



Technische
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Designing Low-Distracted Vehicle Controls: Modality Selection and Interface Design Aspects

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Project Information and Link to the Full Report

Issued by the German Insurers Accident Research
[Unfallforschung der Versicherer]



The full English report will be/is available here:

<https://www.udv.de/udv/veroeffentlichungen>





State and Basics of Vehicle Controls

Increase in functions and interfaces, key challenges in implementing functions

Vehicle Cockpit Evolution

Towards “clean” looking cockpits



VW Golf Plus, 2005

- Limited range of functions
- Physical controls only



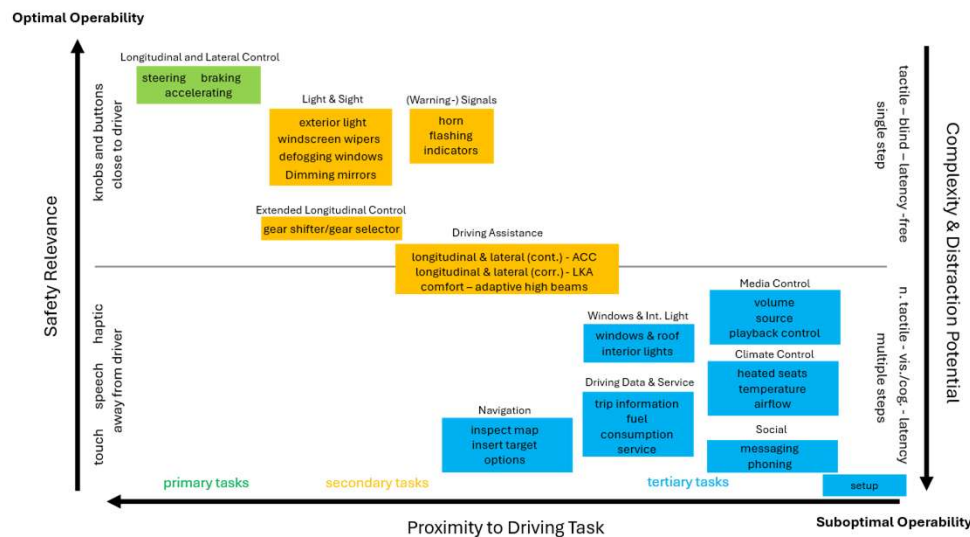
VW Tiguan, 2025

- Extended range of functions
- Physical controls, touch-, and speech-based interfaces

Two Components to Function Operation

1) Task

- > 150 functions available, on average
- Increase in non-driving-related functions



(Klaffer et al., 2026)

2) HMI Type (Modality)

- Physical controls
- Touch-based HMI
- Speech-based HMI



https://www.focus.de/auto/ratgeber/vw-europaeische-kaeuer-bevorzugen-knoepfe-statt-bildschirme_3f96719e-8614-4a23-8606-f61006de5083.html



<https://www.volkswagen-group.com/en/articles/world-premiere-at-the-iaa-with-the-id-cross-concept-volkswagen-is-presenting-a-compact-suv-for-affordable-electric-mobility-19834>

<https://www.volkswagen-newsroom.com/en/press-releases/enhanced-power-and-speed-volkswagen-takes-control-in-the-golf-to-a-new-level-7698>

Two Components to Function Operation

1) Task

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- Physical controls
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Two key challenges regarding function implementation

1. HMI type choice (modality selection):

Which HMI type(s) are suitable for operating a given function?

2. Implementation quality of each HMI type (interface design aspects):

What design aspects ensure a low-distraction implementation of a function?



(Klaffer et al., 2026)

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<https://www.volkswagen-group.com/en/articles/world-premiere-at-the-iaa-with-the-id-cross-concept-volkswagen-is-presenting-a-compact-suv-for-affordable-electric-mobility-19834>

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Literature on the Key Challenges

1) HMI type choice

- Simple tasks: physical controls
- Medium tasks: speech-based HMI
- Complex tasks: speech-based HMI

Well researched
(e.g., Ma et al., 2022, Zhang et al., 2023)

2) Implementation quality

- Guidelines & standards:
Broad but not specific
- Scientific research:
Specific but not broad



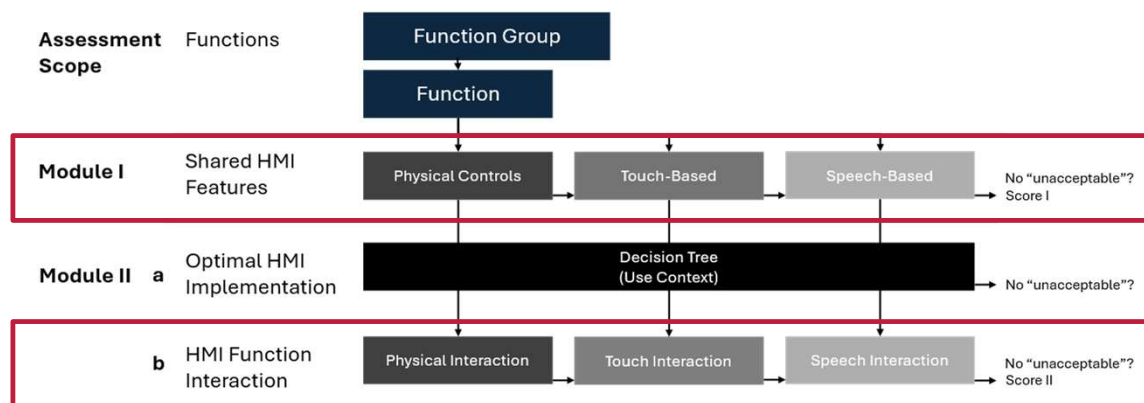
Gap: specific **and** broad
design aspect summary
(for all three HMI types)

e.g., Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices (NHTSA, 2013)
ISO 15005:2017 (International Organization for Standardization, 2017)

A New Design Aspect Summary

HMI checklist

- 51 design aspects across the three HMI types (physical controls, touch-, speech-based HMI)



(Klaffer et al., 2026)

HMI Checklist: Distraction and Operation Safety

M1-TB-2 – Reachability				
The touchscreen has been installed in a position where it can be easily reached by the driver.				
One hand on the steering wheel, arm not extended, seating position is maintained.	One hand on the steering wheel, arm slightly extended, seating position maintained.	One hand on the steering wheel, arm widely extended, seating position maintained.	One hand on the steering wheel, arm widely extended, leaving seating position.	Both hands necessary.
0 ☐	1 ☐	2 ☐	3 ☐	unacceptable ☐
Affects		Driving Performance ↓	Operation Quality ↓	
Weighting	1.0	+ (0.1 × 4)	+ (0.05 × 3)	= 1.55
Explanation	The touchscreen should be close to the driver so that the hand and arm movements needed for the operation are minimized.			
Testing	First take both hands on the steering wheel. Now operate the touchscreen and pay attention to how far you need to reach with your right hand and whether you need to move your upper body in the direction of the screen as well. Try to operate the controls on the right-hand edge of the screen.			
References	Visual-Manual Guideline Criteria Summary – Installation & Interaction ISO 15008:2017 & ISO 3958:1996 Ma & Gong (2024)			

(Klaffer et al., 2026)



Method

Addressing the key challenges: HMI type choice & implementation quality

Setup

Driving simulator equipped with generic interfaces



Lane change task
(driving simulation)

Reference task:
Physically controlled radio

Generic interfaces:
Physical controls, touch-,
speech-based HMI

Driving Task (Main Task)

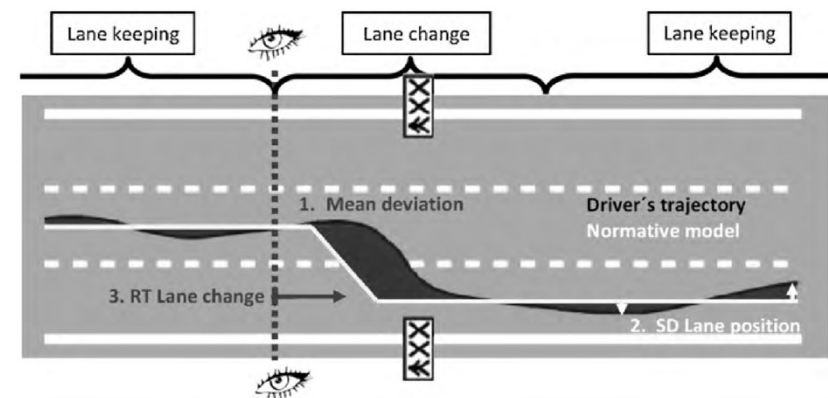
Lane Change Task (ISO 26022:2010)

(International Organization for Standardization, 2010)

- Standardized procedure for measuring driver distraction
- Task: performing lane changes on a three-lane road at a speed of 60 km/h

Measures

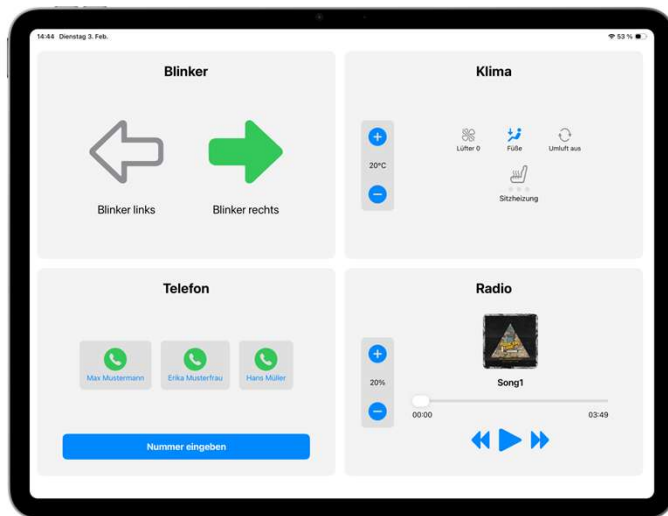
- Deviation from an ideal trajectory
 - Mean Deviation (MDev, whole trial)
 - Std. Deviation of lane position (SDLP, lane keeping)
- Reaction time
 - Lane change (RT)



(Adapted from Huemer & Vollrath, 2010)

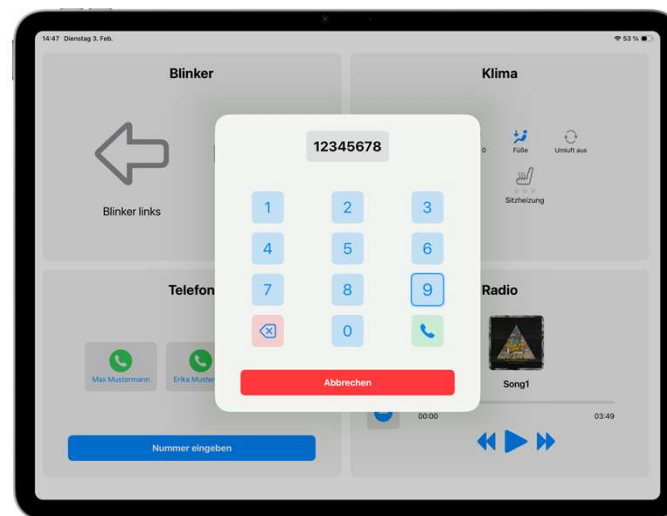
Function Operation Tasks (Secondary Tasks)

Generic interface: physical controls



Simple

Indicating at lane change



Complex

Phone number dialing

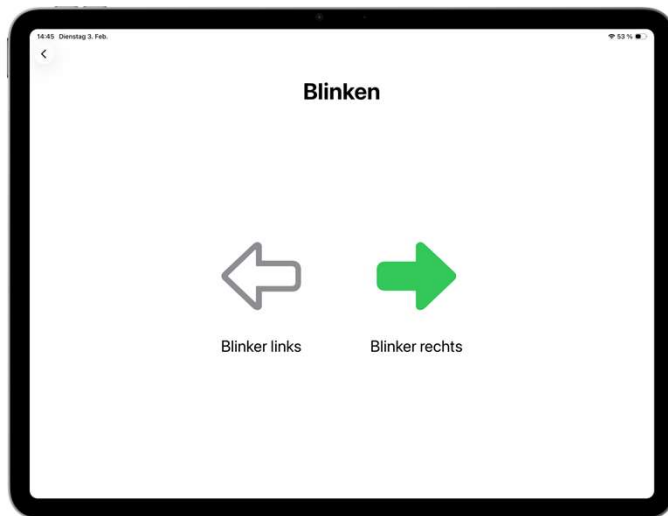


Operation

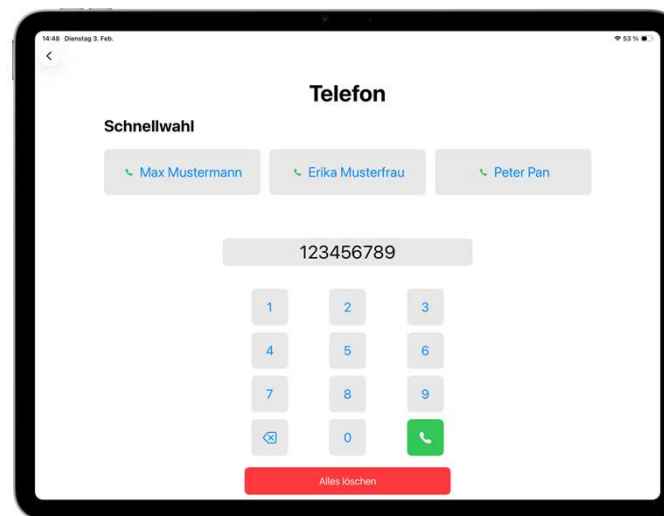
Steering wheel buttons

Function Operation Tasks (Secondary Tasks)

Generic interface: touch-based HMI



Simple
Indicating at lane change



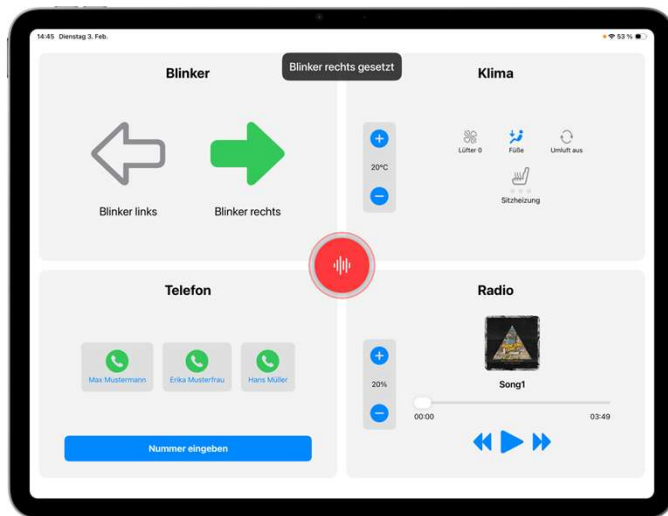
Complex
Phone number dialing



Operation
Touchscreen

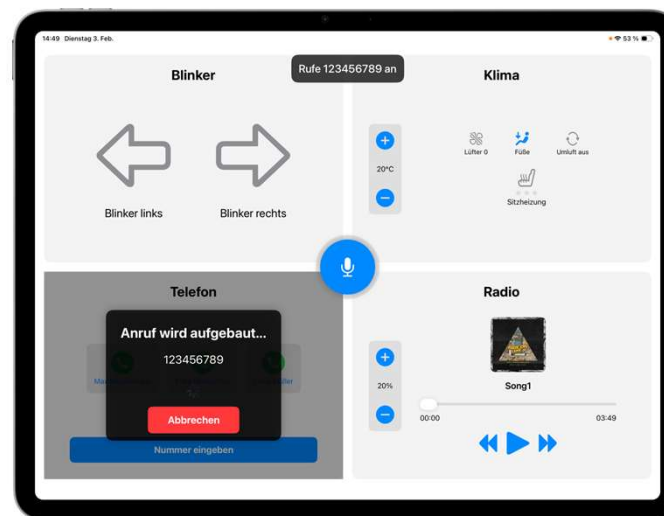
Function Operation Tasks (Secondary Tasks)

Generic interface: speech-based HMI



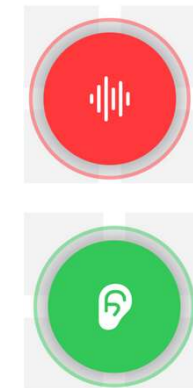
Simple

Indicating at lane change



Complex

Phone number dialing



Operation

Voice

Estimating the Impact of the Design Aspects

Generic interface versions:

Reference version (RV)

- Every design aspect at optimal level

Design aspect test version

- The target aspect is implemented suboptimally
- All other aspects stay optimal

(Klafter et al., 2026)

M1-TB-9 – Minimalism				
The touchscreen interface has a minimalist design and information is presented compactly. This minimizes visual search times and the associated distraction.				
All content is short and concise.	Almost all content is short and concise.	Content is sometimes too long.	Contents rather long.	Contents too long.
0 ☐	1 ☐	2 ☐	3 ☐	unacceptable ☐

↑
Optimal
implementation
Reference version

↑
Suboptimal
implementation
Design aspect test version

Design

Factors and Levels

- HMI type (3) x task (2) x design aspect (on avg. 17 per HMI type)

Realization

- Four design aspects of a single HMI type were tested in a group of 10 participants
- 13 participant groups ($N = 130$)

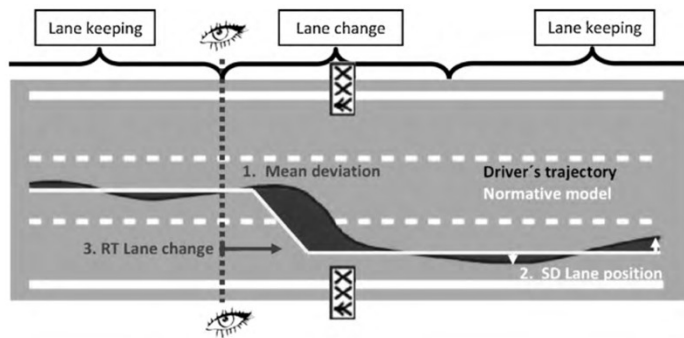
Participant groups and number of design aspects per HMI type

	Physical controls	Touch-based HMI	Speech-based HMI
Part. groups	1 – 3	4 – 9	10 – 13
No. aspects	12 aspects	23 aspects	16 aspects

Measures

Driving performance

Lane Change Task



- Deviation from ideal trajectory (MDev, SDLP)
- Lane change reaction time (RT)

Operation quality

subjective (participant)

1. Bedingung (Code): _____

1. Als wie ablenkend haben Sie die Bedienung der Funktion während des Fahrens erlebt?

- ☐ sehr ablenkend
 ☐ eher ablenkend
 ☐ neutral
 ☐ eher nicht ablenkend
 ☐ nicht ablenkend

2. Wie gut konnten Sie die Funktion bedienen?

- ☐ sehr gut
 ☐ eher gut
 ☐ mittel
 ☐ eher schlecht
 ☐ sehr schlecht

Indicator & phone

objective (experimenter)

Verhalten (Blinken)	
Auslasser (nicht geblinkt)	
Fehler (vertippt, falsch geblinkt)	

Indicator

fertig?	Fehler?
☐	☐
☐	☐

Phone

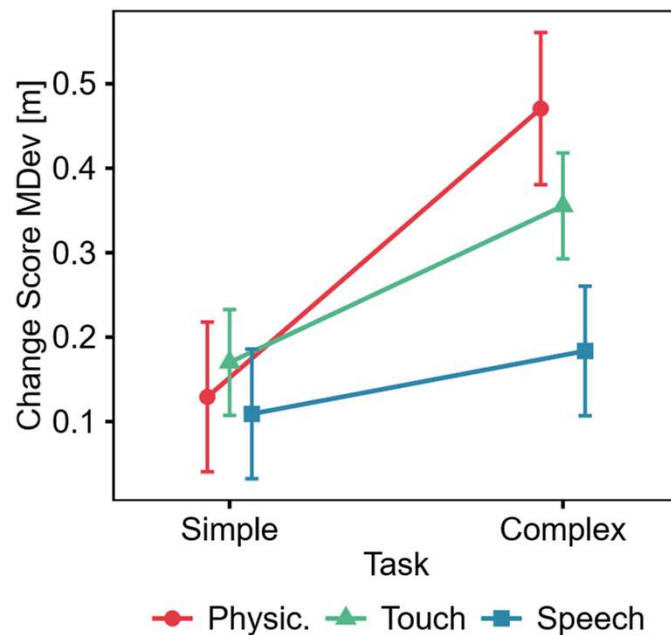


Results

Answering the key challenges: HMI type choice & implementation quality

Task × HMI Type (Reference Version)

MDev: Interaction diagram



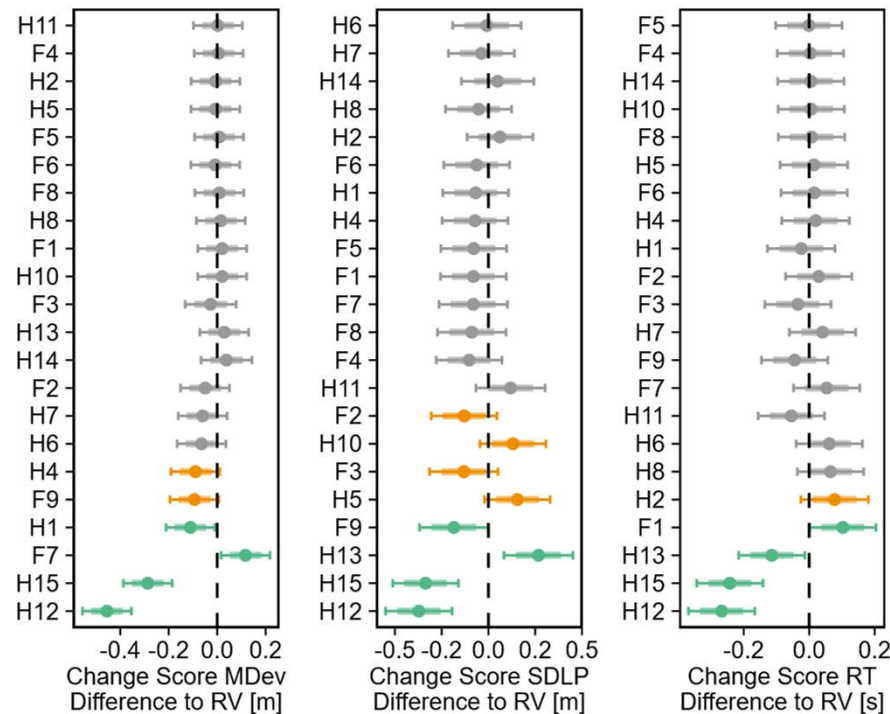
Factors	<i>F</i>	<i>p</i>
HMI type (H)	$F(2, 10.08) = 6.06$	.019
Task (T)	$F(1, 127.58) = 90.34$	< .001
Interaction H × T	$F(2, 127.30) = 11.38$	< .001

Contrast	<i>p</i> simple task	<i>p</i> complex task
Physical c. - touch	1.000	.122
Physical c. - speech	1.000	< .001
Touch - speech	.635	.006

Note: Change Scores were computed by subtracting each participant's baseline driving performance from all trials where functions had to be operated.

Design Aspect Analysis Approach

Step 1: Computing contrasts to the reference version (RV) and interpreting them



80% and 95% CI contrasts:

Outcome	Significance	Pts.
No difference (grey)	$p > .20$	0
Possible difference (orange)	$.05 < p < .20$	± 1
Significant difference (green)	$p < .05$	± 2

Interpretation (contrast score):

-2	-1	0	+1	+2
Worse performance			Better performance	

Design Aspect Analysis Approach

Step 2: Summing up the contrast scores across measures

Driving performance (DP):

Aspect (e.g.)	MDev	SDLP	RT	Sum DP
H15	2	2	2	6
F7	-2	0	0	-2

See page 11 for a description of the driving performance measures.

Operation quality (OQ):

Aspect (e.g.)	Distr.	EoU	Phone_N	Phone_Error	Sum OQ
H15	-2	0	0	0	-2
F7	0	2	-2	0	0

Distr. = perceived distraction

Phone_N = number of numbers inserted

EoU = perceived ease of use

Phone_Error = errors during number insertion

For the simple and complex task each
(example only shown for the complex task)

Design Aspect Analysis Approach

Step 3: Net score calculation

- Weighted sum of driving performance (DP) and operation quality (OQ) score
- DP and OQ in the net score below (red box) are averages of the simple and complex task's individual DP and OQ scores

$$\text{Net} = (0.10 \times \text{-DP}) + (0.05 \times \text{-OQ_normed})$$

└ DP double-weighted compared to OQ

range:
-0.9 to 0.9

Positive values: deterioration
Negative values: improvement

Note

- OQ was normed since it is made up of 8 instead of 6 measures like DP

Top 3 Design Aspect Groups: Physical Controls

1



Mechanical Effort

Net $M = 0.28$
2 design aspects



The control elements should be easy to reach and the interaction should require low effort.

2



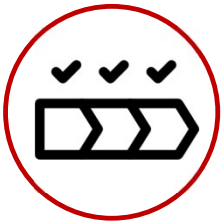
Proximity

Net $M = 0.21$
4 design aspects



The control elements should be placed close to the driver in an expected location.

3



Interaction Effort

Net $M = 0.09$
2 design aspects



Fewer interaction steps are better.
Quick, repeated inputs are acceptable.

Net: Higher positive values indicate greater driving performance and operation quality detriments of a design aspect's suboptimal implementation when compared to its optimal implementation.

Top 3 Design Aspect Groups: Touch-based HMI

1



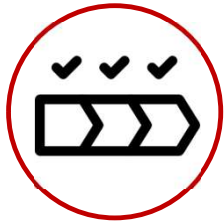
Interaction Effort

Net $M = 0.43$
2 aspects



Larger buttons are better than small ones. Tapping is better than swiping.

2



Interaction Process

Net $M = 0.19$
6 aspects



Fewer interaction steps are better. The likelihood of errors should be reduced.

3



Proximity

Net $M = 0.10$
5 aspects



The screen should be placed close, but not too close, to the driver.

Net: Higher positive values indicate greater driving performance and operation quality detriments of a design aspect's suboptimal implementation when compared to its optimal implementation.

Top 3 Design Aspect Groups: Speech-Based HMI

1



Fallback & Modality Switching

Net $M = 0.39$
5 aspects



Speech-based operation should ideally not switch to another HMI type. When switching, the correct HMI type for the task's complexity must be used.

2



Speech Recognition

Net $M = 0.19$
2 aspects



Commands must be correctly recognized. Otherwise, operation errors may occur that will lead to modality switches.

3



Command Length

Net $M = 0.15$
2 aspects



Short and directly executable commands (without using a wake word first) are better.

Net: Higher positive values indicate greater driving performance and operation quality detriments of a design aspect's suboptimal implementation when compared to its optimal implementation.



Discussion

Summary, limitations, and usage of results

Discussion

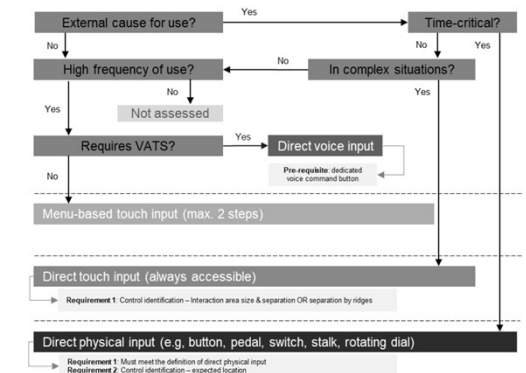
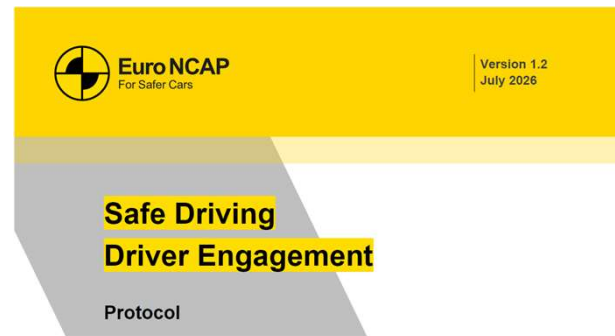
Limitations

- External validity (no real vehicle cockpit, driving and operation tasks somewhat unrealistic)
- Differentiation and interplay of design aspects



What are the results used for?

- e.g., future iteration of the Euro NCAP General Vehicle Controls protocol



(Euro NCAP, 2026)

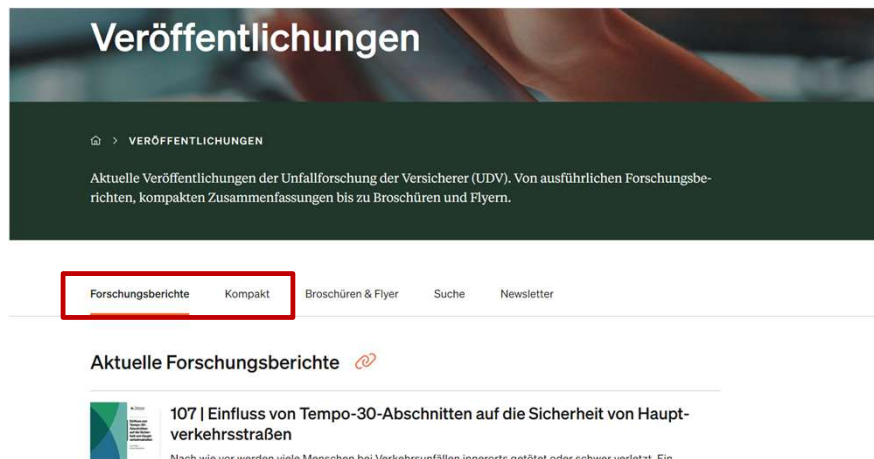
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Thank you for your attention!

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