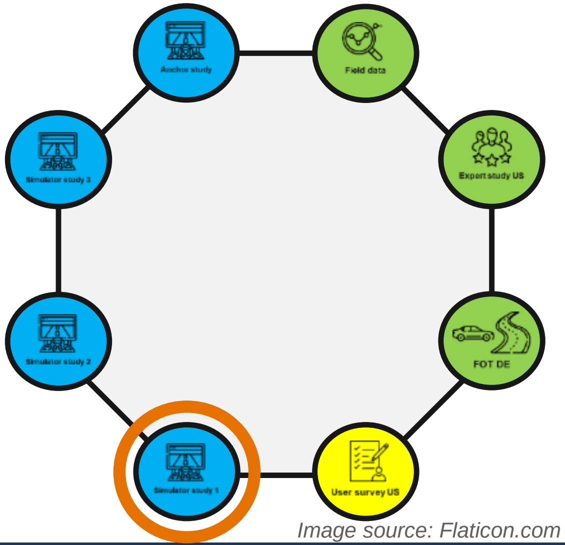
- Cut-out (obstacle occluded by traffic)
- **No FDCR**
- Braking maneuver if no driver reaction within 5 s

NDRT (non-driving related task):

- Position: central information display (CID)
- Predefined sequence of comparable reading and input tasks
- **Visual-motoric task**, only one hand needed
- Well interruptible, but only limited time for each task

Driving task description:

- Driving duration ≈ 45 min
- Highway with 2 lanes in each direction
- Level of Service A
- 4 system limit scenarios
- L2 system based on state-of-the-art concepts (lane changes not supported)



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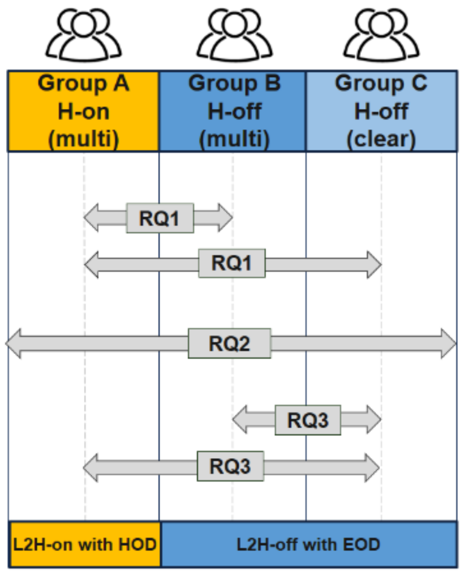
Methodological approach
Data basis: Simulator study 2

Group description:

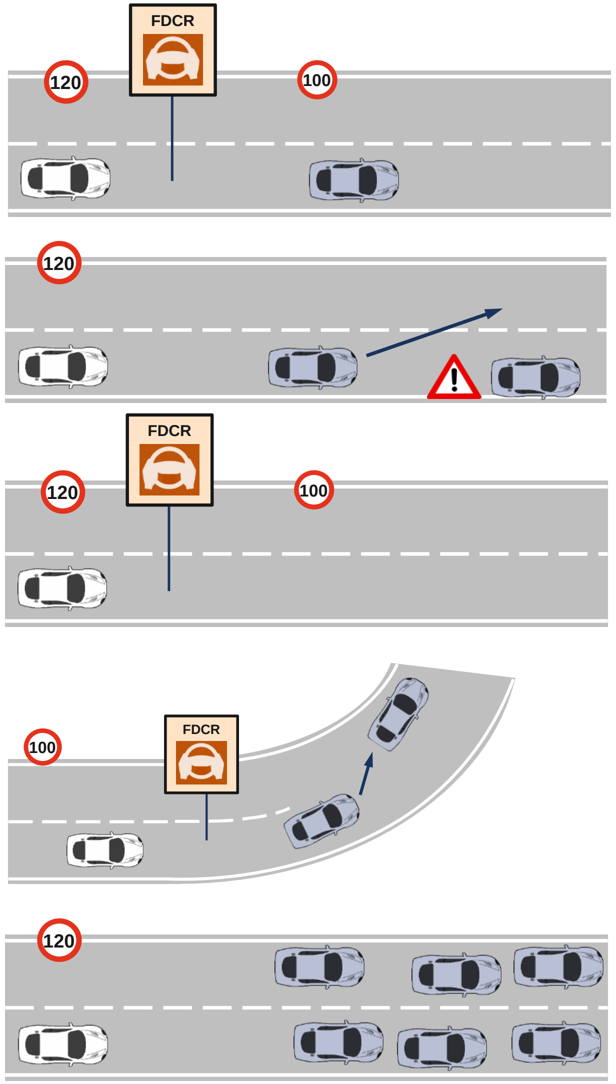


HOD: Hands-on Detection, EOD: Eyes-on Detection

Sample description:

System	Sample size	Gender	Age
L2H-on (multi)	*n* = 20	7 Women 13 Men	M = 25 SD = 5
L2H-off (multi)	*n* = 19	5 Women 14 Men	M = 30 SD = 13
L2H-off (clear)	*n* = 19	6 Women 13 Men	M = 32 SD = 14

Scenario description:



Scenario 1: Speed limit
- Speed limit reduction ahead (120 → 100 km/h)
- **FDCR**

Scenario 2: Obstacle
- Lane blocked by stationary vehicle
- Occlusion by lead vehicle
- **No FDCR**

Scenario 3: Speed limit
- Speed limit reduction ahead (120 → 100 km/h)
- **FDCR**

Scenario 4: Curve
- Curve w/o lane markings + reduction of speed limit
- Vehicle in front changing lane
- **FDCR**

Scenario 5: Traffic Jam
- Traffic jam ahead
- **No FDCR**

Driving task description:
- Driving duration ≈ 15 min familiarization + 45 min test drive
- Highway with 2 lanes in each direction
- Level of Service B
- 5 system limit scenarios (see left)
- L2 system based on state-of-the-art concepts (lane changes not supported)
- **No NDRT (non-driving related task)**

Function variation:
- L2H-on function "**multi-step**" (L0 – L1 – L2) (Group A)
- L2H-off function "**multi-step**" (L0 – L1 – L2) (Group B)
- L2H-off function "**clear cut**" (L0 – L2) (Group B; no ACC as fallback)

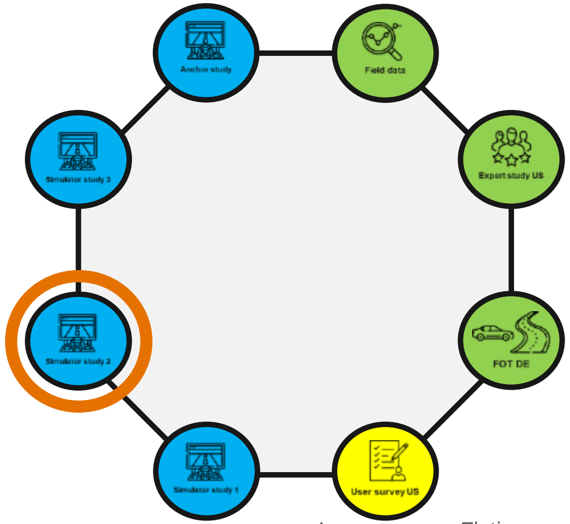


Image source: Flaticon.com

Methodological approach
Data basis: Simulator study 3

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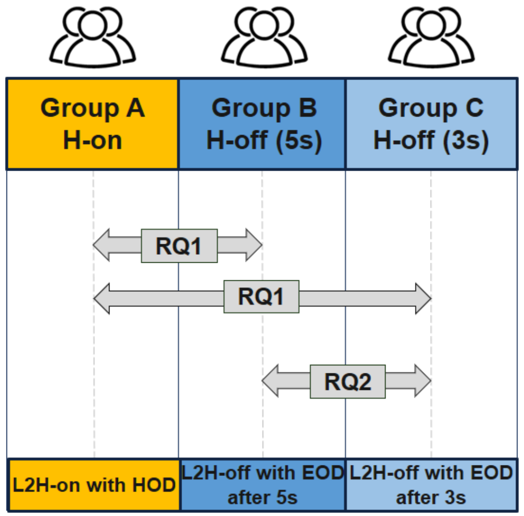
Group description:

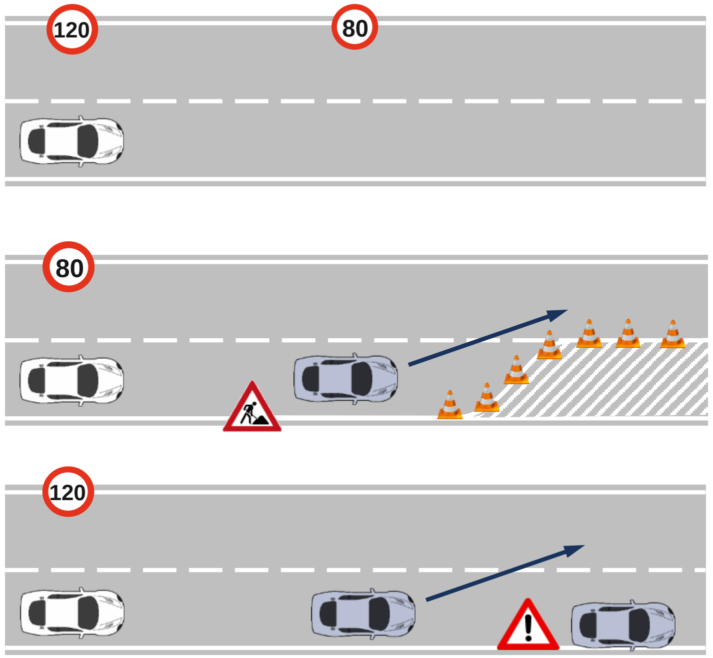


HOD: Hands-on Detection, EOD: Eyes-on Detection

Sample description:

System	Sample size	Gender	Age
L2H-on	n = 21	2 Women 19 Men	M = 36 SD = 16
L2H-off (5s)	n = 20	10 Women 10 Men	M = 32 SD = 11
L2H-off (3s)	n = 20	5 Women 15 Men	M = 32 SD = 13

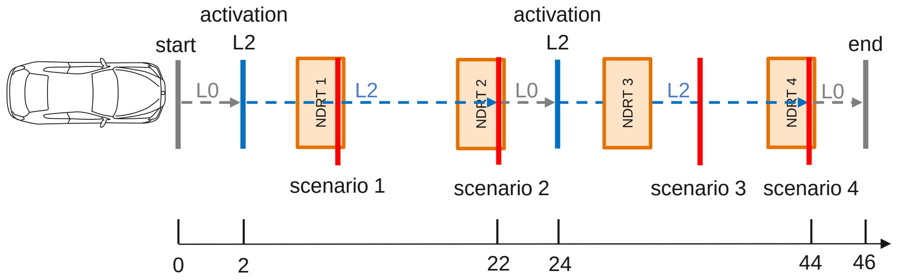
Scenario description:



Scenario 1 and 3:
- Speed limit reduction ahead (120 → 80 km/h)
- **No FDCR**

Scenario 2 or 4:
- Roadworks ahead
- Lane blocked
- Can be anticipated at about 6 s before collision or by signage
- **FDCR at TTC = 2.7 s**

Scenario 2 or 4:
- Cut-out (obstacle occluded by traffic)
- Visible at about 4 s before collision
- **FDCR at TTC = 2.7 s**



Function variation:
- L2H-on function (A)
- L2H-off function "5 s" (stage 1 warnings after 5 s) (B)
- L2H-off function "3 s" (stage 1 warning after 3 s) (C)

NDRT (non-driving related task):
- Position: central information display (CID)
- Predefined sequence of comparable reading tasks
- Offered at four defined points in time during study for ~ 5 minutes
- **Visual-verbal (no hands needed)**
- Well interruptible, but only limited time for each task

Driving task description:
- Driving duration ≈ 45 min
- Highway with 2 lanes in each direction
- Level of Service B
- 4 system limit scenarios
- L2 system based on state-of-the-art concepts (lane changes not supported)

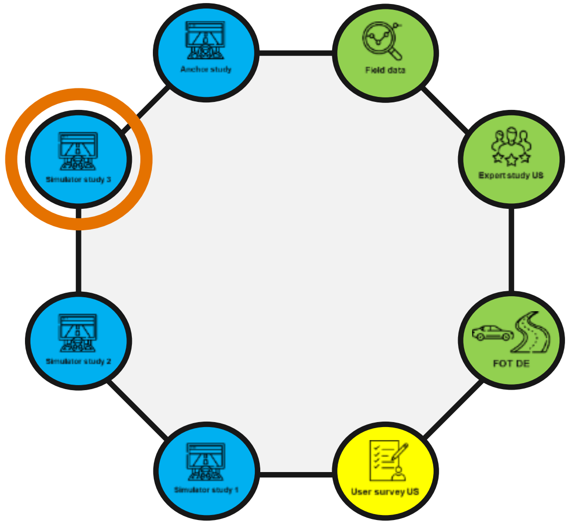


Image source: Flaticon.com

Methodological approach
Data basis: Anchor study (Simulator study 4)

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Group description:

Group A (US)	Group B1 (DE)	Group C (US)	Group D (DE)
L2H-on Experts	L2H-on Experts	L2H-off Experts	L2H-on Experts
	RQ2.1		RQ2.1
	Group B2 (DE)		Group D2 (DE)
	L2 Novices		L2 Novices

RQ2.2

RQ2.2

L2H-on with HOD ⟷ RQ1 ⟷ L2H-off with EOD

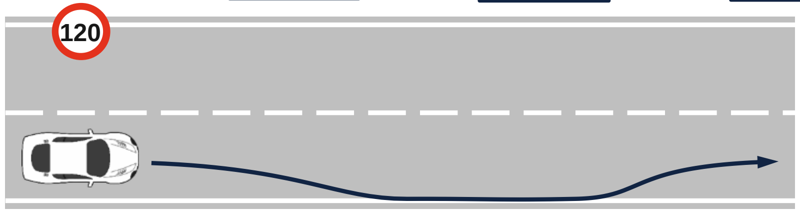
HOD: Hands-on Detection, EOD: Eyes-on Detection

Sample description:

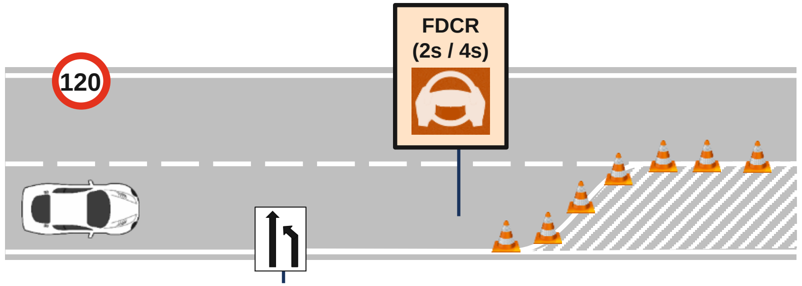
L2H-on (US)	*n* = 19	7 Women 12 Men
L2H-on (DE)	*n* = 20 $n_{Novices}$ = 10	8 Women 12 Men
L2H-off (US)	*n* = 17	1 Women 16 Men
L2H-off (DE)	*n* = 20 $n_{Novices}$ = 11	3 Women 17 Men

Scenario description:

L0/L1 (~3 min)	L2 Drive 1 (~7 min)	NDRT ~3min **Lateral lane drift 1** 1st scenario v_{y1} = 0.6 m/s	L2 Drive 2 (~7 min)	NDRT **End of lane 1** 2nd scenario FDCR 4s or 2s to lane end	L2 Drive 3 (~7 min)	NDRT **Lateral lane drift 2** 3rd scenario v_{y2} = 0.2 m/s	L2 Drive 4 (~7 min)	NDRT **End of lane 2** 4th scenario FDCR 4s or 2s to lane end	L0/L1 (~3 min)



Scenario 1 and 3: Silent failure
- Lane drift with lateral velocity of either 0.6 m/s (1st scenario) or 0.2 m/s (3rd scenario)
- **No FDCR**



Scenario 2/4: Lane end
- Lane ending ahead (ODD limit)
- Predictable, clearly indicated by street signs (at 600, 400 and 200 m) before lane end
- **FDCR at 4 s or 2 s before lane end** or **driver overrule** prior to FDCR

Function variation:
- L2H-on function "**multi-step**" (L0 – L1 – L2)
- L2H-off function "**multi-step**" (L0 – L1 – L2)

Sample variation:
- **With ADAS** / L2 experience vs. **without**
- **US** and **DE** sample

NDRT (non-driving related task):
- Position: central information display (CID)
- Predefined sequence of comparable reading tasks
- Offered at defined points in time during study for ~ 3 min
- **Visual-verbal (no hands needed)**
- Well interruptible, but only limited time for each task

Driving task description:
- Driving duration ≈ 40 min
- Highway with 2 lanes in each direction
- Level of Service B
- 4 scenarios
- L2 system based on state-of-the-art concepts (lane changes not supported)

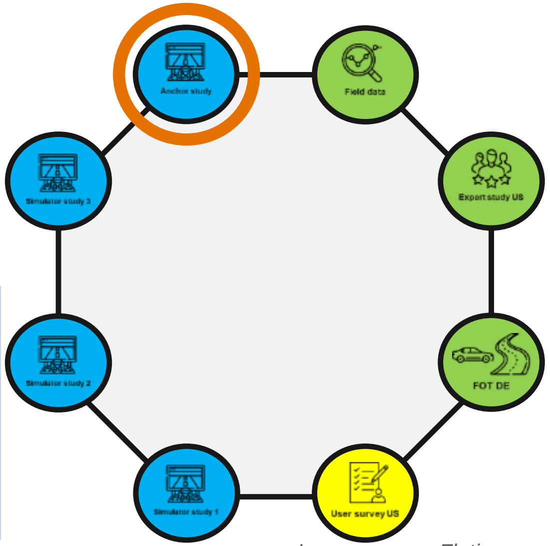


Image source: Flaticon.com

Project Overview L2H-off

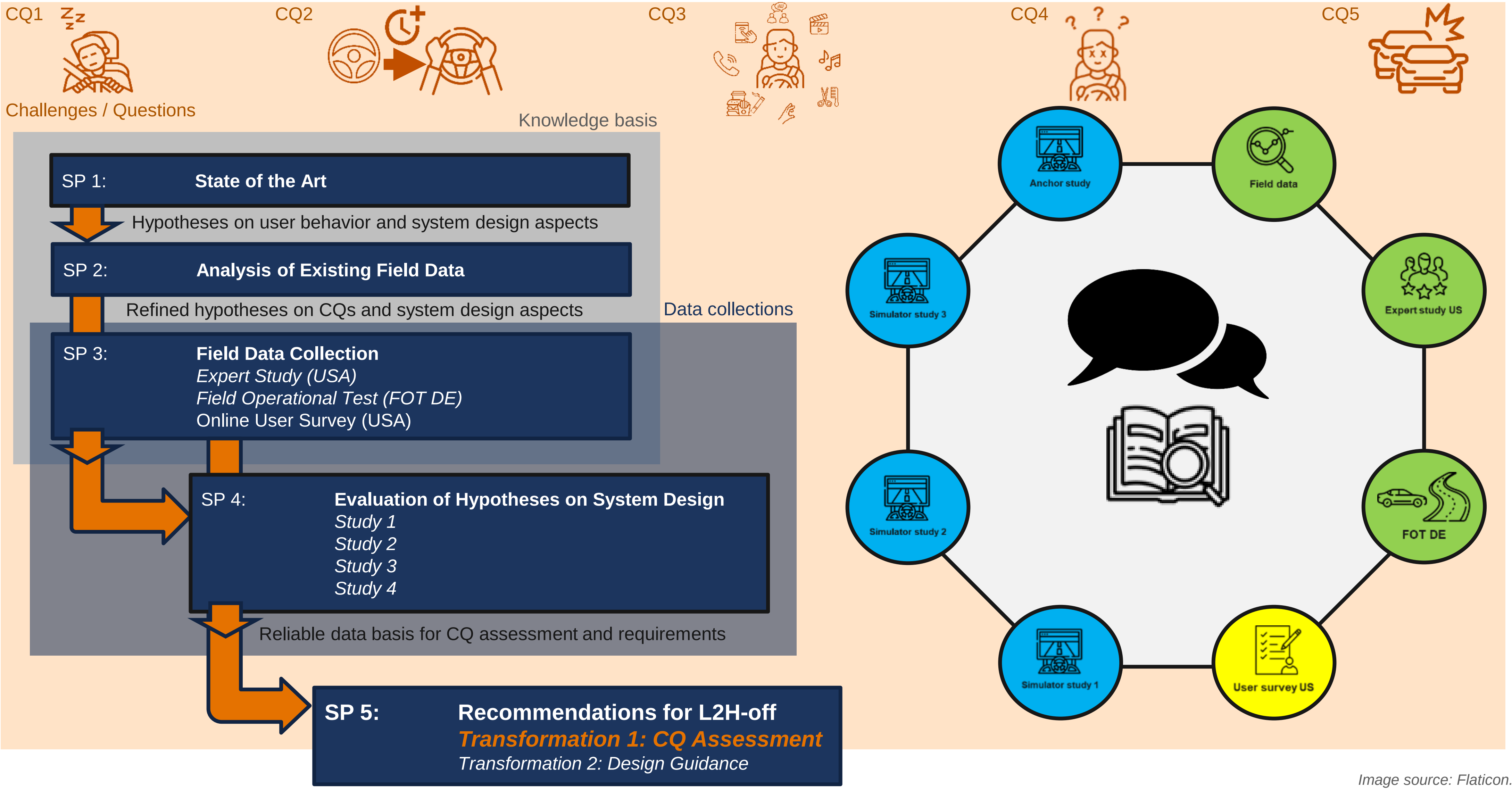


Image source: Flaticon.com / Pixabay.com

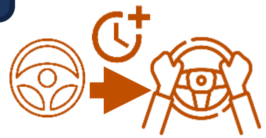
Motivation for the project
Potential Challenges and Questions (CQs)

Challenges and questions potentially related to a hands-free use of L2 functions (focus on interaction behavior):

- **CQ1: Hands-off = mind-off?**
  - There are concerns that a lack of driver involvement in the driving task (exacerbated by the lack of contact with the steering wheel during L2H-off) will reduce the driver's attention to the driving task.

Focus of today‘s presentation

- **CQ2: Prolonged transition times**
  - There are concerns that hands-on (reaction) times (returning hands to the steering wheel) as well as longer reaction times in general lead to an increased risk of accidents.



- **CQ3: Foreseeable misuse**
  - There are concerns that the use of L2H-off functions will lead drivers to foreseeable misuse or to disuse, particularly with respect to an increased initiation of non-driving related tasks.

- **CQ4: Mode confusion**
  - There are concerns that with the introduction of L2H-off functions drivers are no longer aware of their tasks and roles as drivers and have a lesser understanding of ODD and system functioning, which also makes it difficult to anticipate functional limitations.

- **CQ5: Safety level**
  - There is uncertainty as to what level of safety (in terms of contributing to road safety) can be achieved by introducing L2H-off.

Image source: Flaticon.com

CQ2: Prolonged transition times

There are concerns that hands-on (reaction) times (returning hands to the steering wheel) as well as longer reaction times in general lead to an increased risk of accidents.

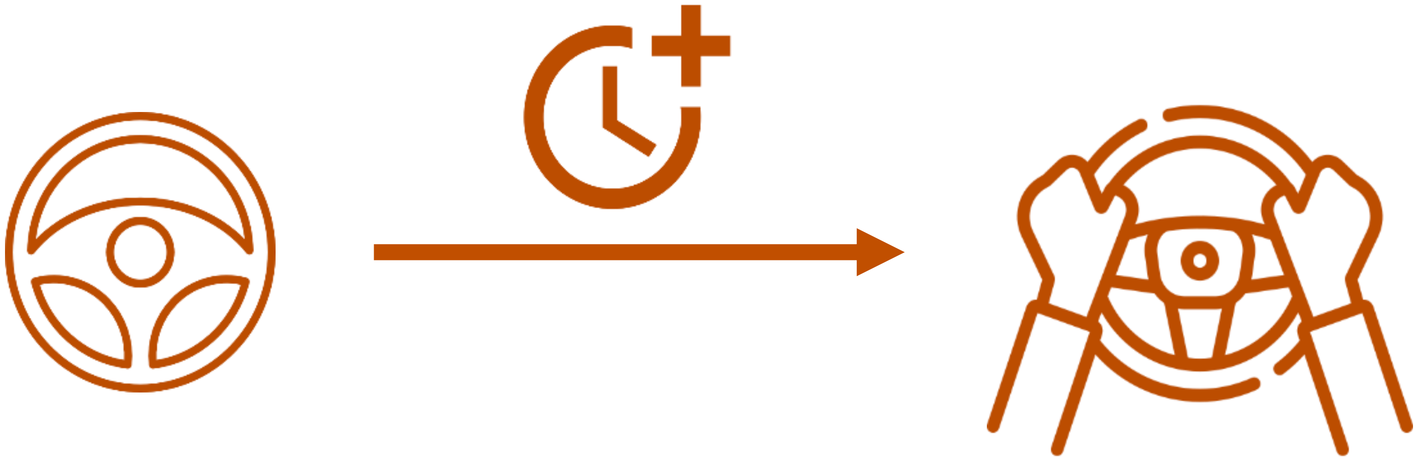


Image source: Flaticon.com

CQ2 Prolonged transition times
Definition

Multiple factors influence the (correct) anticipation of events and the occurrence or timing of driver interventions, e.g.:

- **Potential of anticipation is related to the level of involvement in the driving task *(see CQ1: hands-off = mind-off?).***
- **System understanding enables the correct anticipation of upcoming system limits (see CQ4: mode confusion).**

- **L2H-off functions allow the driver to remove their hands from the steering control –** hand posture is a factor to be considered for driver interventions.
  - Hold of steering control needs to be established before intervention: **Physical disadvantage** when monitoring hands-free if direct steering control input is necessary.

- **In CQ2, the occurrence and timing of driver actions in specific interaction scenarios is analyzed**:
  - Responses to DMS requests
  - Actions indicating an anticipation of system limits or a raised involvement in the driving task
  - Hands-on timing
  - Intervention types and intervention times

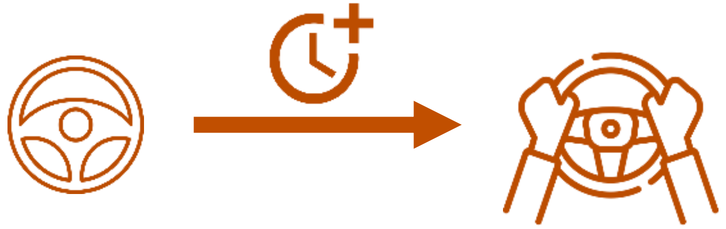
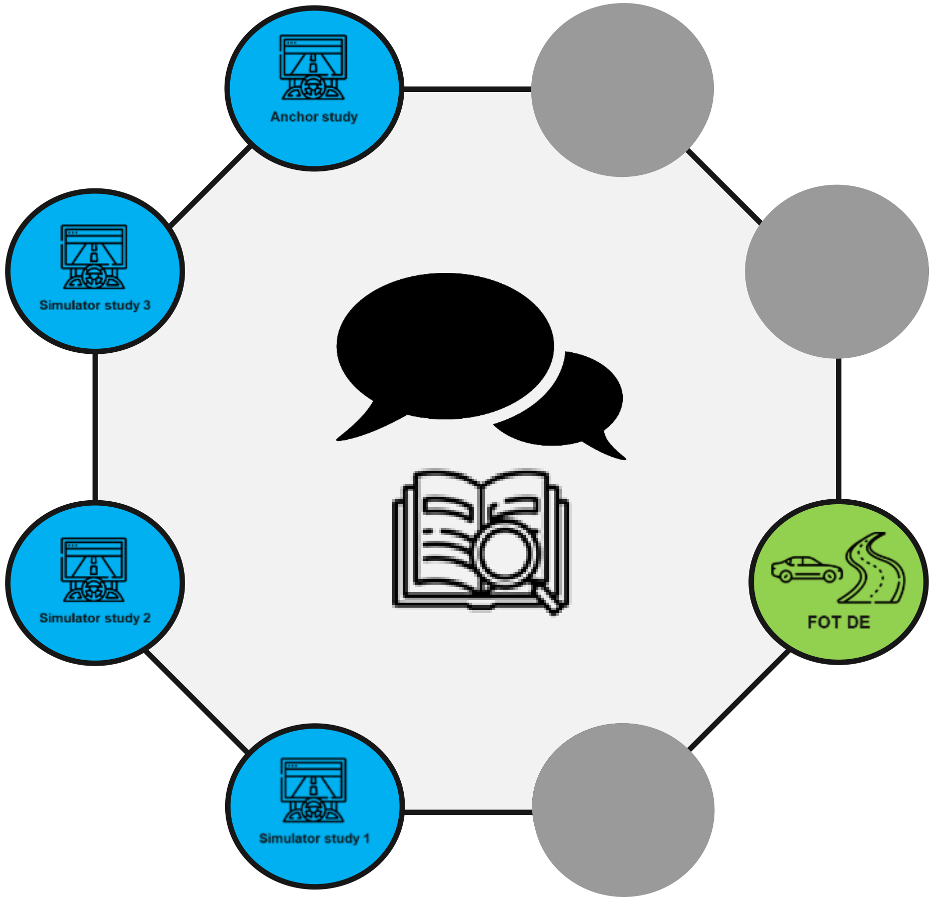


Image source: Flaticon.com

CQ2 Prolonged transition times
Metrics

Conclusions are primarily based on:



Constructs and metrics:

- **Reaction times**
  - Reaction time to Hands-off/Eyes-off warnings
  - Hands-on time & intervention times
- **Driver- & system-initiated deactivations**
  - Intervention type in case of driver- & system-initiated deactivation (steering, brake, button, throttle)
- **Controllability of driving situations**
  - Intervention success
  - Distance-based metrics, e.g. TTC
- **Other**
  - Interview / Protocol

Image source: Flaticon.com

CQ2 Prolonged transition times
Reaction times

Findings from data collections

- **No increase in mean reaction times to *__events__* was found for L2H-off functions** in comparison to L2H-on functions. *(events: DCR*, failure onset, functional limit revealed)*
- **No increase in mean reaction times to *__DMS warnings__* was found for L2H-off functions** in comparison to L2H-on functions.
  - In most cases, drivers do react to the first warning, but in some cases long reaction times occur when Stage 2 and Stage 3 warnings are being triggered (see also CQ1).
  - Prototypical DMS with 3-stage-DMS-cascades in case of misuse/inattention were investigated. Other, less tolerant implementations were not considered in study designs (e.g. more urgent 1- or 2-stage-DMS designs).

Findings from literature

- Hands-off supervision <u>without</u> an adapted DMS (slightly) increases transition times in case of system-initiated transitions (Cahour et al. 2021; Garbacik et al. 2021; Gold et al. 2013; Josten 2021; Othersen 2016).
- A delay found in intervention times of approximately 0.3 seconds (Damböck et al., 2013; Gold et al., 2013; Josten, 2021) has been attributed to the motoric process of moving the hands to the steering wheel **(i.e., physical disadvantage of a transition from hands-free to hands-on).**
- Time to respond to DMS reminders has been proposed as an indicator for driver disengagement. (Mueller et al. 2022)

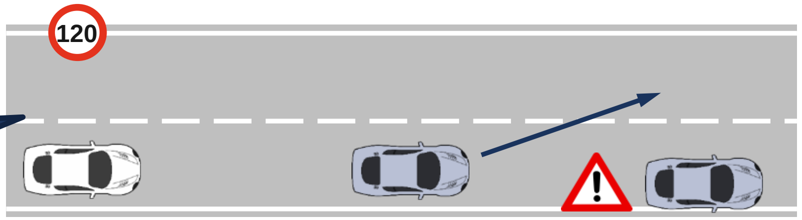
* DCR = direct control request

Image source: Flaticon.com

CQ2 Prolonged transition times

Review: Scenario designs for selected results

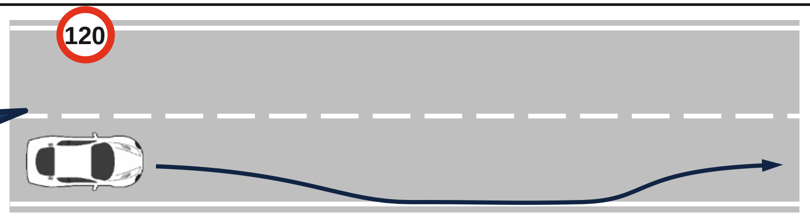
Cut-out



- Unpredictable obstacle
- Occluded by lead vehicle

- **Study 1: No FDCR*,** *braking initiated 5 s after reveal*
- **Study 3: With FDCR***
- **Study 2: No FDCR*,** *but earlier reveal as in other studies*

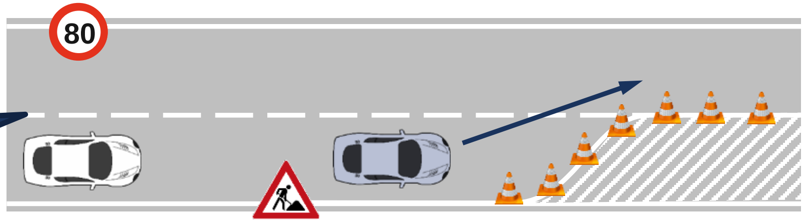
Lane drift



- Unpredictable lane drift (0.2 m/s; 0.6 m/s)

- **No FDCR***
- Study 4

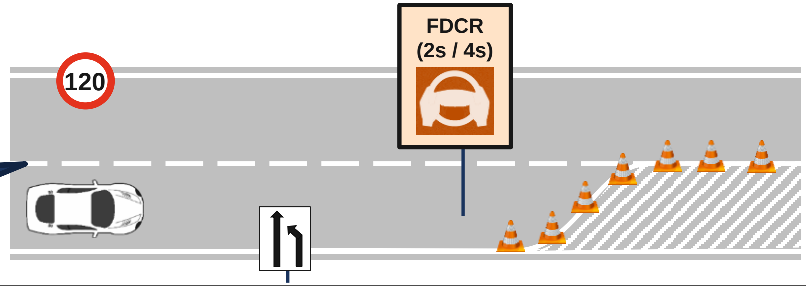
Roadworks



- Predictable roadworks (signage)
- Occluded by lead vehicle

- **Study 1: No FDCR*,** *braking initiated 5 s after reveal*
- **Study 3: With FDCR***

Lane end



- Predictable roadworks (signage)
- No occlusion (no lead vehicle)

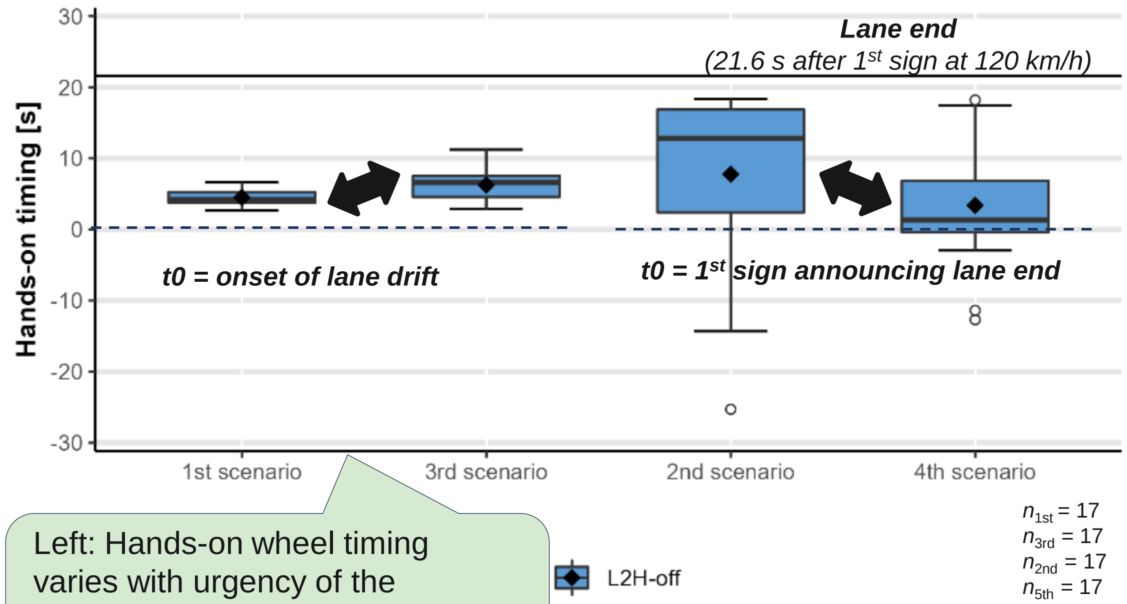
- **FDCR* at 2 s or 4 s**
- Study 4

*FDCR = function direct control request

CQ2 Prolonged transition times
Evidence: Reaction times

Reaction times to silent failures (lane drift) / function limits (lane end)

Data source: Anchor study

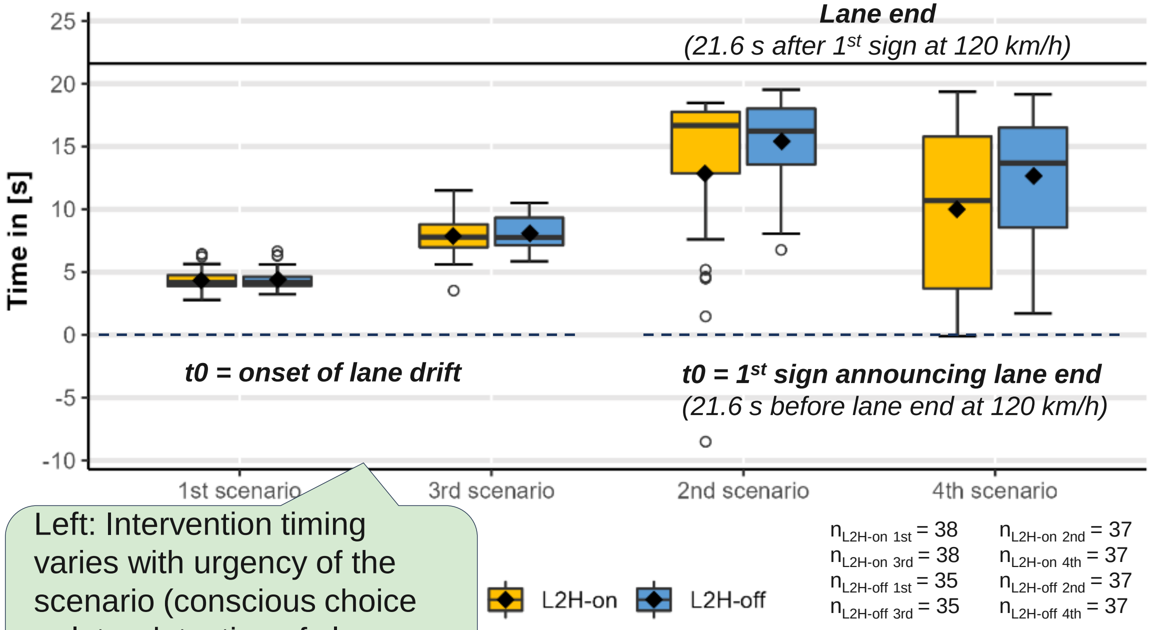


Left: Hands-on wheel timing varies with urgency of the scenario (conscious choice or later detection of slower lane drift).

- **Later hands-on time for slower drift in 3rd scenario (left).**
- **Later hands-on time for 2nd scenario than for 4th scenario (right).**

(Analysis based on drivers using the L2H-off function hands-free at t0 on both occasions per scenario. More drivers use function hands-free at least during one of two occasions each.)

Data source: Anchor study



Left: Intervention timing varies with urgency of the scenario (conscious choice or later detection of slower lane drift).

- **No significant differences between different L2 functions.**
- **Later interventions in the 3rd scenario** than in the 1st scenario (drift velocity) for both L2 functions.
- **Later interventions in the 2nd** compared to the 4th scenario for both L2 functions (limit awareness / system understanding).

CQ2 Prolonged transition times
Driver- and system initiated deactivations

Findings from data collections

- **Hands-free option does not change the <u>type of intervention</u> - drivers intervene primarily by steering in case of system-initiated deactivations*.***
    - Most scenarios chosen for the simulator studies require steering maneuvers.
    - **Type of NDRT** (visual-manual or visual-verbal) does not change the type of primary intervention reaction (steering).

(Success of interventions considered under *controllability*, see following slides.)

Findings from literature

Factors other than hand posture define drivers' reactions at system limits:

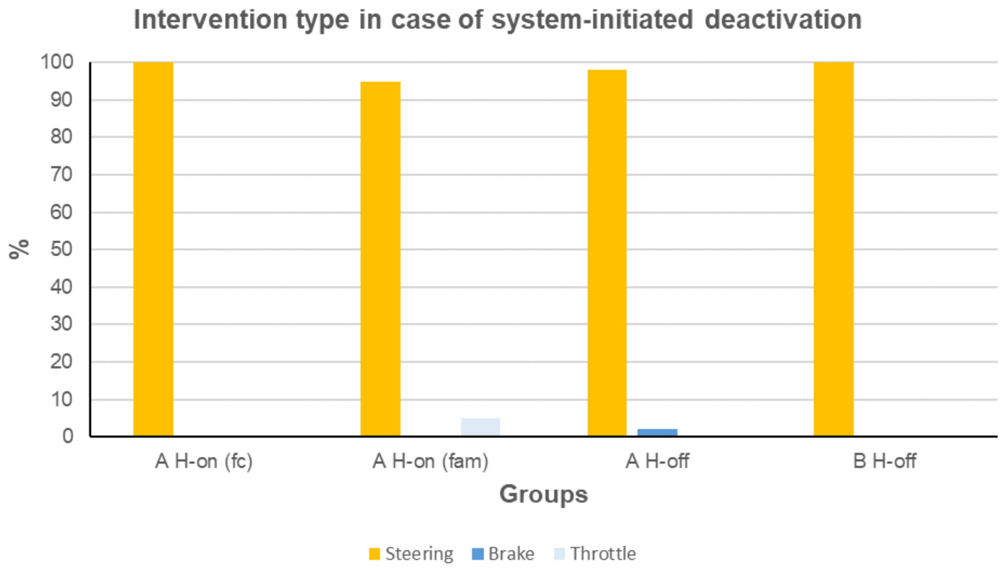
- Gustavsson et al. (2018), Pipkorn et al. (2021) and Victor et al. (2018) attributed driver reactions in system malfunction scenarios not to differences in hand position, but to different levels of trust.
- "The problem is not the driver's ability to handle limited lateral failure dynamics when driving hands-free but rather a cognitive misattribution of the systems capability which is build up by experience of the system and user expectations." Schneider et al. (2022, p. 190)

Image source: Flaticon.com

CQ2 Prolonged transition times
Evidence: Driver- and system initiated deactivations

Type of driver intervention does not differ between L2 functions – hands-free monitoring does not influence the type of first intervention.

Data source: FOT DE



N A H-on (fc) = 30
N A H-on (fam) = 29
N A H-off = 30
N B H-off = 30

Data source: Study 4 (Anchor Study)

First direct driver input in scenario

	1st lane drift (Scenario 1)		2nd lane drift (Scenario 3)	
	L2H-on	**L2H-off**	**L2H-on**	**L2H-off**
Steering	39 / 39	36 / 37	38 / 38	37 / 37
Other		1 / 37		

	1st lane end (Scenario 2)		2nd lane end (Scenario 4)	
	L2H-on	**L2H-off**	**L2H-on**	**L2H-off**
Steering	32 / 38	32 / 37	36 / 38	35 / 37
Braking	4 / 38	3 / 37	2 / 38	
Hard Key	1 / 38	2 / 37		2 / 37
Other	1 / 38			

Data basis reflects the number of drivers using the L2 function at measurement onset as opposed to the overall number of participants.

CQ2 Prolonged transition times
Controllability

Findings from data collections

- **Improved controllability for L2H-off functions in predictable, but occluded events according to minimum TTC.**
  - Similar intervention time-points and controllability for L2H-off and L2H-on functions found in all other scenarios.

- **A small number of incidents** (only in driving simulator studies) **in response to time-critical events was observed for L2H-on and L2H-off functions as well as during manual driving.**
  - Reasons for incidents are manifold (i.e., hand posture is not the relevant factor for incidents).

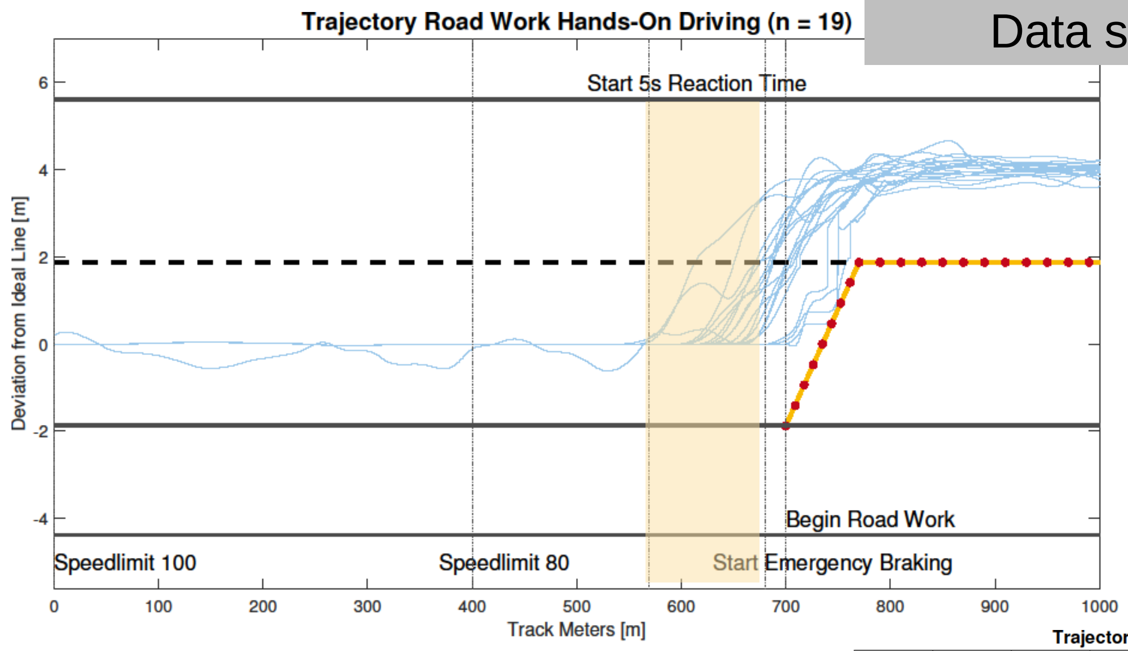
Findings from literature

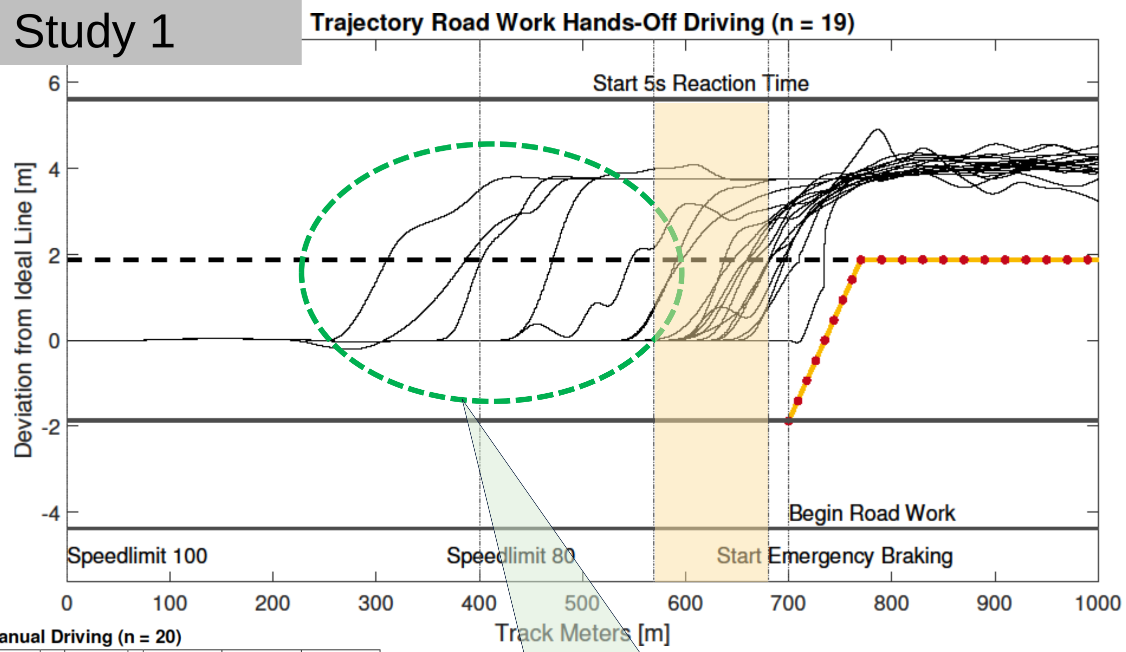
- Hands-off supervision with an adapted DMS results in similar crash rates (Victor et al. 2018) and driver steering time-points (Pipkorn et al. 2021).

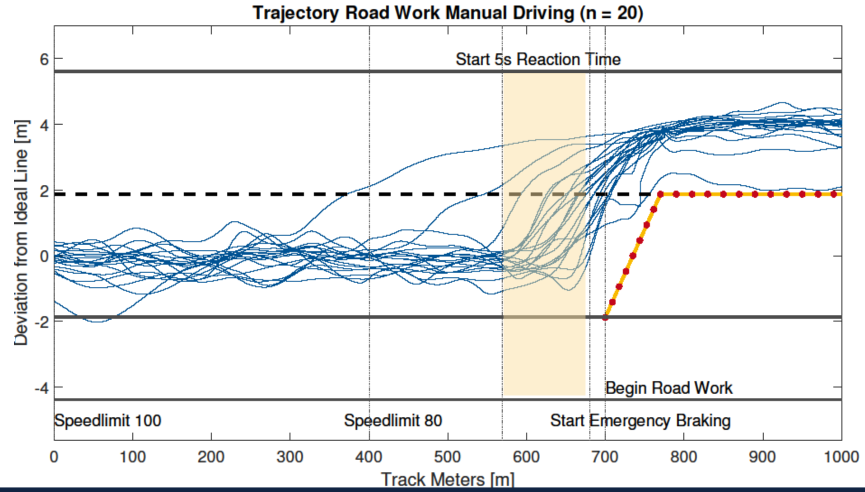
CQ2 Prolonged transition times

Evidence: Controllability

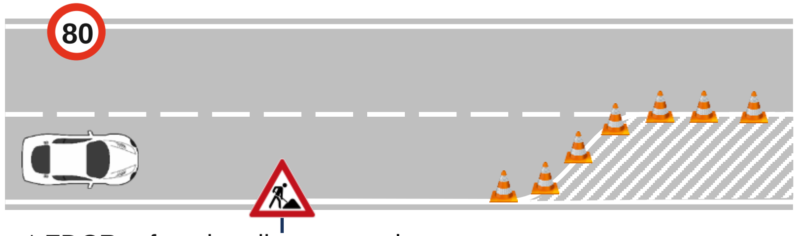
Data source: Study 1







Situation revealed after lead vehicle changes lanes (leaving 5 s time budget), no FDCR*



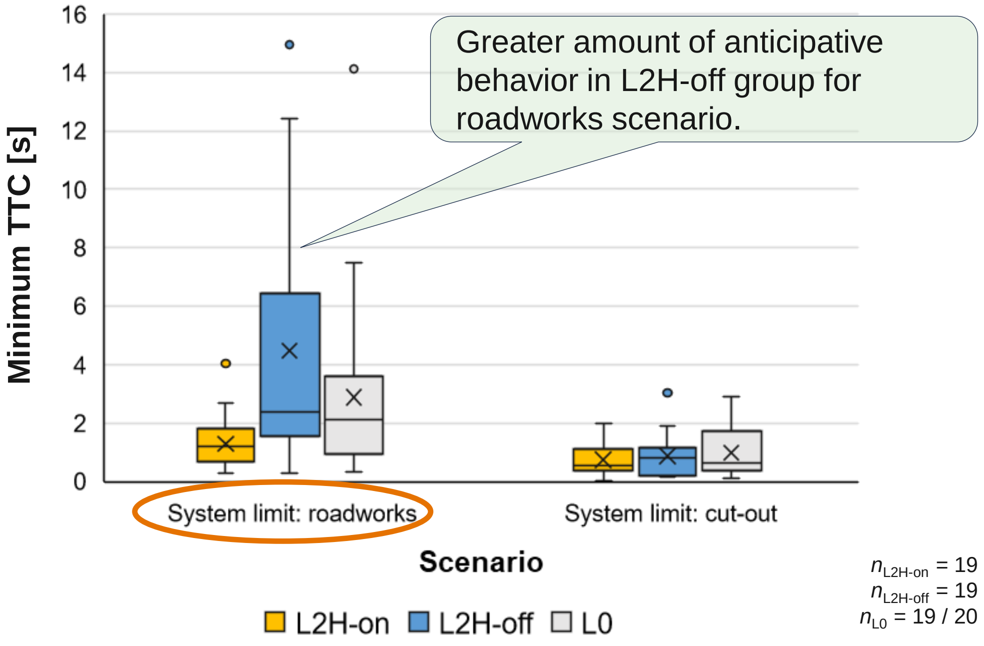
* FDCR = function direct control request

Scenario Roadworks (predictable due to signs, occlusion by lead vehicle):

Interventions in anticipation of roadworks based on signs before lane end fully visible were observed **only in L2H-off group, not in L2H-on group.**

CQ2 Prolonged transition times
Evidence: Controllability

Data source: Study 1



$n_{L2H\text{-}on}$ = 19
$n_{L2H\text{-}off}$ = 19
n_{L0} = 19 / 20

For the manual driving mode (L0), only 19 subjects were analyzed for cut-out scenario due to one case in which another vehicle in front crashed with the broken-down car.

Minimum TTC:

- Scenario *Roadworks:* significantly higher TTC_{min} for L2H-off group compared to L2H-on group **(→ better controllability in L2H-off group)**
  - No differences to manual driving group found
- Scenario *Cut-out*: No difference between groups found

Reactions in case of occlusion:

- Without FDCR* (L2) or collision warning (L0), **a number of drivers in each groups does not intervene before braking maneuver (BM) onset** (at 5 s after situation reveal).
- A majority of the drivers with late interventions (RT > 5 s) overrules the BM to actively handle the situation (→ low TTC).

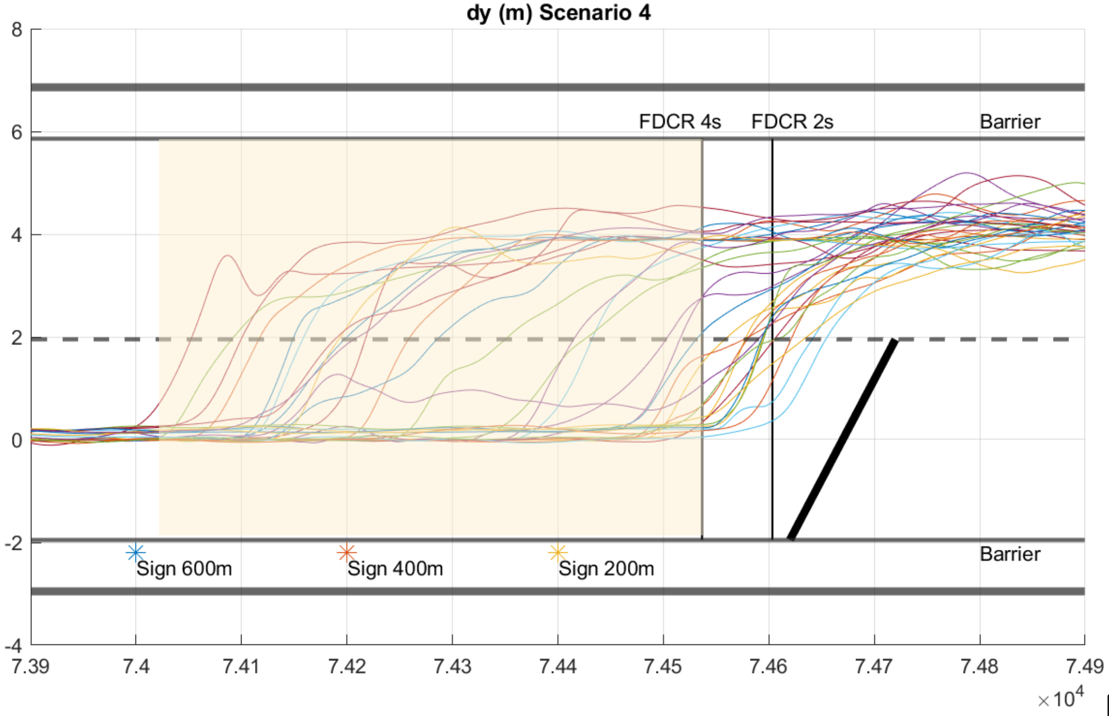
	Roadworks		Cut-out	
	BM (RT > 5 s)	No BM (RT < 5 s)	BM (RT > 5 s)	No BM (RT < 5 s)
L0	9 / 20	11 / 20	17 / 19	2 / 19
L2H-on	13 / 19	6 / 19	17 / 19	2 / 19
L2H-off	11 / 19	8 / 19	17 / 19	2 / 19

* FDCR = function direct control request

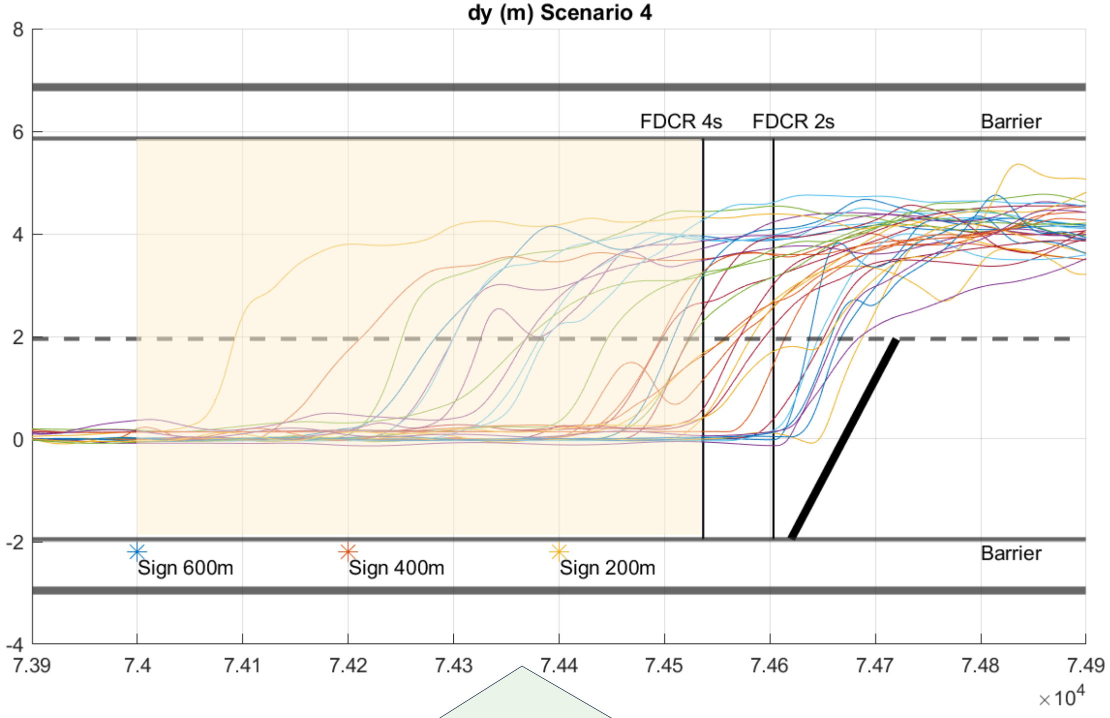
CQ2 Prolonged transition times
Evidence: Controllability

Data Source: Anchor Study (Study 4)

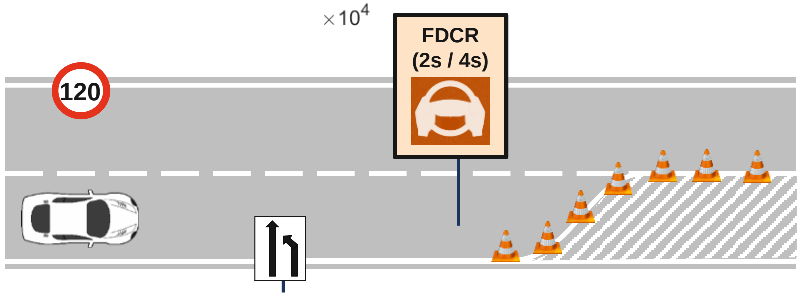
L2H-on



L2H-off



No lead vehicle present, situation announced by signs well in advance



Scenario lane end (predictable by signs, no occlusion by lead vehicle)
No significant difference between L2 functions observed with well-anticipatable lane end scenario (in contrast to Study 1 with occlusion by lead vehicle and defined reveal time)

* FDCR = function direct control request

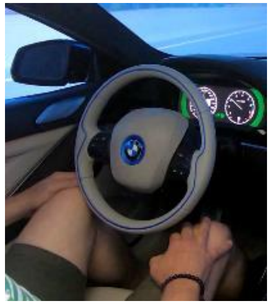
CQ2 Prolonged transition times
Example: Controllability

Data Source: Study 4 (Anchor Study)

Example: Driver's first encounter with a specific ODD limit

- Scenario 2: Lane End (condition with FDCR* = 4s)
- L2H-off Expert driving with L2H-off function during study
  - **Hands move towards the wheel** before last road sign indicating end of lane (1)
  - Hands keep hovering for a couple of seconds
  - Hands are put down, but slight contact with steering wheel is maintained (2)
  - **Upon FDCR, wheel is gripped and steering is initiated (3)**
- Interview confirms awareness of the functional limit (provided by function's manual before test drive):
  - „The lane was going to the end and **I knew the system was not going to change lanes on its own**. In the first situation I waited until the lane was just about to merge […] just my normal reaction"

Initial hand position



1

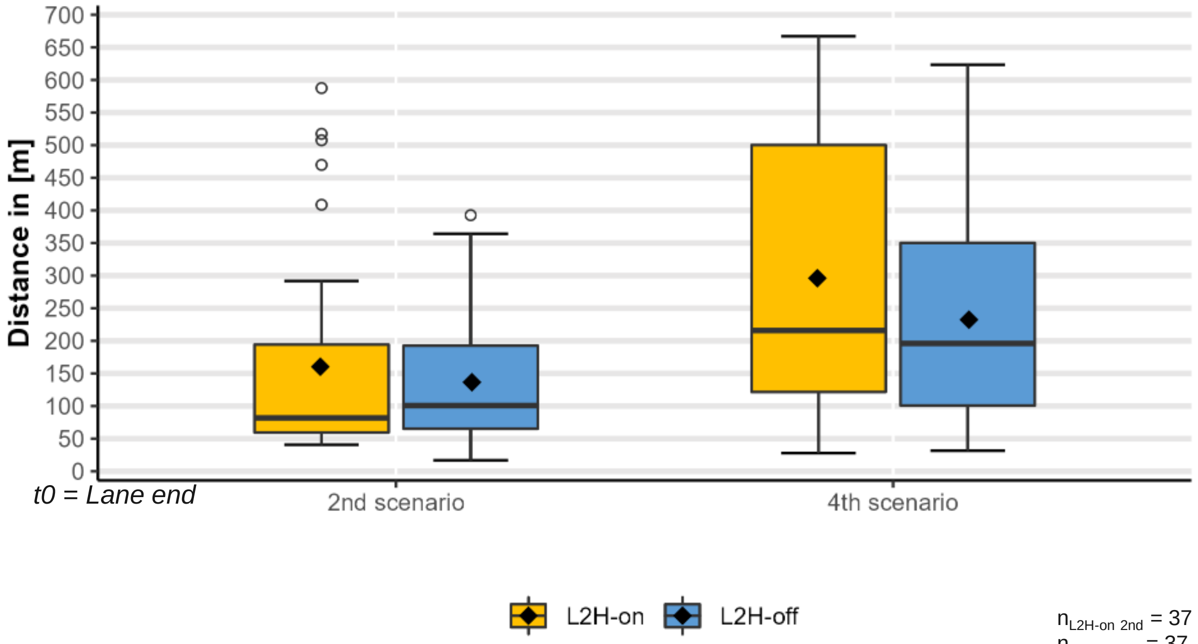
2

3

* FDCR = function direct control request

CQ2 Prolonged transition times
Evidence: Controllability

Data Source: Anchor Study (Study 4)



$n_{L2H\text{-}on\ 2nd} = 37$
$n_{L2H\text{-}on\ 4th} = 37$
$n_{L2H\text{-}off\ 2nd} = 37$
$n_{L2H\text{-}off\ 4th} = 37$

Distance to lane end <u>at point of lane change:</u>

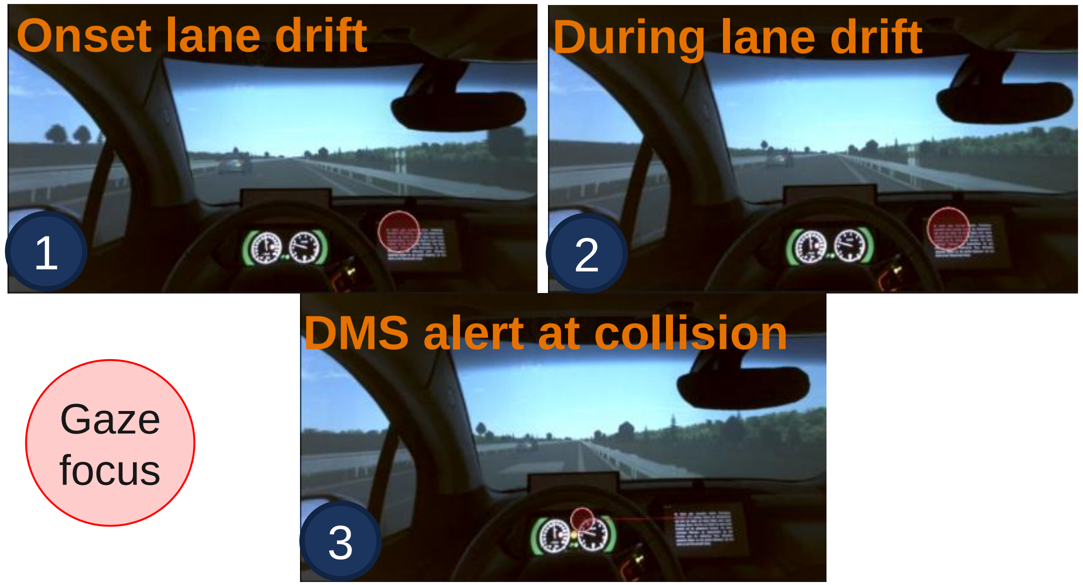
- **No differences between functions**.
- In the 2nd scenario (first encounter of lane end), drivers were closer to the end of lane when they changed lanes.

Timing of 1st driver reaction:

- **Tendency for earlier interventions in the L2H-on group**
  - Only incident observed occurs in L2H-on group.
  - Scenario can be anticipated well (in difference to Study 1; no occlusion by lead vehicle, similar signage).
  - **Mean first interventions occur sufficiently early in both groups.**

Data source: Anchor study (Study 4)

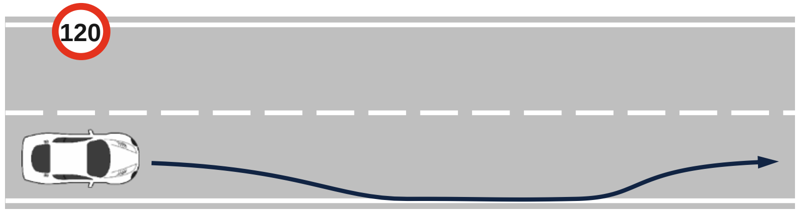
- **Scenario 1: Lane drift (0.6 m/s)**
  - One incident with contact to barrier observed for L2H-on expert during **L2H-off** use in the study
    - Attention primarily directed at secondary task
    - DMS alert (Stage 1) occurs shortly before lane drift onset (see description on right hand side).



- **Driver attempts to terminate DMS alert (Stage 1; EOR) by small movement of steering wheel**
  - Only brief orientation of eyes to road (approx. 92 ms)
- Discovery of collision only after another DMS Stage 1 alert.

- **Conclusion: Potential confusion of hands-on request and eyes-on request due to prior L2H-on experience of this participant (in daily life)**

Improved DMS design might present a solution to the observed problematic behavior (cf. design guidance on criteria to terminate DMS alerts), see CQ4.



CQ2 Prolonged transition times

There are concerns that hands-on (reaction) times (returning hands to the steering wheel) as well as longer reaction times in general lead to an increased risk of accidents.

Overall conclusions

- **The option for hands-free driving did not translate into prolonged reaction times at functional limits.**
  - The physical disadvantage of hands-free driving can be compensated by supporting a sufficient involvement in the driving task (i.e., by DMS design).
- **No indication for a reduced involvement in the driving task was found for L2H-off functions based on the analysis of reaction times to DMS alerts.**
- **Visual-attention-based DMS can improve the controllability of predictable, but occluded events.**

CQ1: Hands-off = mind-off?

There are concerns that a lack of driver involvement in the driving task (exacerbated by the lack of contact with the steering wheel during L2H-off) will reduce the driver's attention to the driving task.

Image source: Flaticon.com

Prolonged transition times
Definition

Adapted from Bubb (2021)

Perception *and (Cognition)*

Action

Primary driving task

Driver keeps the vehicle on course at a certain speed.

- **Visual attention as requirement for primary driving task.**
- **Preparation of and readiness for action indicates involvement in the driving task.**

Secondary driving task

- Necessary depending on the respective traffic situation and support the primary task (e.g., indicator, wiper, horn)

Tertiary driving task

- Operations having nothing to do with actual driving (e.g. control of air condition, radio, navigation, or phone)

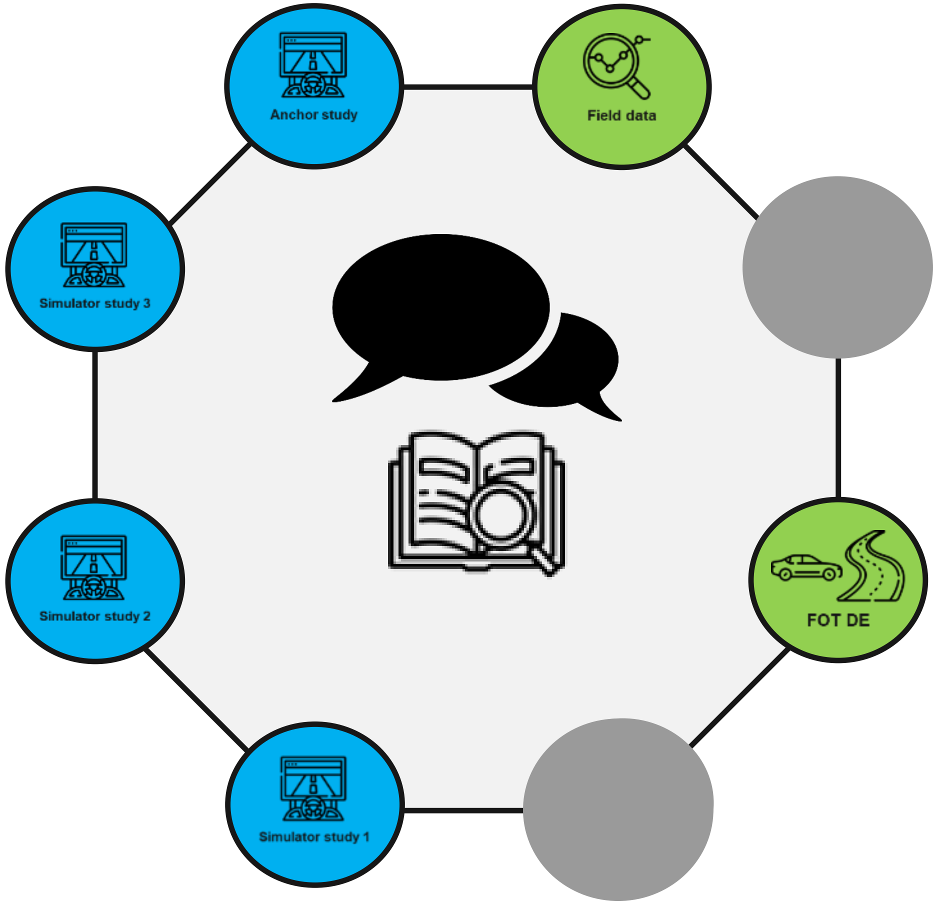
The cognitive component must be considered as well in addition to visual attention (perception; CQ1) and motoric readiness (action; CQ1)

→ See results on CQ4 (mode confusion).

Image source: Flaticon.com

Hands-off = mind-off?
Metrics

Conclusions are primarily based on:



Constructs and metrics:

- **Visual attention**
  - Number of eyes-off road glances > 2 s
  - Attention ratio (Eyes-on road, instrument cluster/steering wheel, other)
- **Monitoring**
  - Number of hands-off/eyes-off warnings
  - Subjective rating of monitoring performance
- **Perceptual readiness at transitions**
  - Visual attention ratio 30 s before and 10 s after the transition
- **Other**
  - Interview & test protocols

- **Motoric ability for safe vehicle guidance**
  - Hands-on/Hands-off proportion
- **Motoric readiness at transitions**
  - Hand position rating
- **Other**
  - Interview & test protocols

Image source: Flaticon.com

CQ1 Hands-off = mind-off?
Visual attention

Findings from data collections

- **Descriptive tendencies of higher visual attention to the road found for L2H-off functions.**
  - **Significant <u>advantage</u> found for L2H-off in Study 1.**

- Little difference in number of eyes-off road glances > 2 s for L2H-off compared to L2H-on groups (in 4 out of 5 data collections).
  - **Higher number of glances > 2 s for L2H-off compared to L2H-on, but no difference to manual driving (Study 1).**

- **3-s-DMS group shows fewer eyes-off road glances > 2 s than 5-s-DMS group, but no clear difference in eyes-on road ratio.**
  - **5-s-DMS with predominantly good subjective evaluation** in terms of timing (e.g. FOT), but also indication of higher annoyance with higher warning frequency found.

  (→ Probability of disuse (CQ3) might increase with higher warning frequency.)

Findings from literature

- Hands-free L2 use <u>without</u> DMS leads to increased visual distraction compared to L2H-on functions, ACC and manual driving. (Boos et al. 2020; Josten 2021; Llaneras et al. 2013; Noble et al. 2021; Othersen 2016)

- Visual attention based DMS eliminate this negative effect:
  - With (3-step) monitoring requests, L2H-off gaze ratio to the road is better than without. (Blanco et al. 2015; Kurpiers et al. 2019; Llaneras et al. 2017; Victor et al. 2018)
  - Monitoring requests prevent high fatigue level and very long eyes-off-road times (e.g., 4 s eyes-off road). (Victor et al. 2018)

- Alert annoyance habituation should be considered for system design. (Blanco et al. 2015)

Image source: Flaticon.com

CQ1 Hands-off = mind-off?
Evidence: Visual Attention

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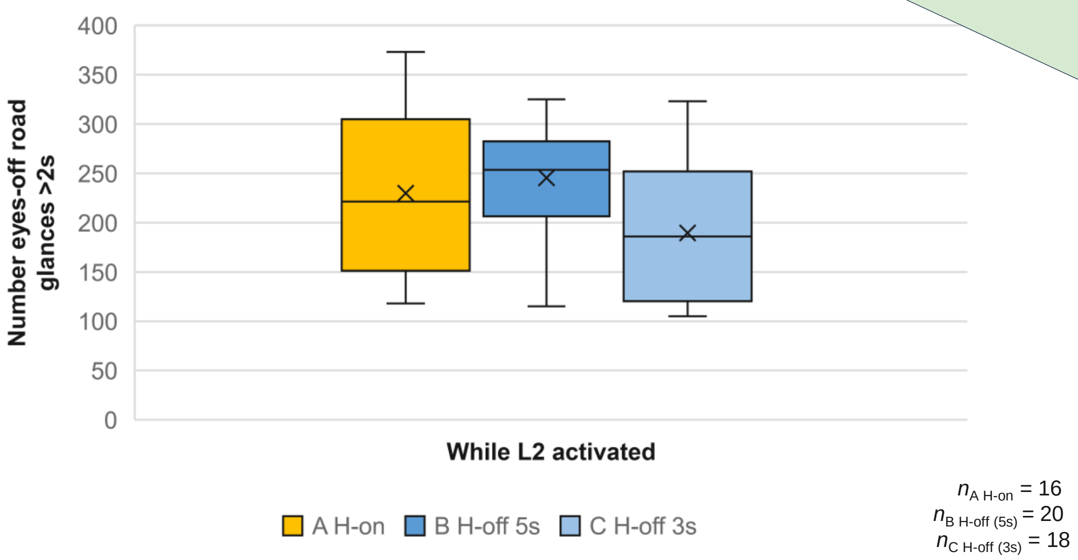
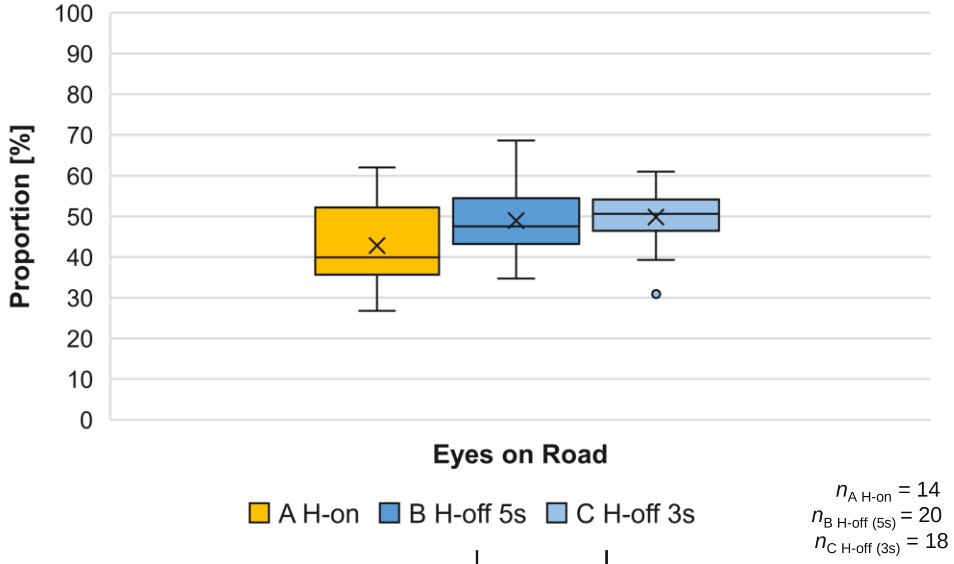
Data source: Study 3

3 s-DMS shows **fewer eyes-off road glances > 2 s** than 5 s-DMS (left) but there is **no difference in eyes-on road ratio** (right; Study 3 with visual/verbal NDRT).





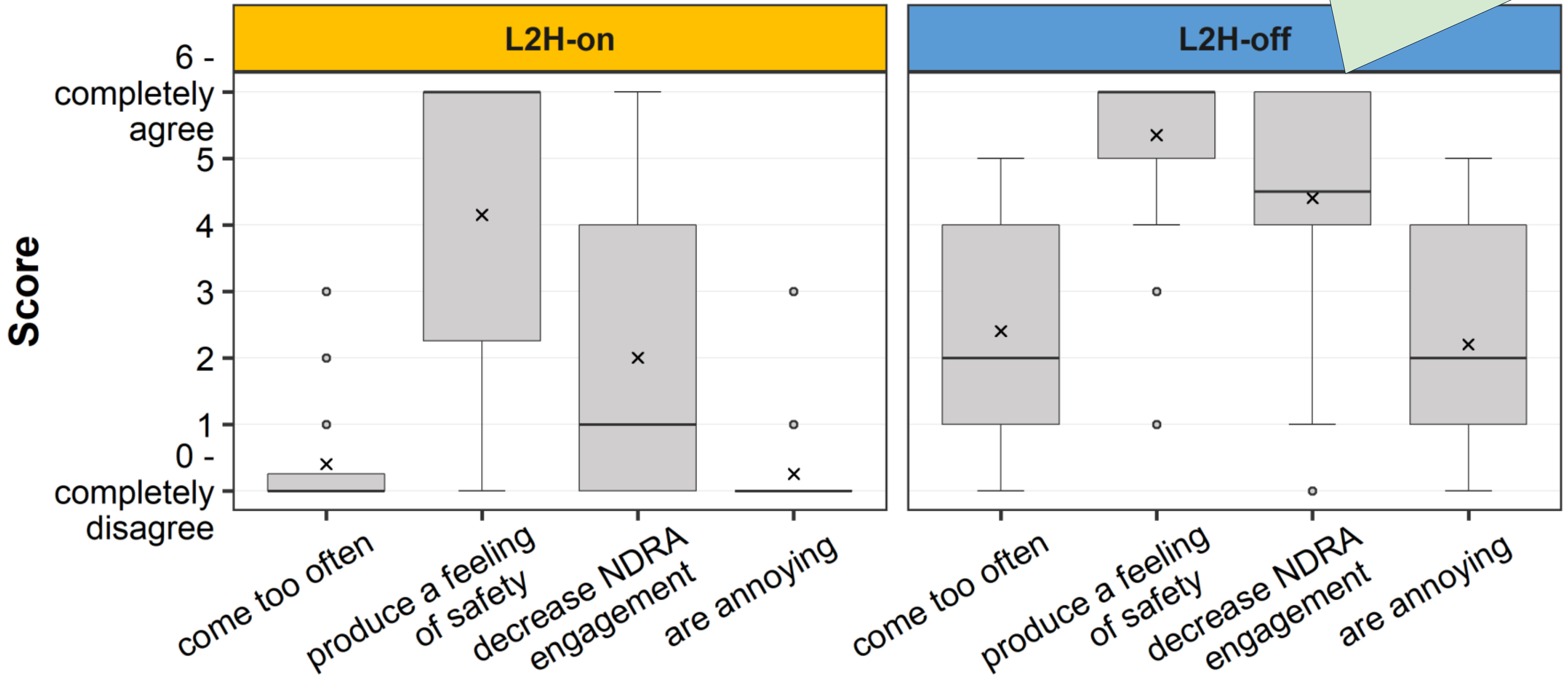
Driving Mode	*M*	*SD*
H-on	42.85	9.91
H-off 5s	48.97	7.80
H-off 3s	49.79	6.89

Glance behavior in combination with visual-verbal non-driving related task (NDRT) presented during the drive.

CQ1 Hands-off = mind-off?
Evidence: Visual Attention

Data source: Study 1

5-s-DMS with higher subjective influence on NDRT (NDRA) engagement, but also significantly higher annoyance and (subjectively) too frequent warning frequency



n (per group) = 20

CQ1 Hands-off = mind-off?
Monitoring

Findings from data collections

- **Less warnings when using L2H-on functions in comparison to L2H-off functions.**
  - No differences between L2 functions for hypothetical eyes-off warnings (post-hoc analysis FOT), but **high outliers for L2H-on group**.
- Warning cascade in FOT is predominantly terminated after DMS Stage 1. **Only few participants received Stage 3 warnings in all of the studies.**
  - Without (voluntary) non-driving related task: very low number of eyes-off warnings in comparison (FOT, Study 2)
- **Predominantly positive assessment of L2H-off DMS**, e.g. with regard to perceived effect on driving safety and NDRT engagement.

Findings from literature

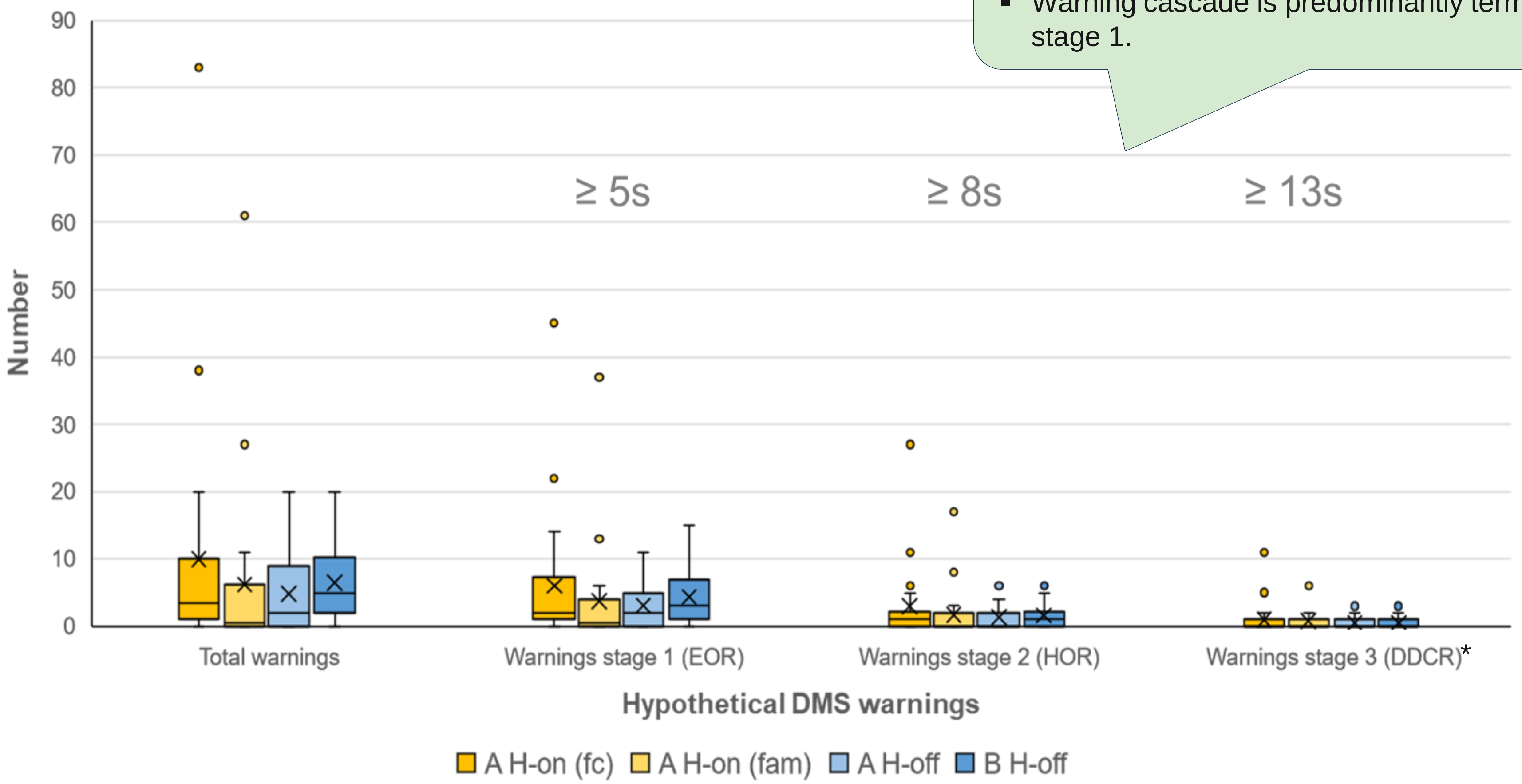
- With 3-step monitoring requests, L2H-off gaze ratio to the road is better than without. (Blanco et al., 2015; Kurpiers et al., 2019; Llaneras et al., 2017; Victor et al., 2018)
- Information (‘training’) on the functionality decreases the number of Stage 2 DMS alerts. (Llaneras et al., 2017)

Image source: Flaticon.com

CQ1 Hands-off = mind-off?
Evidence: Monitoring

Data source: FOT DE

- No differences in **hypothetical** eyes-off warnings (post-hoc analysis), but high outliers for L2H-on group.
- Warning cascade is predominantly terminated in warning stage 1.



N A H-on (fc) = 19
N A H-on (fam) = 19
N A H-off = 19
N B H-off = 26

* DDCR = DMS direct control request

CQ1 Hands-off = mind-off?
Perceptual readiness

Findings from data collections

- L2H-off users showing anticipative actions to upcoming system limits provide **evidence of perceptual readiness**.
  - Some L2 users report to actively monitor the function’s behavior in complex or unfamiliar situations of use.
  - Higher <u>eyes-on road</u> ratio <u>before deactivation</u> with L2H-off than with L2H-on functions (cf. FOT DE).

- Subjects in FOT DE indicated that **L2H-off is more complex to use than L2H-on**.
  - Higher <u>eyes-on instrument cluster</u> ratio for L2H-off <u>before activation</u> (cf. FOT DE).

Findings from literature

- Visual attention and hands-on wheel are not always sufficient for an adequate driver reaction. (Victor et al. 2018, Gustavsson et al. 2018)

Image source: Flaticon.com

CQ1 Hands-off = mind-off?
Example: Perceptual readiness at transitions

Data source: Anchor study (Study 4)

- **Scenario 3: Lane drift (0.6m/s)**
  - L2 experienced driver

Drivers show anticipative actions / preparation for interventions.

1. Onset lane drift

Hand positioning at beginning of scenario

2. Initial intervention

Hands are moved into close proximity of wheel, indicating perception of lane drift

3. Initial intervention aborted

Hands are brought away from the wheel again, but kept in close proximity

4. Final intervention

Wheel is grasped for steering

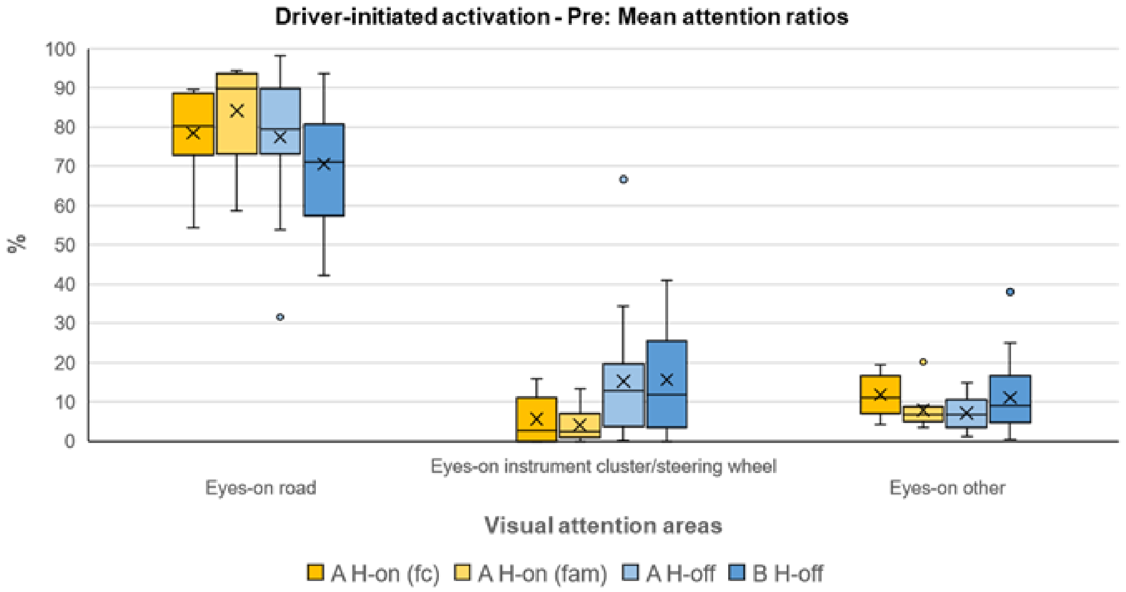
CQ1 Hands-off = mind-off?

Evidence: Perceptual readiness at transitions

Visual attention ratio (activation)

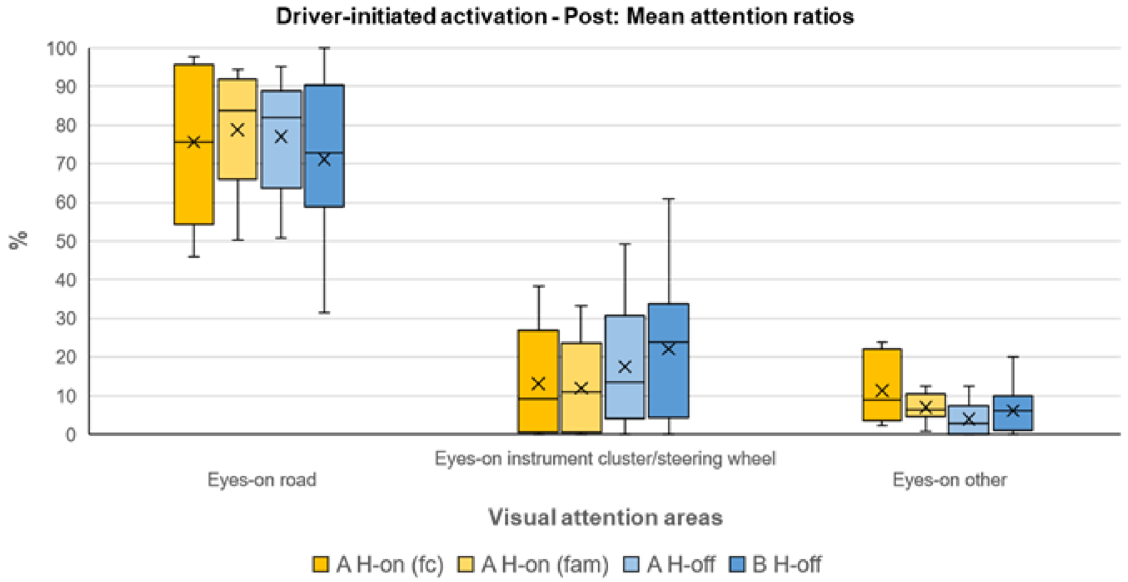
Higher amount of attention attributed to instrument cluster when activating L2H-off functions as indicator for higher complexity.

Data source: FOT DE



N A H-on (fc) = 10
N A H-on (fam) = 9
N A H-off = 18
N B H-off = 23
N = events

Data source: FOT DE



CQ1 Hands-off = mind-off?
Motoric ability for safe vehicle guidance

Findings from data collections

- **L2H-off users in FOT DE have hand(s) on the steering wheel approx. 45% of usage time**, large spread observed in FOT data and over studies (e.g., 24% SD in hands-off times in Study 1).
  - Might also be interpreted as an indication of balanced trust (i.e., neither over-trust nor distrust).
- **Level of motoric control is adapted during L2 use.**
  - Preparatory changes in hand posture in anticipation of system limits are common for L2H-off. L2H-off users do not always monitor hands-free (see above).
  - Users monitor L2H-on functions mostly with hands-on wheel, but outliers with relatively high hands-off proportion exist.

Findings from literature

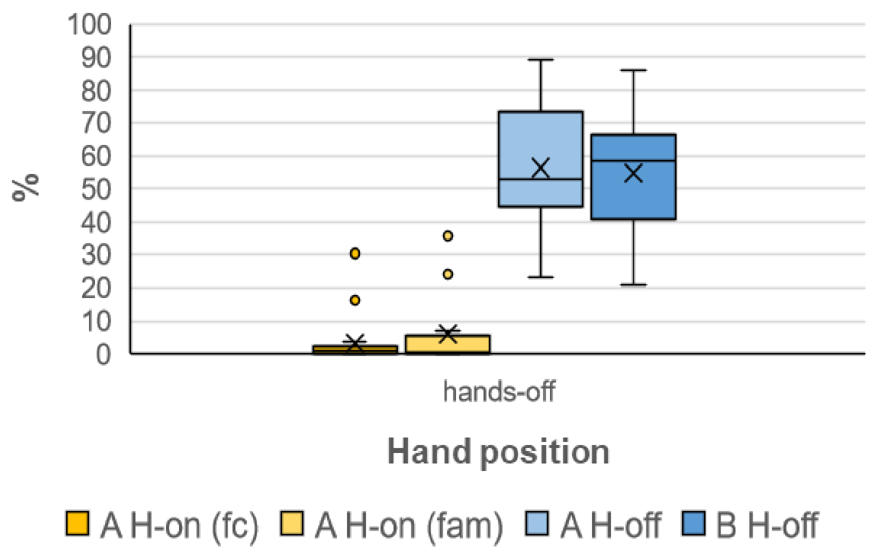
- Not all drivers take their hands off the steering wheel during L2H-off use. (Naujoks et al., 2015)
- Some users use L2H-on functions in a hands-free fashion. (Mueller et al., 2022)
- Hand posture changes with the level of workload, increases with the presence of driving automation and correlates with eyes-off road times and misuse (as reviewed by Mueller et al., 2021)

Image source: Flaticon.com

CQ1 Hands-off = mind-off?
Evidence: Motoric ability for safe vehicle guidance

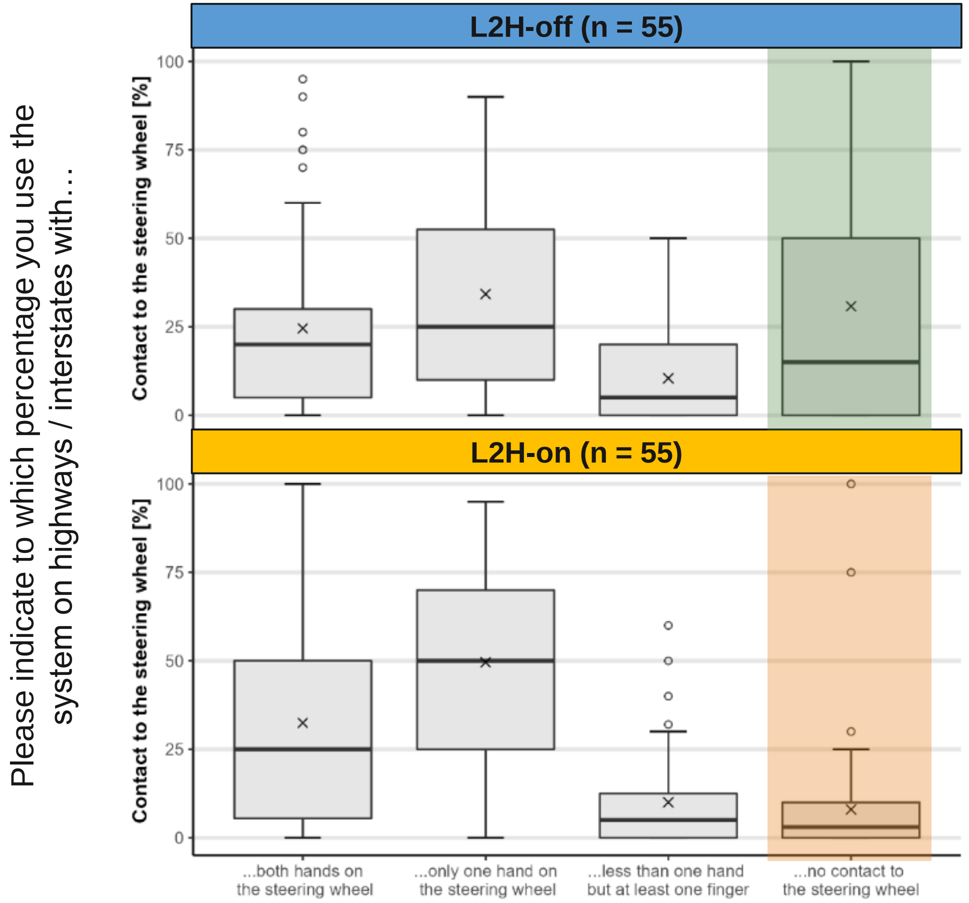
Hands-on / Hands-off proportions during L2 use

Data source: FOT DE



Users mostly monitor L2H-on functions with hands-on wheel, but outliers with relatively high hands-off proportion exist.
L2H-off users do not always monitor hands-free.

Data source: User survey (as affirmation of objective data)



CQ1 Hands-off = mind-off?
Motoric readiness at transitions

Findings from data collections

- **Awareness of when the hands should be moved towards the steering wheel seems to exists.**
  - L2H-off users in FOT DE: The closer the transition, the closer the subjects get to the ready-to-drive hand position (higher “motoric control”).
  - Anchor study (Study 4) confirms this finding for FDCR* and when closely monitoring system behavior (silent failures): Drivers move hands towards steering wheel based on situational knowledge and anticipation.

Findings from literature

- Strategic adaptations of driver behavior have been observed in other contexts: Drivers adapt their engagement to the traffic state, engaging more in processing the secondary task while driving in low-velocity ranges compared with driving at higher speeds (Naujoks et al. 2016)

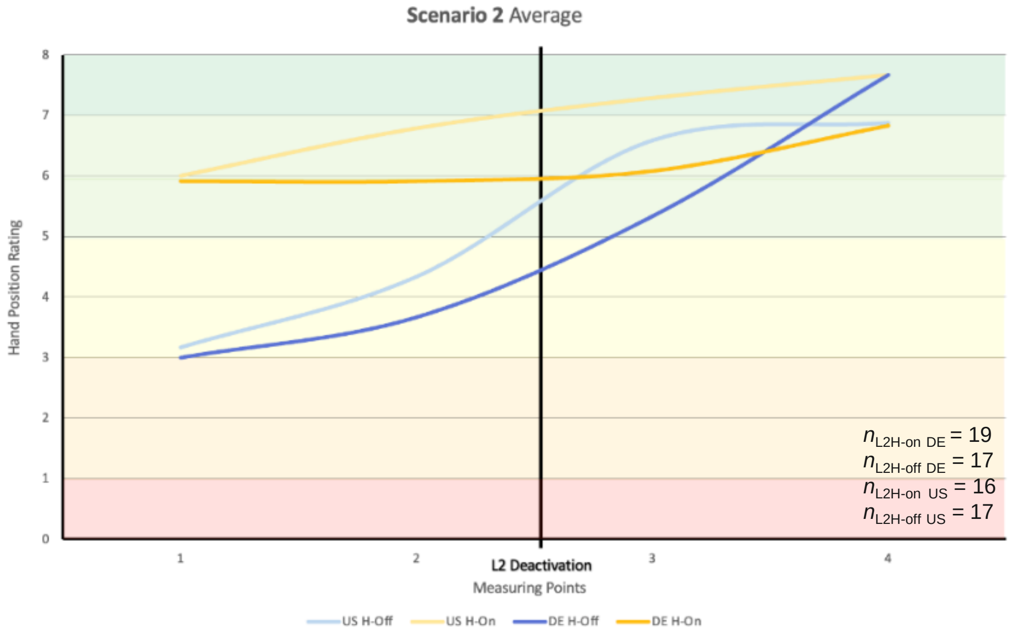
*FDCR = function direct control request

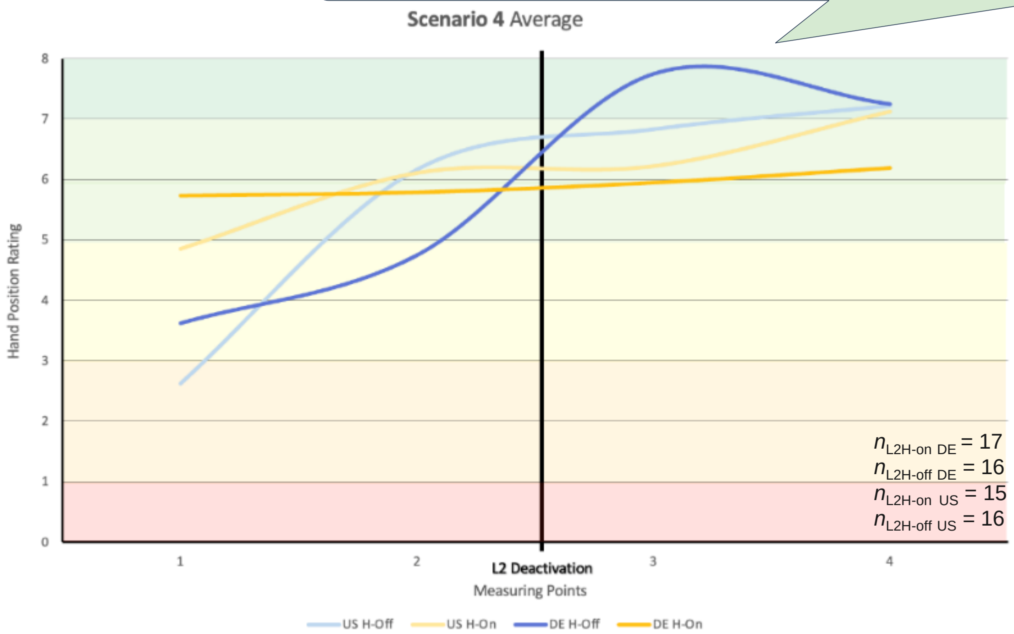
Image source: Flaticon.com

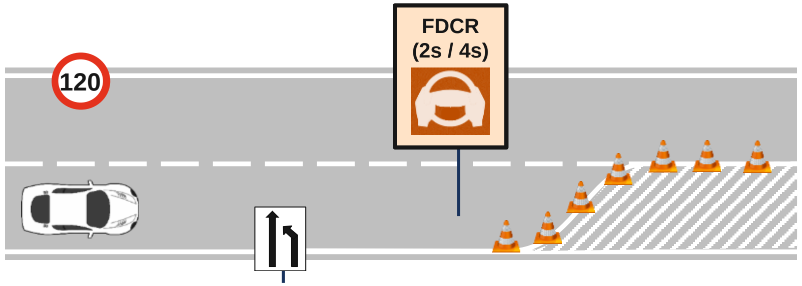
Hands-off = mind-off?
Evidence: Motoric readiness at transitions

L2H-off: Changes in hand posture in preparation to the upcoming, well-known ODD limit / transition (higher motoric control; based on video ratings of hand positions)

Data source: Anchor study







Scenario	Description
2nd scenario (first encounter with limit)	End of lane necessitates manual lane change With FDCR* (2s / 4s before end of lane)
4th scenario (second encounter with limit)	End of lane necessitates manual lane change With FDCR* (2s / 4s before end of lane)

*FDCR = function direct control request

CQ1 Hands-off = mind-off?

There are concerns that a lack of driver involvement in the driving task (exacerbated by the lack of contact with the steering wheel during L2H-off) will reduce the driver's attention to the driving task.

Overall conclusions

- **Hands-off does not equal mind-off.**
  - **Visual attention to the road during L2H-off use is similar or improved in comparison to the use of L2H-on functions.**
  - **Drivers adapt their level of motoric control during L2 use. L2H-off functions are not used continuously hands-free.**

- The cognitive component must be considered in addition to visual attention (perception) and motoric ability to intervene (action) → see results CQ3 and CQ4.

CQ3: Foreseeable misuse

There are concerns that the use of L2H-off functions will lead to foreseeable misuse or to disuse, particularly with respect to an increased initiation of non-driving related tasks.

Image source: Flaticon.com

CQ3 Foreseeable misuse
Definition

(Reasonably) Foreseeable misuse

- means the usage of a system in a non-intended way.
- excludes intentional alterations made to the system's operation. (ISO 21448:2022)

Relevant aspects of foreseeable misuse:

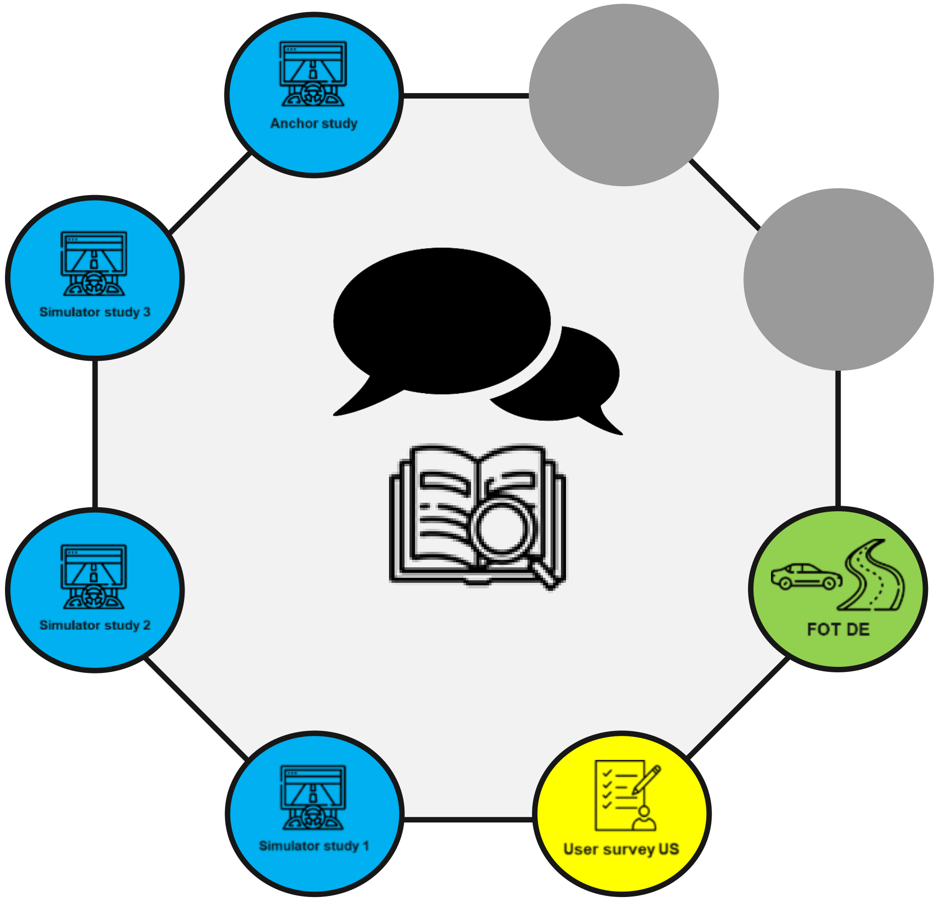
- Insufficient monitoring of the function (indirect misuse), including hands-free monitoring where it is not admissible (see analyses in CQ1: Motoric ability for safe vehicle guidance).
- **Activities that lead to insufficient monitoring (driver distraction; focus of CQ3).**
  - NDRT* engagement during L2 use
- Use of functions in other non-intended ways (e.g., in heavy rain, snowfall)
- Intended / reported potential misuse

*NDRT = non-driving related tasks

Image source: Flaticon.com

CQ3 Foreseeable misuse
Metrics

Conclusions are primarily based on:



Constructs and metrics:

- **Distraction**
  - Objective NDRT* engagement
    - Types of NDRTs
    - Number of tasks solved (in experimental studies)
  - Subjective (inclination for) NDRT engagement during L2
  - (Visual) Strategies during NDRT engagement
- **Misuse**
  - Trust in Automation (TiA, Körber, 2019)
  - Acceptance (CTAM; Osswald et al., 2012)
  - Time H-off (while using L2H-on function)
- **Disuse**
  - Trust in Automation (TiA, Körber, 2019)
  - Acceptance (CTAM; Osswald et al., 2012)
- **Other**
  - Interview

*NDRT = non-driving related task

Image source: Flaticon.com

Findings from data collections

- **No greater *objective* NDRT involvement** observed **during L2H-off function use**, neither in comparison to L2H-on function, nor in comparison to manual driving (Study 1) or in comparison between participant groups (Study 4).
  - Ratings and exemplary incidents show that **hands-on requests do not necessarily lead to a termination of NDRT engagement**.
- **No generally higher *subjective* inclination** for the involvement in non-driving related activities for L2H-off functions in comparison to L2H-on functions.
  - Large dispersion in NDRT inclination during manual driving (Study 1) and in reported NDRT engagement for L2 use in general (e.g., US Survey).

Findings from literature

- **Performing secondary tasks is more common while using L2** than while driving manually (e.g., Solís-Marcos et al. 2018; Noble et al. 2021; Llaneras et al. 2013).
- **Drivers with prior L2 experience are more likely to participate in distracted driving behaviors** when L2 is active than during manual driving (Dunn et al. 2021).
- **DMS alerts are an effective countermeasure** to interrupt secondary task interactions (Llaneras et al. 2017).

Image source: Flaticon.com

CQ3 Foreseeable misuse
Evidence: Distraction

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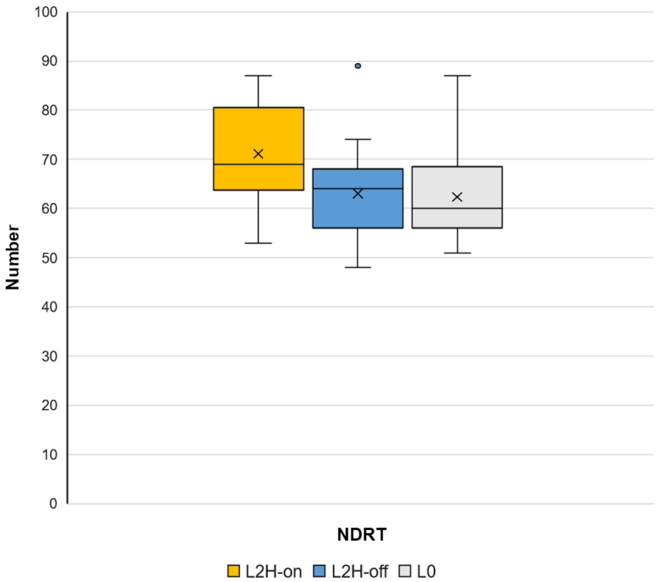
No greater objective NDRT involvement observed in the studies conducted.

Objective NDRT engagement

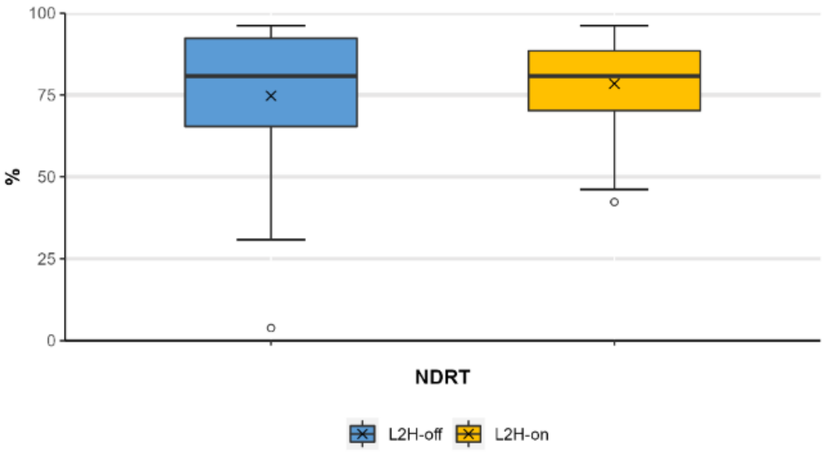
Data source: Study 1



- **Study 1: Visual-motoric non-driving related task** (NDRT; reading & typing)
- **L2H-on drivers completed significantly <u>more</u> NDRTs compared to the L2H-off sample.**
- **<u>No</u> significant difference between L2H-off and manual driving.**

$n_{L2H\text{-}on}$ = 20
$n_{L2H\text{-}off}$ = 19
n_{L0} = 20

Data source: Anchor study (Study 4)

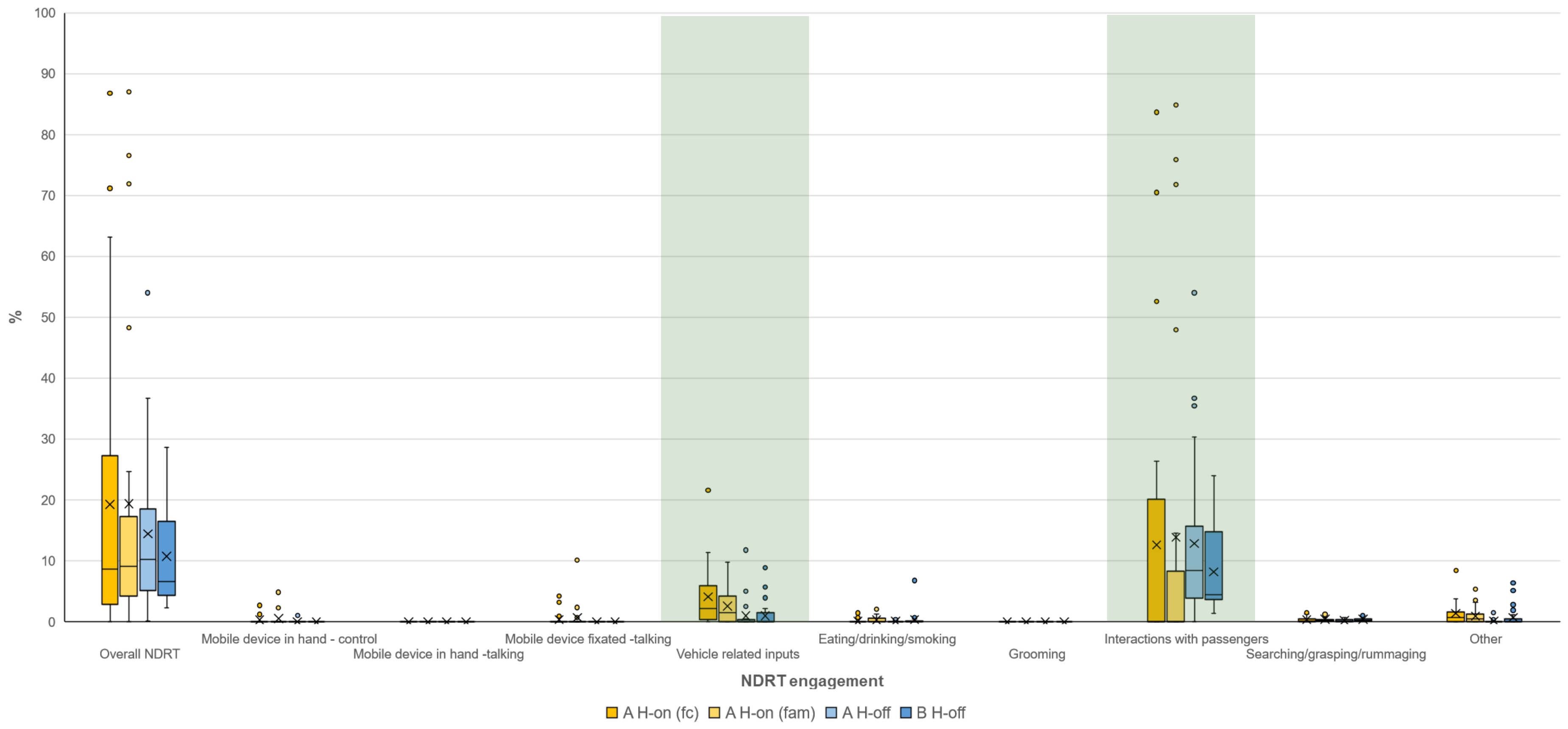


- **Study 4: Visual-verbal NDRT** (reading & speaking)
- **No significant difference in number of solved tasks between L2H-on and L2H-off.**

n_{DE} = 38
n_{US} = 35
$n_{L2H\text{-}off}$ = 35
$n_{L2H\text{-}on}$ = 38

Objective NDRT engagement

Data source: FOT DE



Categories based on Metz et al., 2014

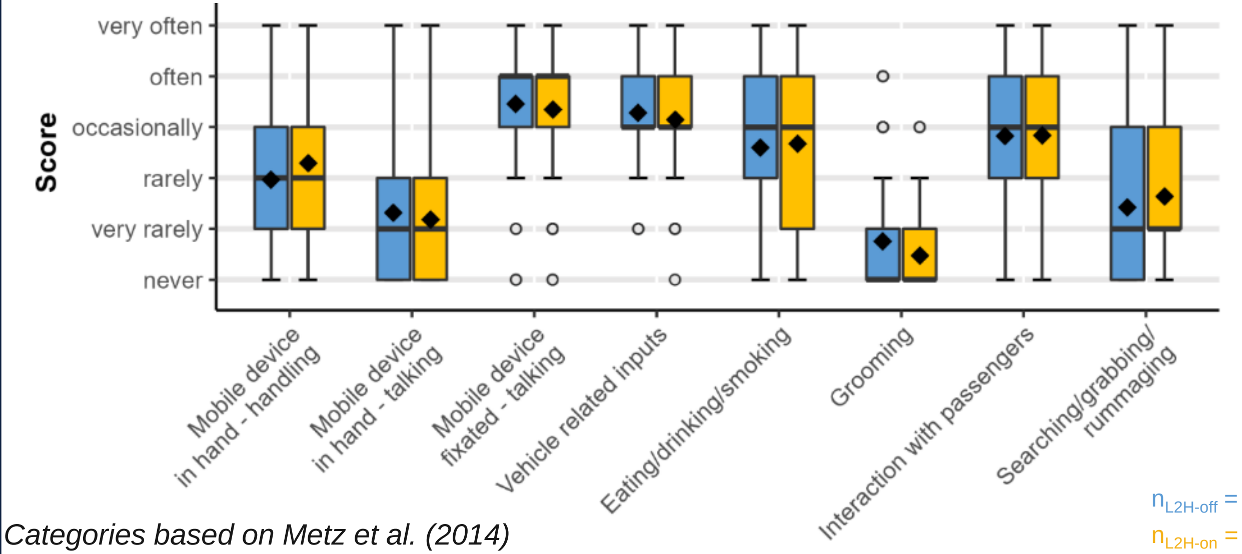
- Distribution of observed secondary activities over an **entire 45 min analysis interval (= 100%).**
- In real traffic, observed non-driving related activities tend to be rather **"non-critical" activities** (e.g., interaction with passengers, vehicle related inputs)

$n_{\text{A H-on (fc)}} = 22$
$n_{\text{A H-on (fam)}} = 22$
$n_{\text{A H-off}} = 22$
$n_{\text{B H-off}} = 28$

CQ3 Foreseeable misuse
Evidence: Distraction

Reported NDRT (non-driving related task) engagement

Data source: US Survey



Categories based on Metz et al. (2014)

*Please indicate the frequency to which you engage in the following activities on highways/interstates **when the function is active.***

- **No differences** regarding the reported involvement in different NDRTs.
- Large range of reported frequencies for many NDRT categories in both L2 groups.

Reported consequences of DMS alerts - **In general, the alerts (e.g., to put hands back on steering wheel or to stay attentive) issued by the system…**

- **…stopped my engagement in the following activities (n = 30):**
  - L2H-off (*n* = 11): visual (and motoric) distracting tasks (e.g., texting, video calls, reading, looking away from the street)
  - L2H-on (*n* = 19): visual and motoric distracting tasks (e.g., checking the phone, browsing, watching videos, rummaging)
    - Stopped *n* = 3 of *n* = 19 L2 users to take their hands off the steering wheel
- **…reduced my engagement in the following activities (n = 32):**
  - L2H-off (*n* = 12): visual (and motoric) distracting tasks (e.g., texting, video calls, infotainment system)
  - L2H-on (*n* = 20): visual and (hands free) motoric distracting tasks (e.g., browsing, texting, eating/rummaging without hands on the steering wheel)
- **…had no effect on the engagement in predominately acoustic tasks (*n* = 16)**

CQ3 Foreseeable misuse
Misuse and Disuse

Findings from data collections

- **Tendency for more positive attitude towards L2H-off found** (i.e., disuse not more likely)**, but no indication for over-trust** (i.e., misuse not more likely)**.**

- **No indications for a L2H-off specific potential for misuse or disuse.**
    - L2H-on drivers seem to use opportunities to remove their hands from the steering wheel and are sometimes not even aware that they are required to keep their hands on the steering wheel.

Findings from literature

- **Relevance of attitudes towards automation for occurrence of misuse:** The likelihood of engaging in secondary tasks increases the greater the positive attitude towards automated driving features is (Kim et al. 2021; Feldhütter et al. 2019).

- Some people appear to use hands-on-wheel systems in a hands-free fashion (as reviewed by Mueller et al. 2022).

- Subjective agreement to use L2 assistance when tired or bored found in other studies. (Stapel, Gentner, & Happee 2022)

- Some reports found in online user forums show **tendency to turn off the L2H-off function to engage in NDRT and avoid DMS alerts (disuse)**.

Image source: Flaticon.com

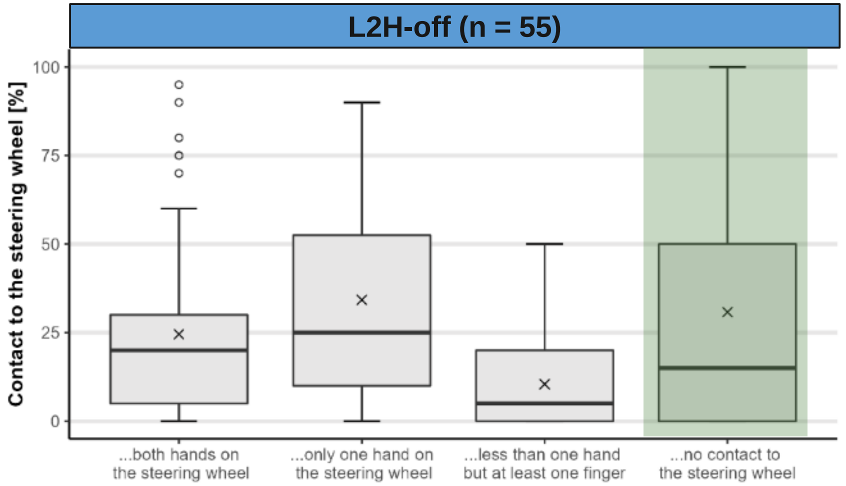
CQ3 Foreseeable misuse
Evidence: Misuse

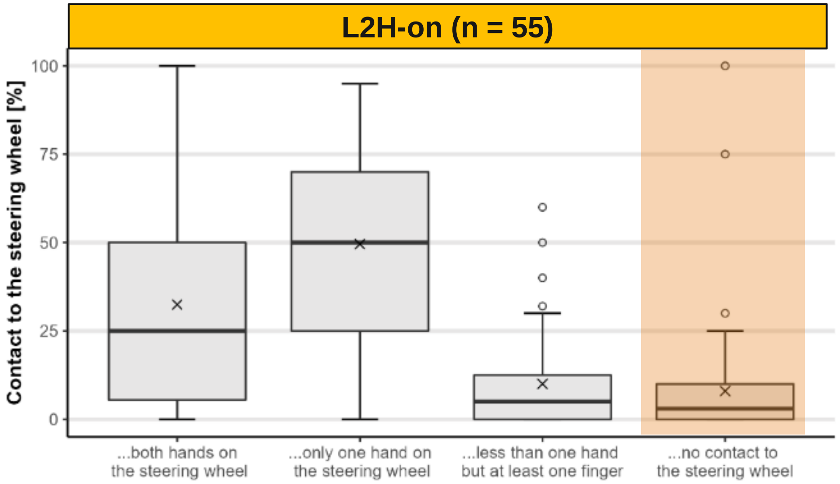
Data source: US Survey

- 27/55 **L2H-off users** reported that the function insists that they **keep contact to the steering wheel.**
- 14/55 **L2H-on users** reported that the function does **NOT** insist that they **keep contact to the steering wheel.**

- **L2H-off drivers do not always make use of the opportunity to take their hands off the steering wheel in all situations (left).**
- **L2H-on users seem to use the opportunity to remove their hands from the steering wheel (right).**

Please indicate to which percentage you use the function on highways / interstates with…





CQ3 Foreseeable misuse

There are concerns that the use of L2H-off functions will lead to foreseeable misuse or to disuse, particularly with respect to an increased initiation of non-driving related tasks.

Overall conclusions

- **No increase in the engagement in secondary tasks found through the use of L2H-off functions**.
- **No misuse- or disuse-relevant differences between L2 functions observed**
  - in trust ratings.
  - in the willingness to perform non-driving related tasks during L2 use.
- L2H-on drivers do not continuously keep their hands on the steering wheel (see also results CQ1).

CQ4: Mode confusion

There are concerns that with the introduction of L2H-off functions drivers are no longer aware of their tasks and roles as drivers and have a lesser understanding of ODD and system functioning.

Image source: Flaticon.com

CQ4 Mode confusion
Definition

- Understanding the function and its limitations as well as understanding one's own tasks when interacting with the function are prerequisites for mode awareness and to anticipate functional limitations.

- Mode confusion is one possible **reason for deficient mode awareness.**
  - Systems that provide gaze-based attentiveness requests have been used as a measure to increase mode awareness (Kurpiers et al. 2019).

- Mode awareness combines **two major aspects**:
  - the knowledge about which mode is currently active and the knowledge about the function's abilities and limits, as well as the tasks and roles as driver (**knowledge-based confusion**)
  - as well as the resulting mode compliant behavior (**behavior-based confusion**). (Kurpiers et al. 2020)

Image source: Flaticon.com

CQ4 Mode confusion
Metrics

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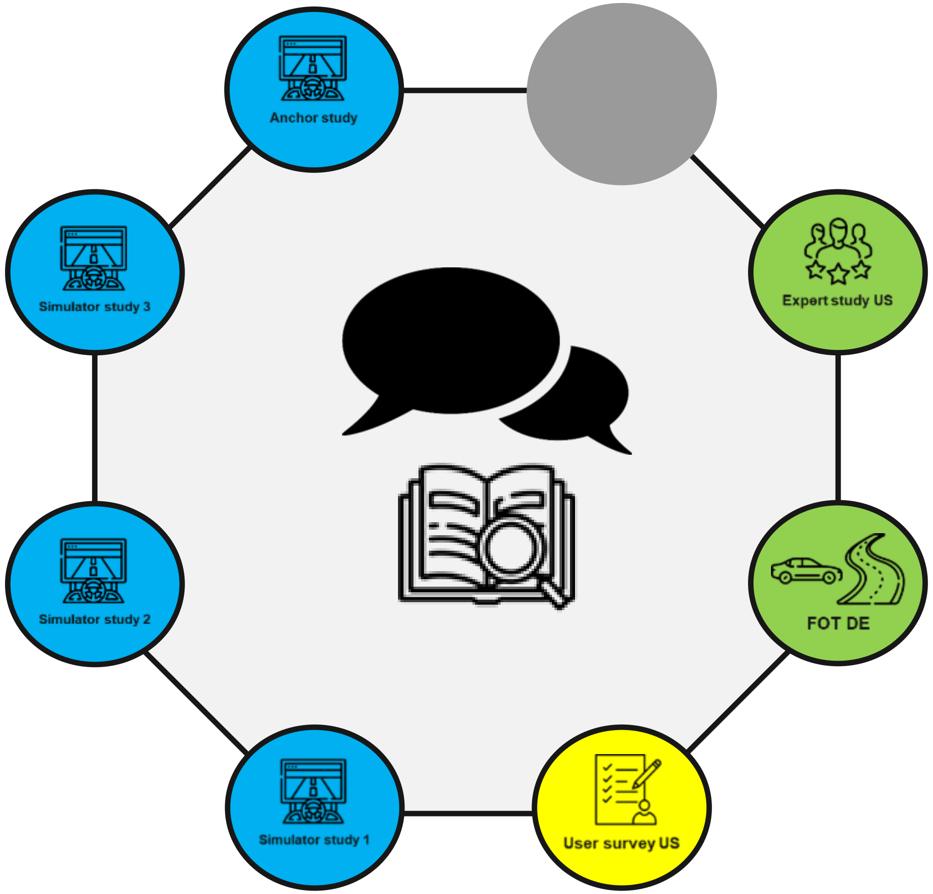
Conclusions are primarily based on:



Constructs and metrics: *

- **Knowledge-based confusion**
  - System understanding (questionnaire)
  - Role understanding (questionnaire)
  - Interview data (for interpretation)

- **Behavior-based confusion**
  - Time hands-free, although mode is L0/L1 (for L2H-off users)
  - Time hands-free, although mode is L2H-on (for L2H-off users)
  - Number of attempted activations of L2, although L2 not available
  - Interview data (for interpretation)

** Additional metrics indicative for knowledge/behavior-based mode confusion are considered in-depth elsewhere (e.g.: trust, NDRT engagement, attention ratio, behavior at system limits; cf. CQs 1, 2, 3, 5)*

Image source: Flaticon.com

CQ4 Mode confusion
Knowledge-based confusion

Findings from data collections

- Over all studies, there were **no significant differences between L2 functions** (H-on and H-off) regarding **system understanding and driver role understanding.**
  - **No significant differences between differently complex L2H-off functional designs** (clear-cut vs. multi step) in case of instructed use (Study 2).
- Over all studies and L2 functions (H-on and H-off) there was a **good to very good understanding of system functionality / functional limits and driver responsibilities**.
  - **Lesser awareness without explicit instruction** (i.e., in survey), as user manual is not read by all users (resulting in, e.g., lesser awareness of functional limits).

Findings from literature

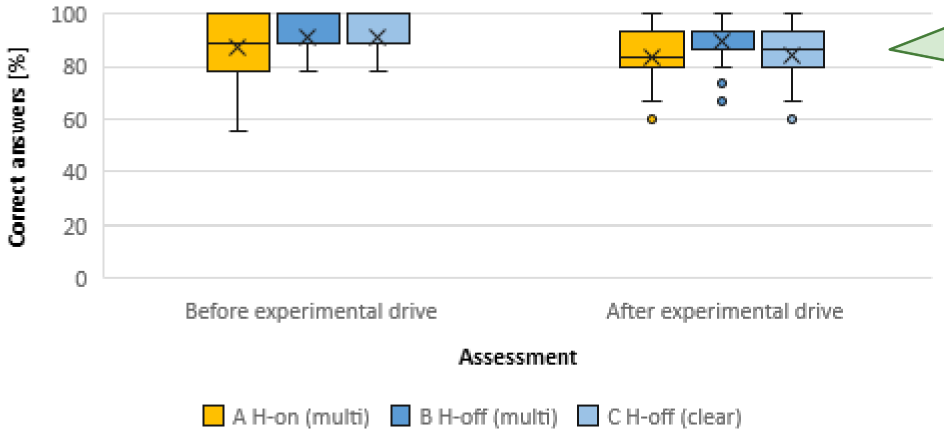
- The likelihood for mode confusion increases if the systems or **alternating system modes appear similar** for the user. (Boos et al. 2020; Kurpiers et al. 2020)
- Systems with **clear-cut modes** of either on or off should increase mode awareness/**decrease mode confusion** as there are less transitions the driver may go through. (Consumer Reports 2020)

Image source: Flaticon.com

CQ4 Mode confusion
Evidence: System- and role understanding

System understanding

Data source: Study 2



N H-on (multi) = 19
N H-off (multi) = 18
N H-off (clear) = 18

Overall **good to very good system understanding** (high percentage of correct answers)

- **Recap study design**: Difference between clear-cut and multi-step system: ACC not available (L0 or L2) vs. ACC available (L0, L1 or L2)
- **16 items rated pre- and post-drive** (correct, incorrect / unsure)
  - Rating pre-drive based on reading the function's manual (adapted from state-of-the-art manuals)
- **Rating included e.g.:**
  - Assistance mode after overruling system (by braking / by steering)
  - Capabilities for longitudinal guidance
  - Capabilities for lateral guidance
  - Available assistance modes (L0, L1, L2)

- **No differences** between L2H-on and L2H-off group.
- **Overall good system understanding, but single outliers.**
- **Participants of both multi-step groups appear to be unsure whether or not ACC remains activated after a FDCR***, even after experiencing the function, indicating a potential for mode confusion while using multi-step functions with different levels of assistance provided.

*FDCR = Function direct control request

CQ4 Mode confusion
Behavior-based confusion

Findings from data collections

- **Over all studies, there were little behaviour-based indications for mode confusion** when looking at inappropriate hands-free times (for vehicles incorporating both L2H-on and L2H-off) and attempted activations of L2.
  - **Qualitative video analysis** revealed single cases of potential (mode) confusion behavior.
  - **FOT data** on hands-free driving (when hands-free driving was not applicable) indicate that confusion (between different L2 modes) might have occurred for some participants.
- No differences were found between clear-cut und multi-step L2H-off functions, but **increased complexity by different assistance modes should nonetheless be considered** (cf. field data: expert assessment and FOT).

Findings from literature

- The likelihood for mode confusion increases if the systems or **alternating system modes appear similar** for the user. (Boos et al. 2020; Kurpiers et al. 2020)
- Systems with **clear-cut modes** of either on or off should increase mode awareness/**decrease mode confusion** as there are less transitions the driver may go through. (Consumer Reports 2020)
- Information (training) may not completely rule out the occurrence of misconceptions about DMS alerts. (Llaneras et al. 2017)

Image source: Flaticon.com

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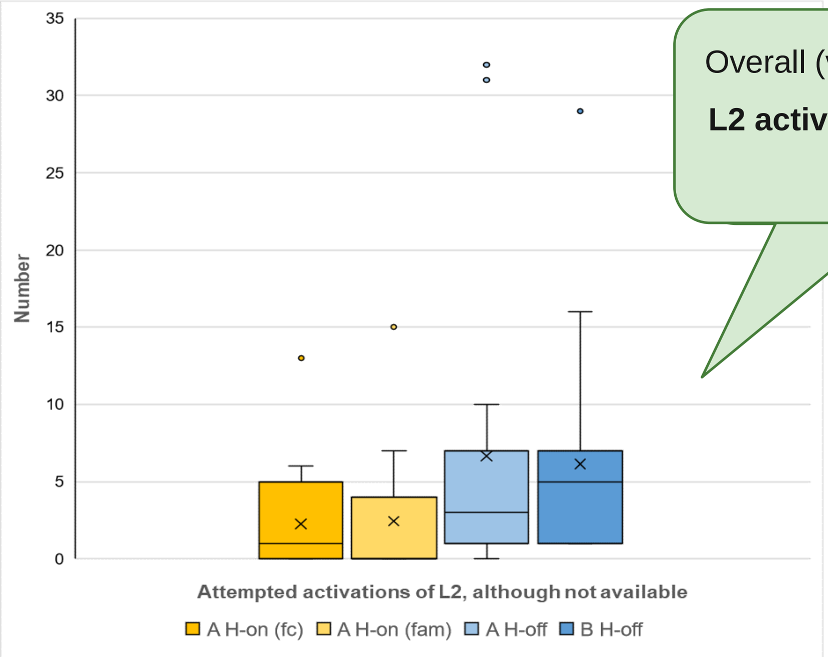
Attempted activation of L2, although function not available

Data source: FOT DE

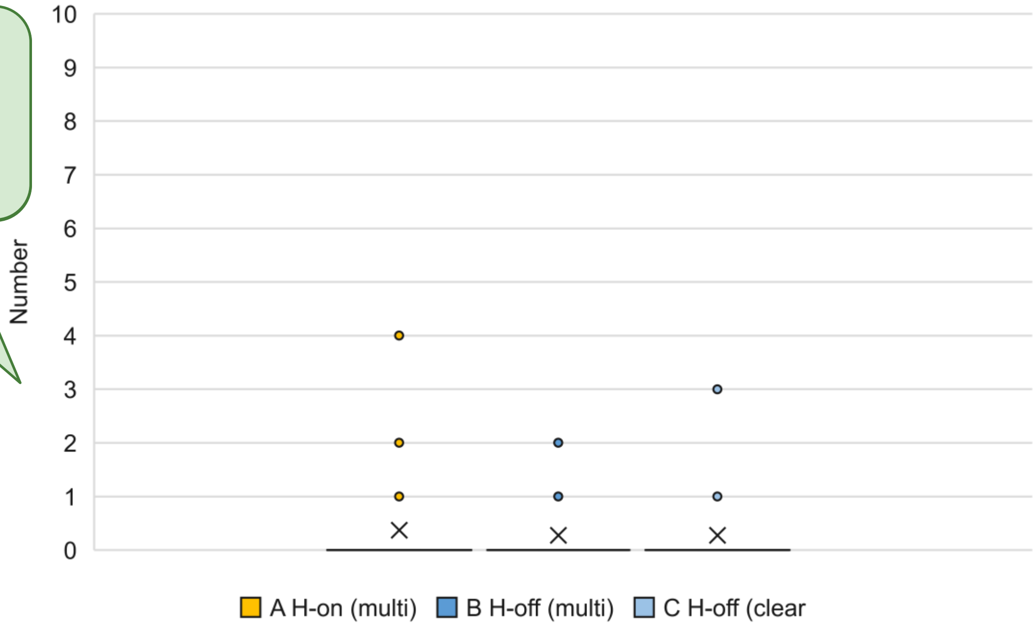


Overall (very) **few attempted L2 activations when L2 not available**

- **Single outliers with high number of attempted L2 activations** when L2 not available, but in general low number of attempted activations.

N A H-on (fc) = 15
N A H-on (fam) = 16
N A H-off = 15
N B H-off = 15

Data source: Study 2



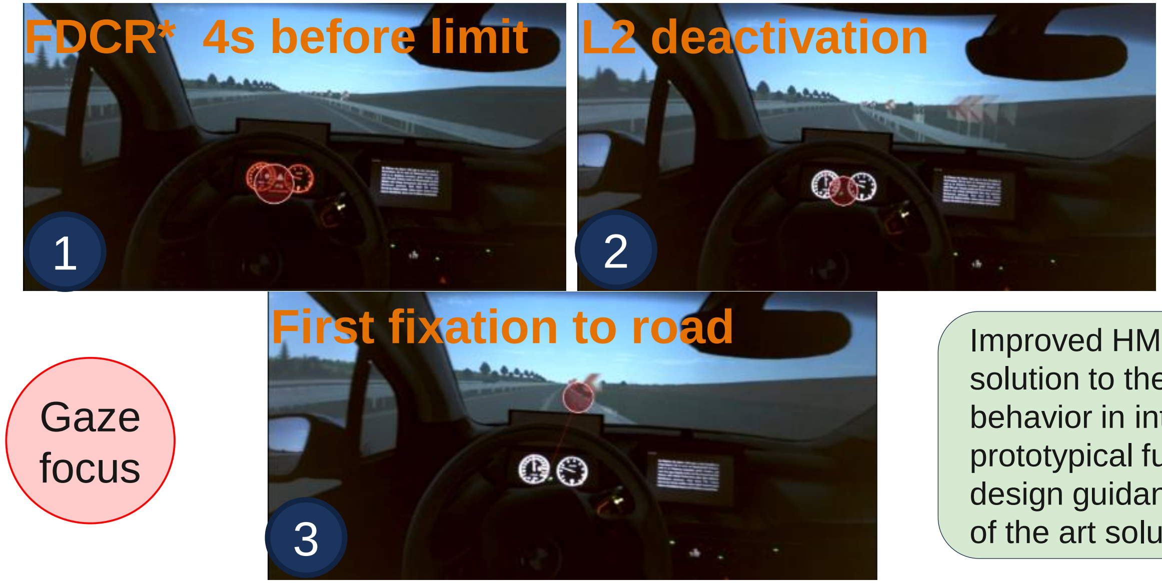
- **No differences** between H-on and H-off groups in the number of attempted activations while L2 not available.
- Low number of attempted activations when L2 not available.

N H-on (multi) = 19
N H-off (multi) = 18
N H-off (clear) = 18

CQ4 Mode confusion
Example: Behavior-based confusion

Data source: Anchor study (Study 4)

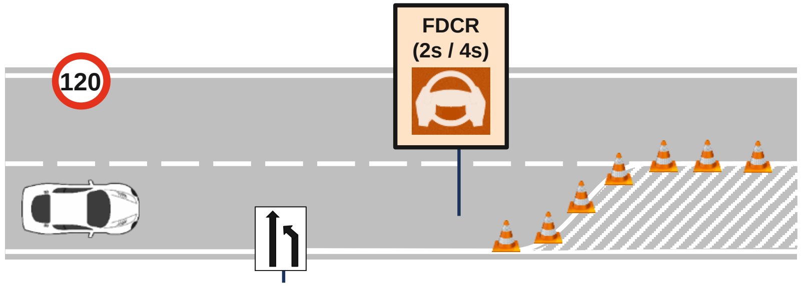
- **Scenario 2: Lane end (without occlusion)**
  - One incident with contact to barrier observed for L2 Novice during **L2H-on** use (with 4s FDCR*)
    - Attention throughout end of lane scenario at secondary task (except for one quick glance to the road)
    - **Fixation on HMI at FDCR**, hands-on as reaction, but no intervention.



Gaze focus

- **Limit awareness not a problem:** “System cannot change lanes, I needed to intervene myself” (Interview)
- **Reaction to FDCR*:**
  - Gaze is fixated on HMI for complete duration of FDCR
  - **Second hand moves to steering wheel**
  - Gaze on road only after FDCR* signal has terminated
    - Active intervention follows gaze on road
- **Conclusion: Potential confusion of DMS warning (hands-on request) and FDCR* at the functional limit** (first contact to FDCR)

Improved HMI design might present a solution to the observed driver behavior in interaction with prototypical function in the study (cf. design guidance on HMI design; state of the art solutions).



* FDCR = function direct control request

CQ4 Mode confusion
Example: Behavior-based confusion

Data source: Anchor study (Study 4)

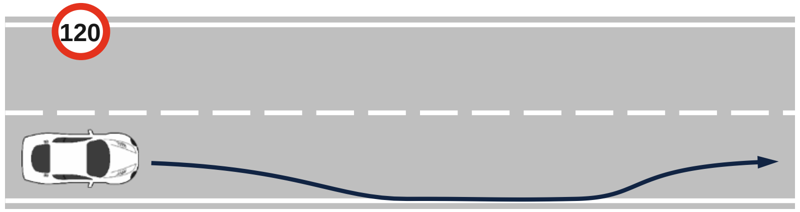
- **Scenario 1: Lane drift (0.6 m/s)**
  - One incident with contact to barrier observed for L2H-on expert during **L2H-off** use in the study
    - Attention primarily directed at secondary task
    - DMS alert (Stage 1) occurs shortly before lane drift onset (see description on right hand side).

Gaze focus

- **Attempt to terminate DMS alert (Stage 1; eyes-on request) by small movement of steering wheel**
  - Only brief orientation of eyes to road (approx. 92 ms)
- Discovery of collision only after another DMS Stage 1 alert.

- **Conclusion: Potential confusion of hands-on request and eyes-on request due to prior L2H-on experience of this participant (in daily life)**

Improved DMS design might present a solution to the observed problematic behavior (cf. design guidance on criteria to terminate DMS alerts), see CQ4.



CQ4 Mode confusion

There are concerns that with the introduction of L2H-off functions drivers are no longer aware of their tasks and roles as drivers and have a lesser understanding of ODD and system functioning.

Overall conclusions

- **In the experimental settings, a rather good to very good understanding of the functionality, the functional limits and the driver responsibilities was observed.**
  - Metrics analyzed in CQ1 (visual attention) and CQ3 (misuse) confirm this interpretation.
  - Without prior information, drivers show a lesser awareness of functional limits and their role (cf. survey).
- **Some examples for confusion were observed at transitions.**
  - The hands-free option is not the relevant factor in those examples.
  - Salient and distinguishable indications of modes/mode changes, alerts and warnings may help increase mode awareness and prevent mode confusion.
- **The potential for confusion seems to increase if the function offers different but similar modes** (e.g., L2H-on and L2H-off / variability in the assistance level after transitions).

CQ5: Safety level

There is uncertainty as to what level of safety can be achieved by introducing L2H-off.

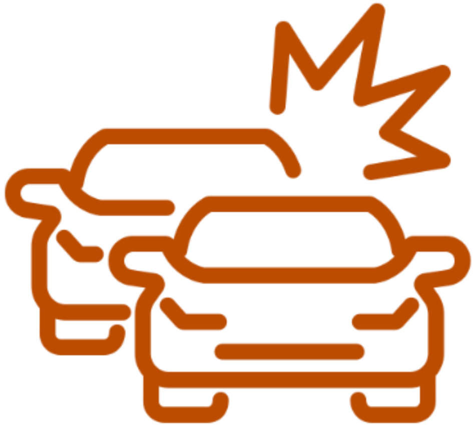


Image source: Flaticon.com

CQ5 Safety level
Definition

The focus of CQ5 is on the **(potential) outcome of interactions as well as the vehicle behavior resulting out of the interaction between driver and function**.

Different perspectives on safety ensure a **holistic picture**. Two major aspects of safety are distinguished for analysis in this project:

- **Objective safety** (objective data)
- **Perceived safety** (subjective data)

Objective safety can be seen from **two different perspectives:** (cf. Hollnagel 2014)

- **Safety-I**, which is outcome-oriented **(focus on specific events)**, taking into account:
  - Scenarios from driving simulator studies
  - Incident candidates from field data collections
- **Safety-II**, which is process-oriented **(focus on overall patterns of results)**.
  → CQ5 takes into account the results for all prior CQs.

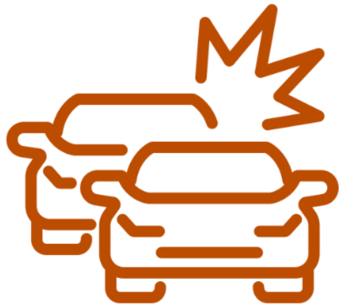
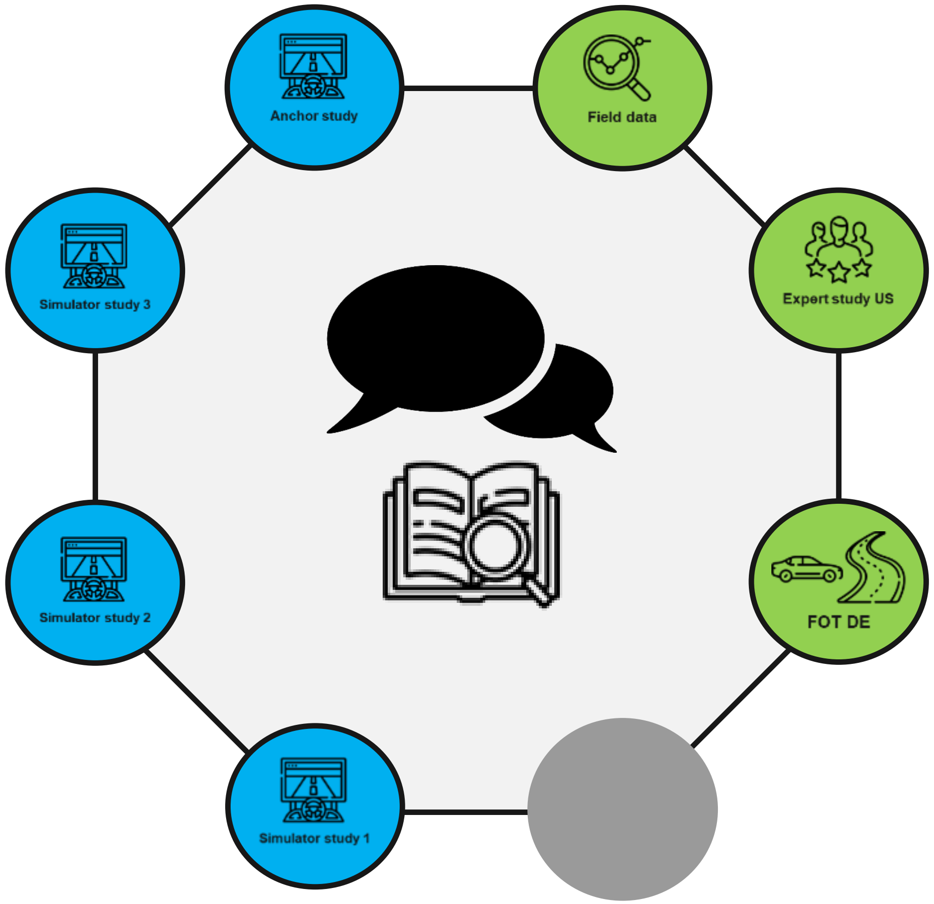


Image source: Flaticon.com

CQ5 Safety level
Metrics

Conclusions are based on:



Constructs and metrics:

- **Objective safety (Safety-I) → Outcome-based**
  - Number of incidents/accidents
  - Transitions & incident candidates:
    - TTC, THW, long. & lat. distance
    - Long. & lat. acceleration
- **Objective safety (Safety-II) → Process-based**
- **Perceived safety**
  - H-on/-off proportion (L2H-off)
  - Trust (TiA; Körber 2019)
  - Acceptance (CTAM; Osswald et al. 2012)
  - Preferred L2 function (H-on/-off) & L2 intention to use (overall, longitudinal, lateral, H-off)
- **Other**
  - Interview and test protocol

Image source: Flaticon.com

CQ5 Safety level
Objective safety

Findings from data collections

- All investigated situations in the simulator studies are **normally controllable with both L2H-on and L2H-off functions.**
  - Some of the transitions and silent failures in the simulator studies were designed intentionally time-critical.
  - A similarly small number of unsuccessful interventions was observed in all groups (including manual driving) in the simulator studies, the vast majority of interventions was handled successfully.
  - Reasons for collisions include misconceptions about HMI symbols, a limited system understanding or the chosen intervention strategy.
- **No increase in safety-critical interactions observed for L2H-off in field data analyses.**
  - No differences in terms of criticality metrics for transitions in the FOT between L2H-on and L2H-off.

Findings from literature

- Hands-free monitoring can lead to a (slightly) decreased quality of transitions to direct control compared to L2H-on (Cahour et al. 2021; Garbacik et al. 2021; Gold et al. 2013; Ishida & Itoh, 2017; Josten 2021; Josten et al. 2016; Othersen, 2016)
- L2H-off use with an adapted DMS results in similar crash rates and driver steering timepoints (Victor et al. 2018; Pipkorn et al. 2021)

Image source: Flaticon.com

CQ5 Safety level
Incident candidates - Process

L3Pilot (Metz et al., 2019)

1. **Rule-based incident candidate detection and classification** based on vehicle data by threshold criteria

euroFOT (Benmimoun et al., 2011)

Incident candidates and classification

2. **Video-based validation and safety criticality and driver controllability assessment** of incident candidates

100-Car-Study (Dingus et al., 2006, similar approaches in Hickman et al., 2010; Olson, et al., 2009)

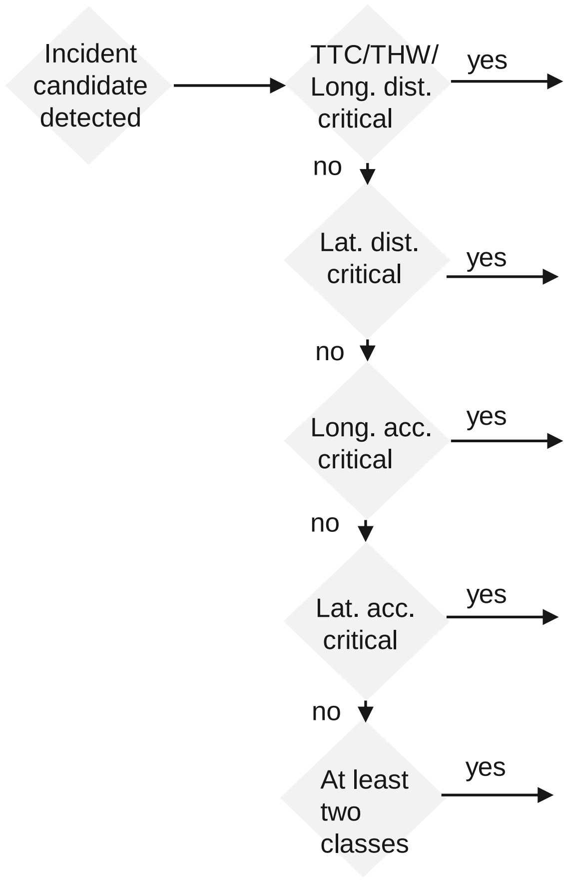
Validated events
(Safety criticality & driver controllability)

3. **Description of scenario and situation** based on validated events

Potential challenges and issues

CQ5 Safety level
Incident candidates: Process level 1

Rule-based detection



Incident classification

Type	Class
Distance-based	Longitudinal critical
	Lateral critical
Vehicle dynamics-based	Longitudinal critical
	Lateral critical
Both types	Mixed critical

Incident type		Metrics	Criteria
Distance-based	Front	THW [sec] TTC [sec] Δv [km/h]	Forward THW < 0.35 s & Δv < 20 km/h Forward THW < 0.5 s & Δv > 20 km/h Forward TTC < 1.75 s
	Side	Distance [m] TTC to rear [sec]	Distance to side vehicle < 0.5 m & projected TTC to vehicle in target lane < 1.75 s to vehicles approaching from rear (in case of lane change)
	Rear	THW to rear [sec] TTC to rear [sec] Δv to rear [km/h]	Rear THW < 0.35 s & Δv < 20 km/h Rear THW < 0.5 s & Δv > 20 km/h Rear TTC < 1.75 s
Vehicle dynamics-based		ax [m/s²] ay [m/s²]	Longitudinal acceleration: ax < - 6 m/s² (at 50 km/h) ax < - 4 m/s² (at 150 km/h) Lateral acceleration: ay >= 2.5 m/s² (at 0 km/h) ay >= 7 m/s² (at 50 km/h)

Lane deviation was analyzed only after incident classification for selected incidents

Adapted from L3Pilot (Metz et al., 2019)

CQ5 Safety level
Incident candidates: Process level 2

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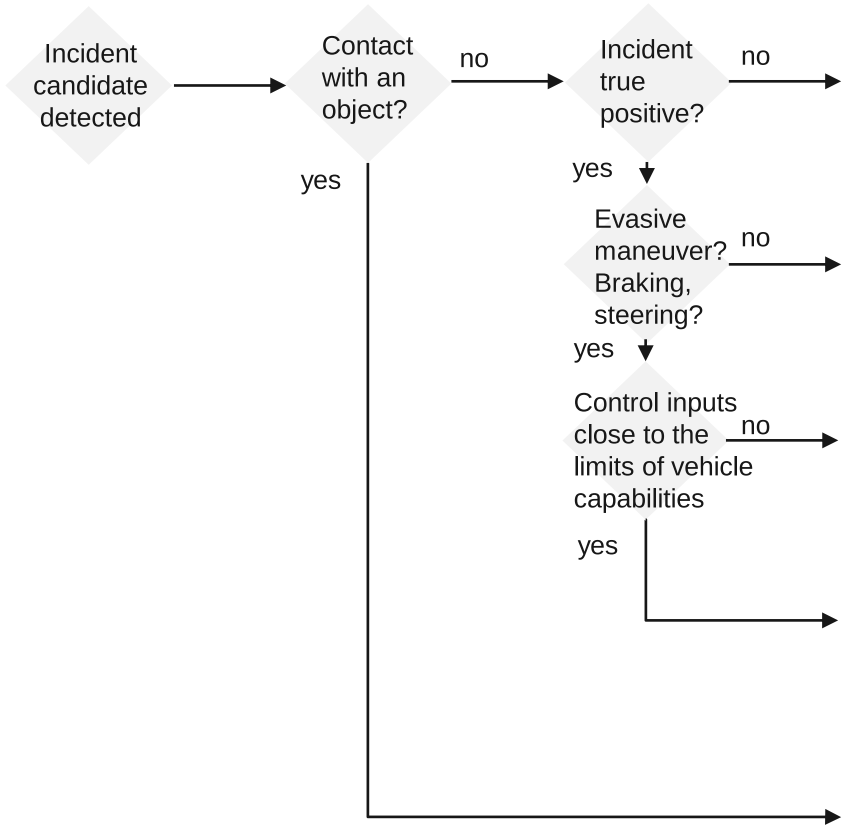
Rule-based detection

Video validation



Safety-criticality

Level	Criticality	Description
0	Normal driving	No safety relevant circumstances are present
1	Increased risk	Any circumstances that increase the level of risk associated with driving, but does not result in many of the events defined below. […] This increased risk is usually caused by the driver him/herself and not by others.
2	Crash-relevant	Any circumstances where the subject vehicle performs an **evasive maneuver** to avoid a road departure or a crash with another vehicle, pedestrian, cyclist, animal or object, still with the possibility of a less effortful reaction.
3	Near-crash	Any circumstance that requires a **rapid evasive maneuver** by the subject vehicle, […] to avoid a crash or road departure. A rapid evasive maneuver is defined as […] any combination of control inputs that **approaches the limits of the vehicles capabilities**.
4	Crash	Any contact with an object, either moving or static, on ground (with exception of continuous contact of roadway by vehicles tires) at any speed in which kinetic energy is measurably transferred or dissipated.

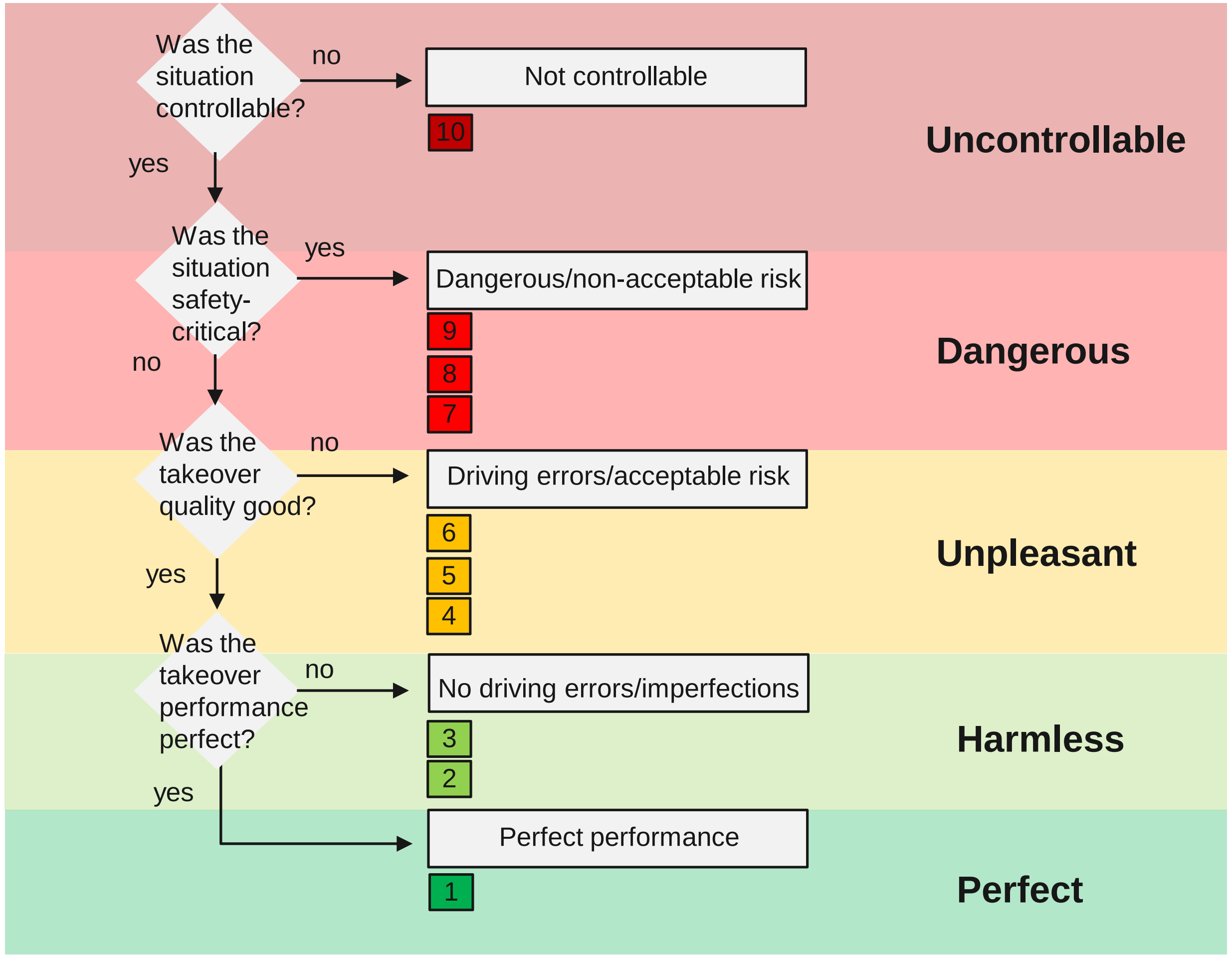
Driver controllability

TOC-rating

Neukum et al. (2008) / Naujoks et al. (2018)

Adapted from L3Pilot (Metz et al., 2019)

Driver controllability



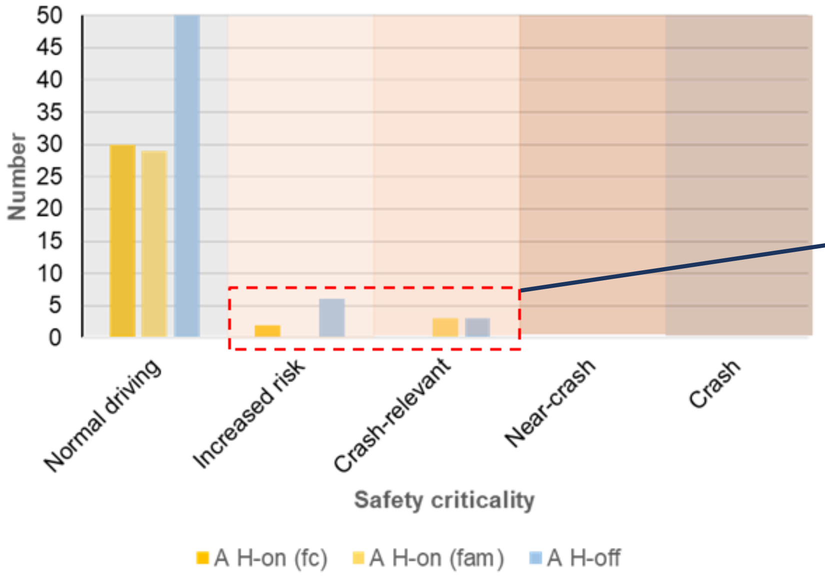
	Perfect	Imprecisions	Driving errors	Endangerment	Non-controllable event
Braking response			too strong too weak too late missing		
Longitudinal vehicle control			safety-distance too low inadequate speed		
Lateral vehicle control		jerky steering movement imprecise lane keeping	safety-distance too low strong oscillation crossing lane markings	endangerment of others self-endangerment	collision lane departure/ leaving road loss of vehicle control
Lane change/ lane choice			hesistant/ interrupted too late missing wrong lane		
Securing/communication		unnecessary/wrong use of indicator	missing/too late use of indicator missing/too late control glance		
Vehicle/system operation		imprecisions	problems		
Facial expression of driver		visible emotions			
	1	2 3	4 5 6	7 8 9	10

Adapted from Neukum et al. (2008) and Naujoks et al. (2018);
Source: https://toc-rating.de/wp-content/uploads/2018/08/TOC_Bewertungsbogen.pdf

CQ5 Safety level
Evidence: Objective Safety

Incidents

Data source: FOT DE (TOC-rating incident candidates)

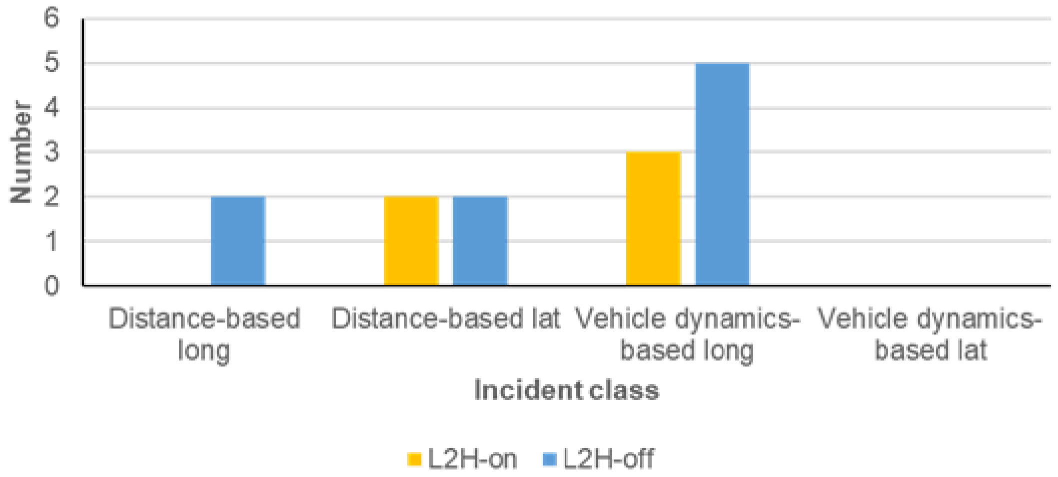


Participant database:
$n_{A\ H\text{-}on\ (fc)} = 4$
$n_{A\ H\text{-}on\ (fam)} = 10$
$n_{A\ H\text{-}off} = 30$

n A H-on (fc) DB = 9
n A H-on (fc) VB = 29
n A H-on (fam) DB = 19
n A H-on (fam) VB = 27
n A H-off DB = 27
n A H-off VB = 30
DB – distance-based
VB – vehicle-dynamics based

TOC-rating: Neukum et al. (2008) and Naujoks et al. (2018)

Data source: FOT DE (incident candidates)



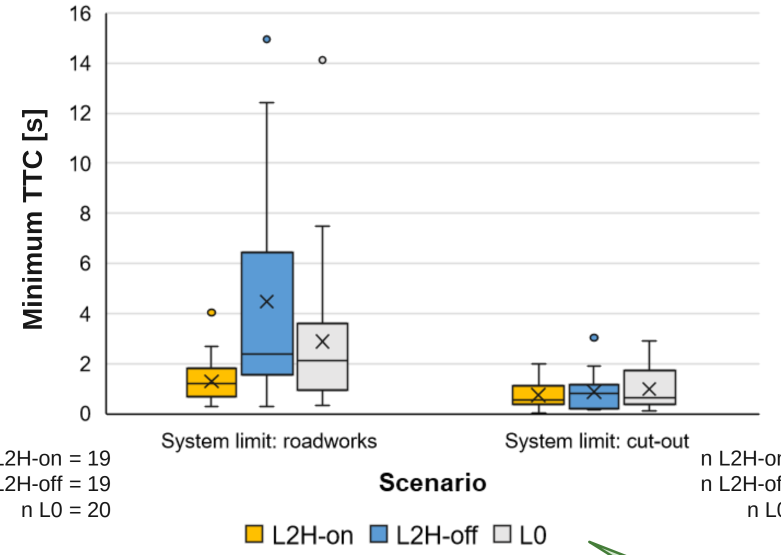
No noticeable accumulation of incidents for L2H-off or L2H-on functions.

n A H-on (fc) DB = 9
n A H-on (fc) VB = 29
n A H-on (fam) DB = 19
n A H-on (fam) VB = 27
n A H-off DB = 27
n A H-off VB = 30

CQ5 Safety level
Evidence: Objective Safety

Criticality metrics

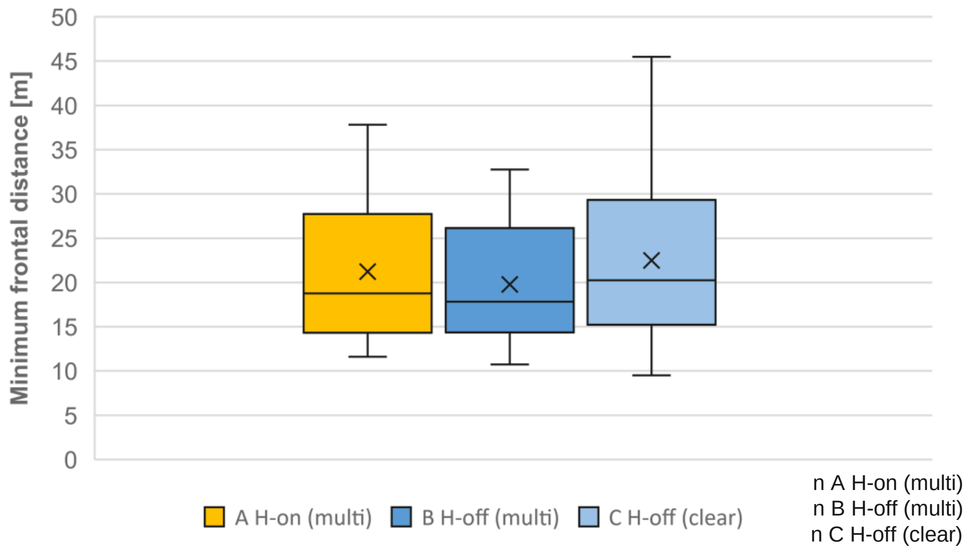
Data source: Study 1



n L2H-on = 19
n L2H-off = 19
n L0 = 20

n L2H-on = 19
n L2H-off = 19
n L0 = 19

Data source: Study 2



n A H-on (multi) = 20
n B H-off (multi) = 19
n C H-off (clear) = 19

No disadvantage for L2H-off found in comparison to L2H-on or manual driving

CQ5 Safety level
Perceived safety

Findings from data collections

- **No over-trust in L2H-off evident.**
  - Slightly more positive attitude towards L2H-off functions compared to L2H-on functions (e.g., system preference, trust; cf. CQ3).
- **Variable L2 performance might challenge perceived safety and promote disuse.**
  - FOT: System stability is a relevant aspect for users, frequent function drops in challenging conditions are perceived as annoying.
  - FOT participants report a lack of trust in some driving scenarios, i.e.
    - highways exits (n=6),
    - roadworks (n=4),
    - complex situations (n=3),
    - closely approaching cars (n=8).

Findings from literature

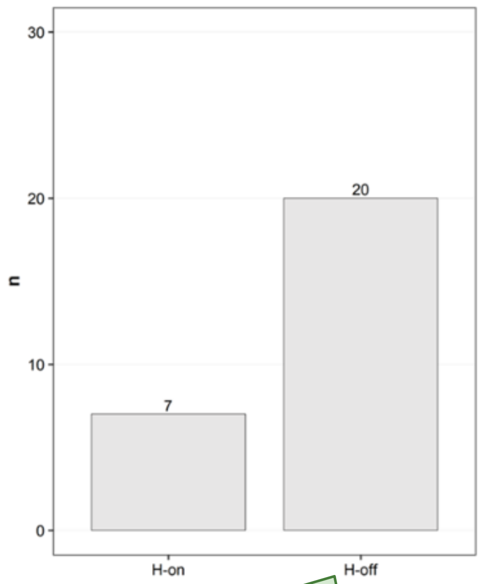
- Some drivers are annoyed by attention reminders and other measures to ensure responsible use, but **most users find measures helpful and feel safer with them**. (Mueller et al. 2022)
  - Around 50% of users report to feel “extremely safe knowing that their system is designed to alert drivers when it thinks they are not paying attention” (Mueller et al. 2022, p. 23)
- Driving environment affects the willingness to use automation (e.g., lowest agreement to use found during unstable traffic). (Stapel et al. 2022)

Image source: Flaticon.com

CQ5 Safety level
Evidence: Perceived Safety

System preference

Data source: FOT DE



n=27

L2H-off functions preferred over L2H-on in FOT by those who experienced both functions (Group A).

CQ5 Safety level

There is uncertainty as to what level of safety can be achieved by introducing L2H-off.

Overall conclusions

- L2H-off and L2H-on are comparable in regard to
  - the controllability of system limits / control transitions (simulator studies).
  - investigated objective safety metrics.

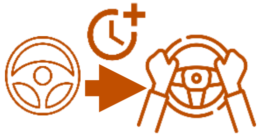
- **Balanced trust levels found for L2H-off.**
  - Users reportedly adapt their monitoring behavior with expectations on function performance (FOT), but results also indicate a need to raise awareness for L2 limitations (cf. survey).

Project Overview L2H-off
Summary: CQ Assessment

Challenges and questions potentially related to a hands-free use of L2 functions:

- **CQ1: Hands-off = mind-off?**
  - Hands-off does not decrease the (visual) involvement in the driving task when monitoring the driver's visual attention.

- **CQ2: Prolonged transition times**
  - The physical disadvantage of hands-free driving can be compensated by supporting a sufficient involvement in the driving task.



- **CQ3: Foreseeable misuse**
  - The potential for misuse is closely related to the DMS design and does not increase by hands-free monitoring alone.

- **CQ4: Mode confusion**
  - Hands-free monitoring does not increase mode confusion in comparison to L2H-on functions when providing prior information on driver role and system functioning.
  - Misconceptions of HMI signals can prevent successful driver interventions.

- **CQ5: Safety level**
  - A similar interaction quality with L2H-off and L2H-on functions was found in terms of criticality metrics and perceived safety.

Image source: Flaticon.com

Project Overview L2H-off

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CQ1 CQ2 CQ3 CQ4 CQ5

Challenges / Questions

Knowledge basis

SP 1: **State of the Art**

Hypotheses on user behavior and system design aspects

SP 2: **Analysis of Existing Field Data**

Refined hypotheses on CQs and system design aspects

Data collections

SP 3: **Field Data Collection**
Expert Study (USA)
Field Operational Test (FOT DE)
Online User Survey (USA)

SP 4: **Evaluation of Hypotheses on System Design**
Study 1
Study 2
Study 3
Study 4

Reliable data basis for CQ assessment and requirements

SP 5: **Recommendations for L2H-off**
Transformation 1: CQ Assessment
Transformation 2: Design Guidance

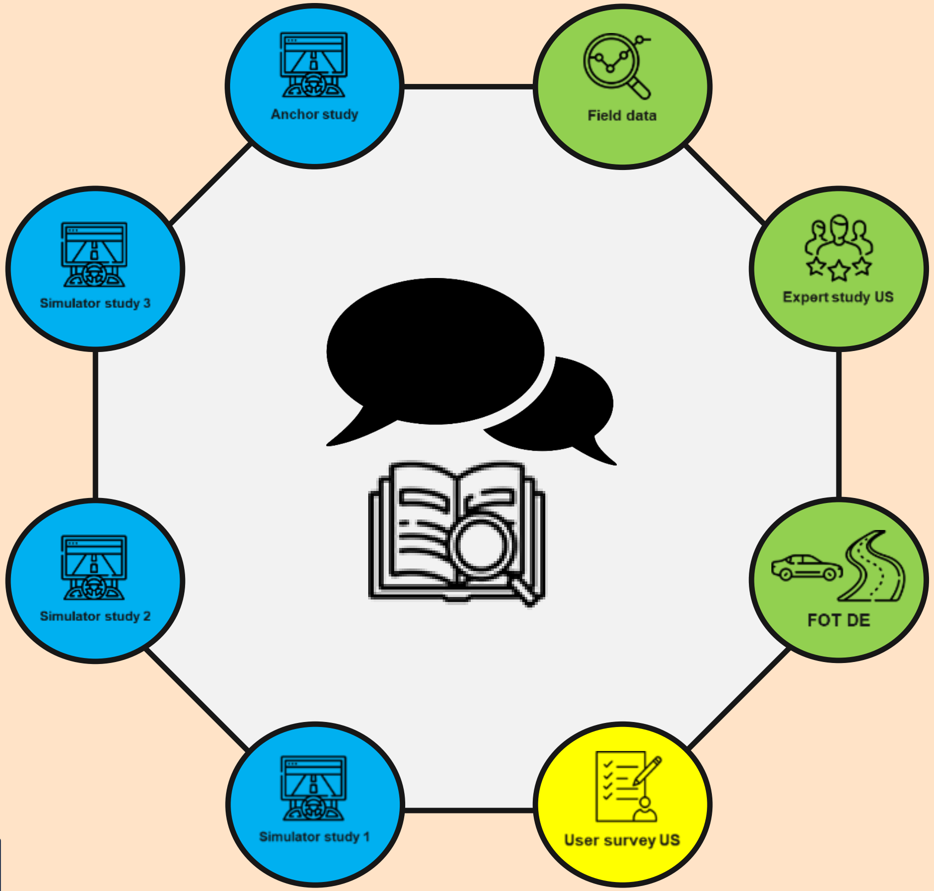

Image source: Flaticon.com

Design Guidance
Logical Approach and Structure

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All principles follow the same structure:
- Design guidance with explanation
- Included where relevant: References to …
  - project results,
  - literature and/or existing regulations.

1. General

2. Operational Design Domain

Set boundaries

3. Function

Entry / exit options

4. Transitions

Entry / exit reasons

5. Driver Monitoring

6. ODD Monitoring

Entry / exit information

7. Driver Information and Warning

No reaction / function failure

8. Risk Mitigation Function

3.5.3 The driver shall be deemed attentive if the driver’s visual attention is directed towards the OEDR*-relevant areas.

Explanation: Since the OEDR is with the driver, the visual attention of the driver needs to be directed towards the areas relevant for the OEDR. If the driver directs the visual attention towards the road, safety-relevant information is sufficiently likely to be perceived by the driver.

**Glossary:* Object and Event Detection and Response (OEDR) means the subtasks of the dynamic driving task (DDT) that include monitoring of the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback). For a SAE L2 function, the responsibility for the complete OEDR lies with the driver. (SAE J3016 2018, 3.20)

3.5.7 The Driver Monitoring System (DMS) should remind and warn the driver of the monitoring task via the driver information and warning (DIW) system if the driver is deemed inattentive.

Explanation: The visual attention of the driver on OEDR*-relevant AOIs is necessary. Therefore, the DIW notifies the driver if this condition is detected as not fulfilled (cf. Kurpiers et al., 2019). Depending on the degree of the inattentiveness, a warning further encourages the driver to return the attention to OEDR-relevant areas (cf. Kurpiers et al., 2019, Llaneras et al., 2017). Therefore, timely reminders to keep the visual attention towards OEDR-relevant areas lead to a higher overall attention of the driver.

References: FOT DE, Simulator Study 2, Simulator Study 3, Kurpiers et al., 2019, Llaneras et al., 2017

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Project Overview L2H-off

CQ1 CQ2 CQ3 CQ4 CQ5

Challenges / Questions

Knowledge basis

SP 1: **State of the Art**

Hypotheses on user behavior and system design aspects

SP 2: **Analysis of Existing Field Data**

Refined hypotheses on CQs and system design aspects

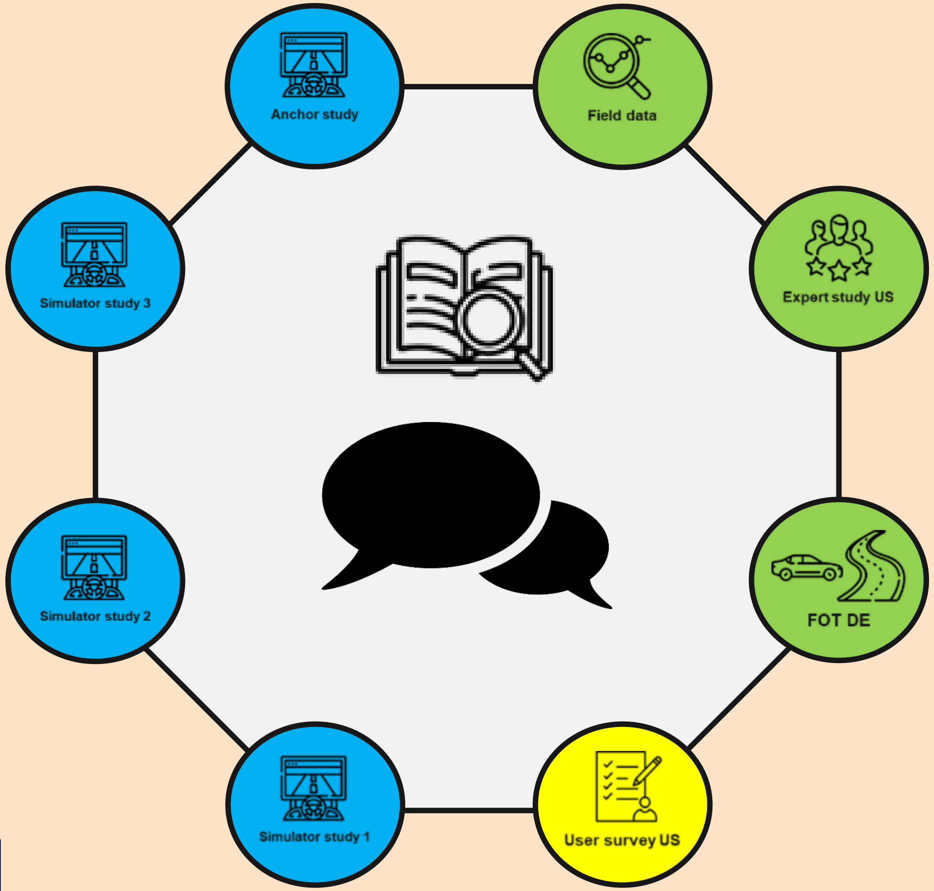
Data collections

SP 3: **Field Data Collection**
Expert Study (USA)
Field Operational Test (FOT DE)
Online User Survey (USA)

SP 4: **Evaluation of Hypotheses on System Design**
Study 1 – Driver monitoring approaches
Study 2 – Mode confusion
Study 3 – Eyes-on request timing
Anchor study – Generalizability of findings (Study 4)

Reliable data basis for CQ assessment and requirements

SP 5: **Recommendations for L2H-off**
Transformation 1: CQ Assessment
Transformation 2: Design Guidance



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