Should My Vehicle Drive As I Do?

David Käthner, Stefan Griesche

DLR, Braunschweig

Wissen für Morgen

DLR

Problem Description

situation today: drivers have varrying preferences for implemented automation behavior

approach: adaptation of the automation to indvidual driving preferences

goal: increase of driving comfort and attractiveness of vehicle automation

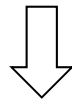| individual driving styles	driver A: defensive	driver B: assertive

But should my vehicle drive as I do?
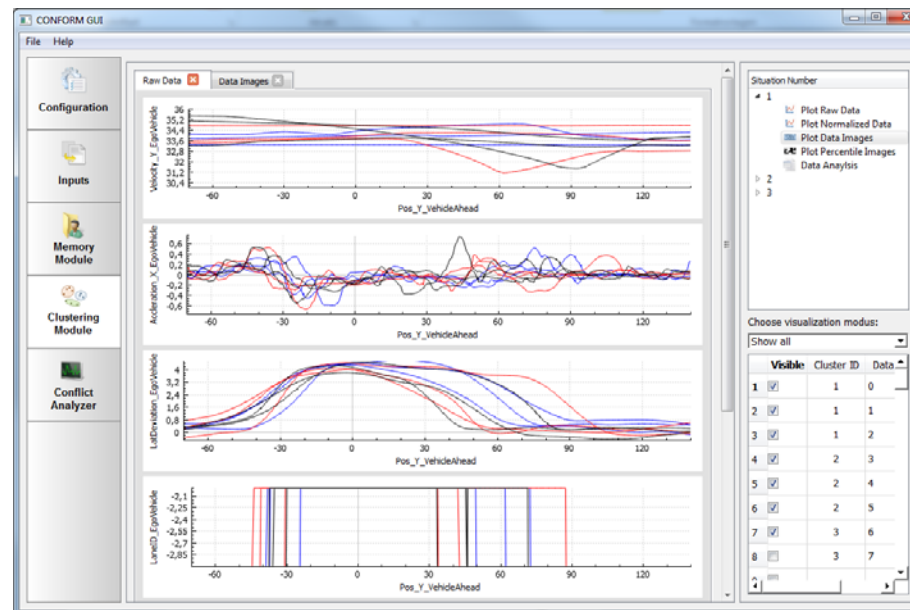
Modelling of Driver Preferences

1. situation dependent learning of individual driver behavior
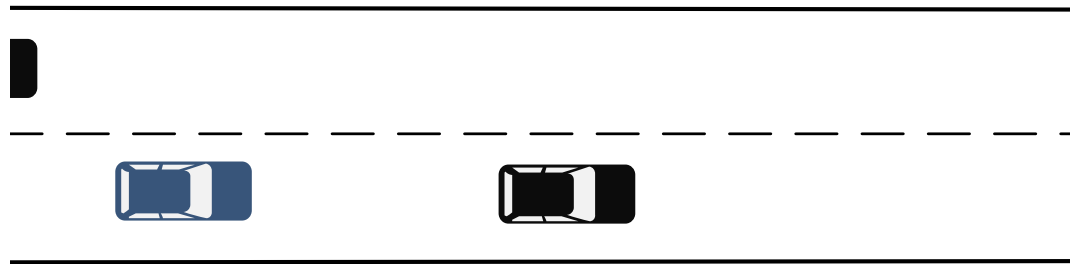2. clustering of inter- and intraindividual differences

⇩

development of the tool
CONFORM

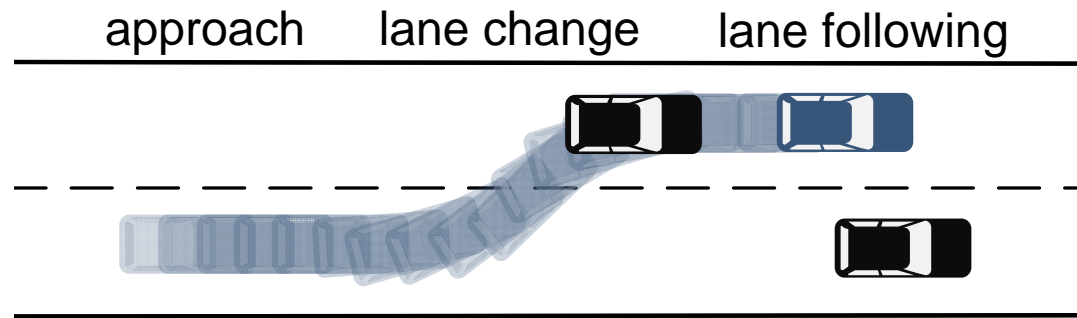(**Conf**lict rec**o**gnition by
image p**r**ocessing **m**ethods)

method: multivariate time
series clustering with pattern
recognition

Use Case: overtaking on two lane highway

Use Case: overtaking on two lane highway

approach   lane change   lane following

Simulator experiment: goals

phase 1: How do I drive?

- modelling of individual driving styles and clustering

phase 2: Should my vehicle drive as I do?

- drivers' preferences: same driving style, similar, different?

Simulator experiment: automation level

phase 1: How do I drive?
- modelling of individual driving styles and clustering

phase 2: Should my vehicle drive as I do?
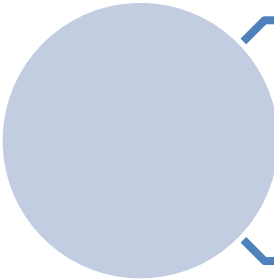- automated driving – SAE level 2

DLR

Simulator experiment: methods

phase 1: How do I drive?

- dynamic simulator: 41 subjects (34 male, 7 female)

phase 2: Should my vehicle drive as I do?

Simulatorexperiment: Versuchssetting

phase 1: How do I drive?
- dynamic simulator: 41 subjects (34 male, 7 female)

phase 2: Should my vehicle drive as I do?
- dynamic simulator: 35 of the 41 subjects from phase 1

Phase 1: How do I drive?
Procedure with subject John Doe

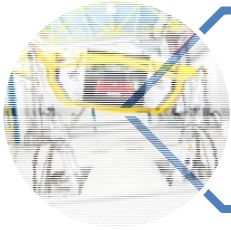John gets invited to participate in the study at DLR.

Phase 1: How do I drive?
Procedure with subject John Doe
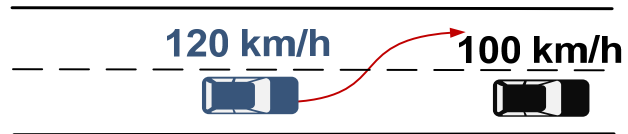
simulator
training

5 min

Phase 1: How do I drive?
Procedure with subject John Doe
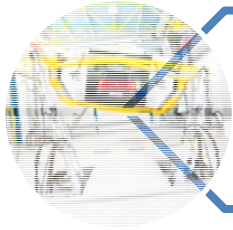
simulator
training   situation A: 25 times

5 min   15 min

120 km/h   **100 km/h**

Situation A
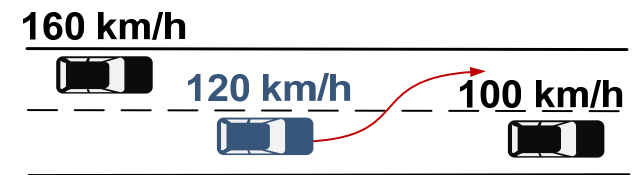
Phase 1: How do I drive?
Procedure with subject John Doe

simulator training | situation A: 25 times | situation B+C: 50 times
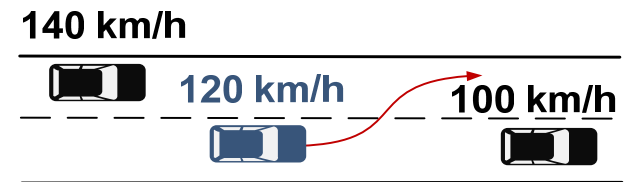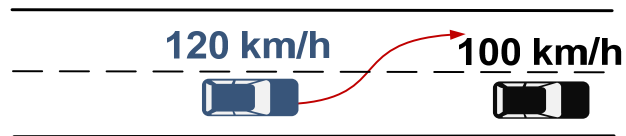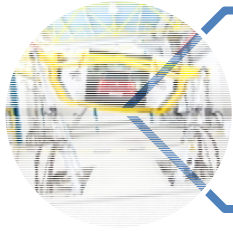
5 min | 15 min | 30 min

120 km/h → **100 km/h**

Situation A

140 km/h
120 km/h → **100 km/h**

Situation B

160 km/h
120 km/h → **100 km/h**

Situation C

DLR

Phase 1: How do I drive?
Procedure with subject John Doe

Manuelles Überholmanöver:
Situation B - Linke Spur PKW 140 km/h

Phase 1: How do I drive?
Procedure with subject John Doe

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe
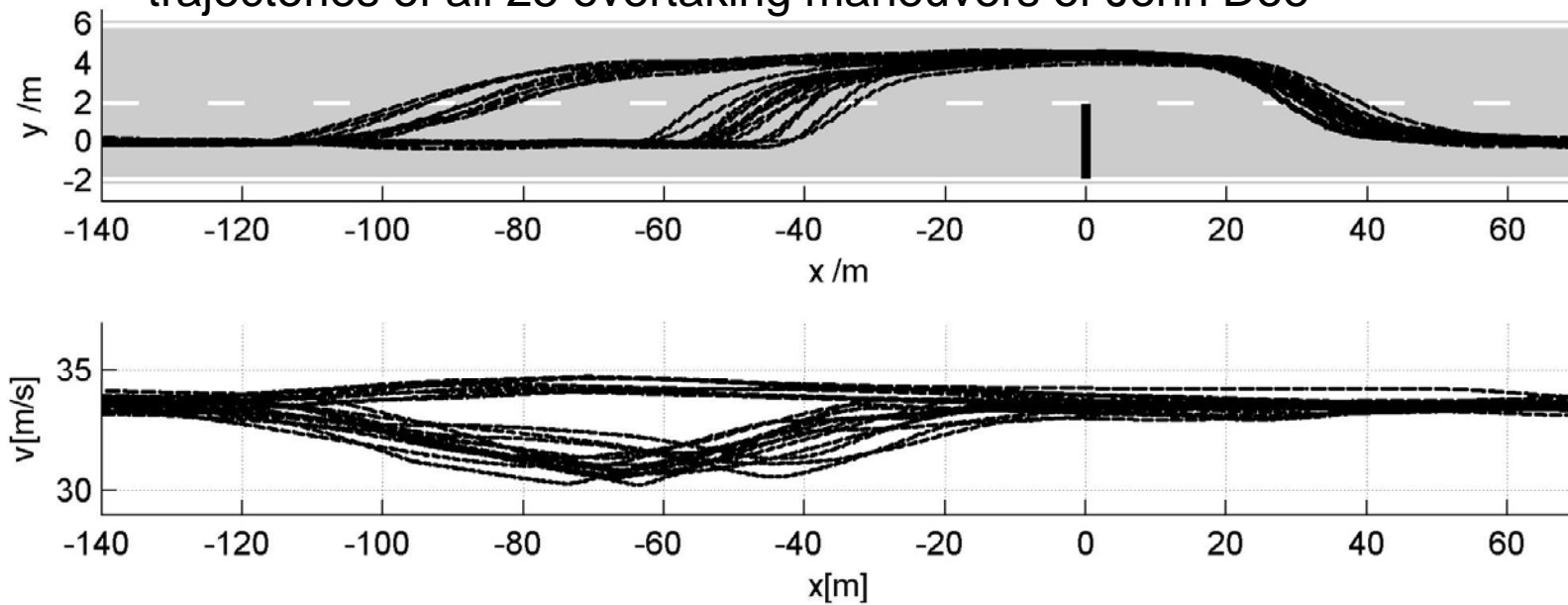
Phase 1: How do I drive?
analysis and modelling

John Doe has completed the first phase
and will be asked to return in 3 months.

… meanwhile, analysis of phase 1

DLR

Phase 1: How do I drive?
analysis and modelling

goals:

1. determine a representative overtaking maneuver for each driver for each situation
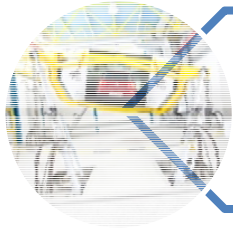2. assign drivers to driving style clusters

approach: modelling with CONFORM

determine the input variables:

- lateral deviation to the middle of the right lane
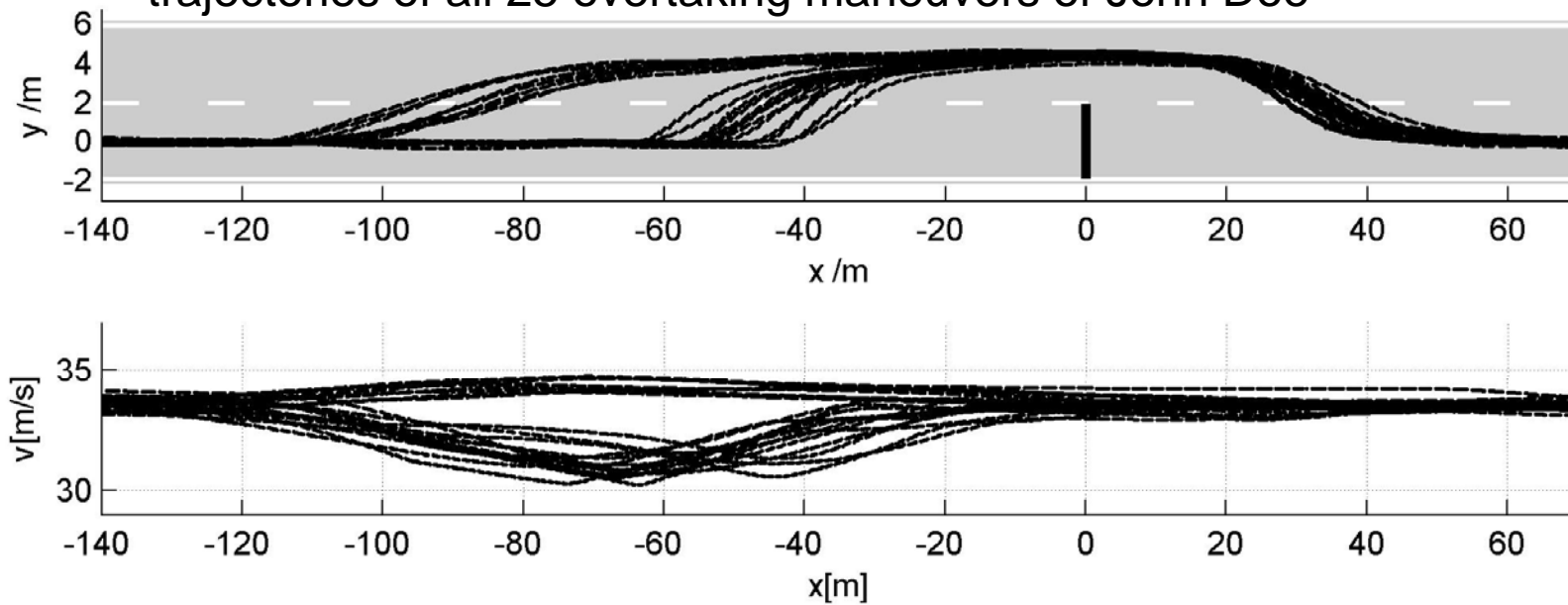- own velocity
- lateral acceleration

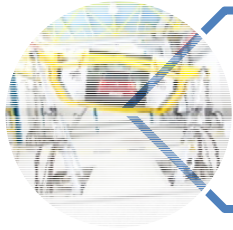all relativ to the distance between ego vehicle and leading vehicle

Phase 1: How do I drive?

analysis: driving data from the overtaking maneuvers

situation B – left lane car with 140 km/h:
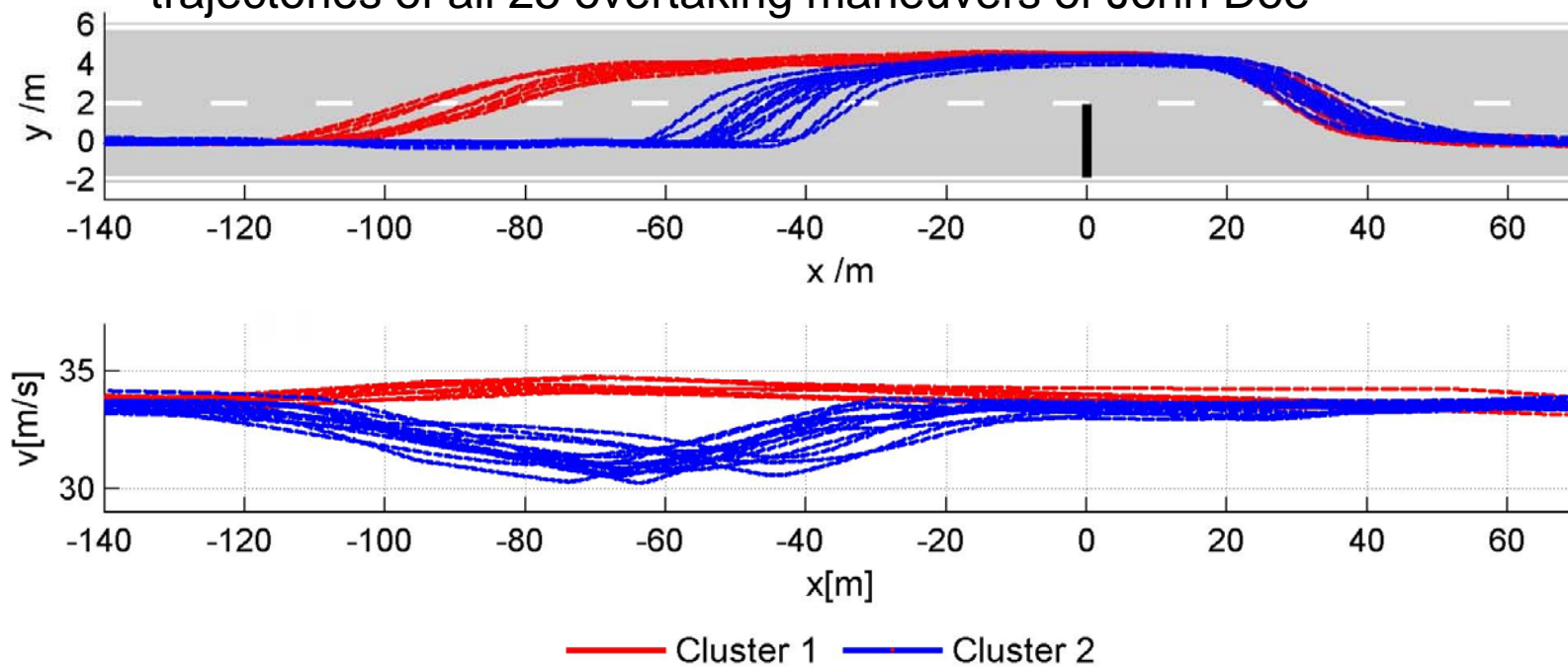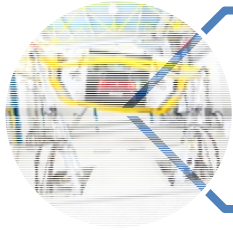trajectories of all 25 overtaking maneuvers of John Doe

Phase 1: Wie fahre ich?

Analyse: Herleitung des individuellen Fahrstils

situation B – left lane car with 140 km/h:
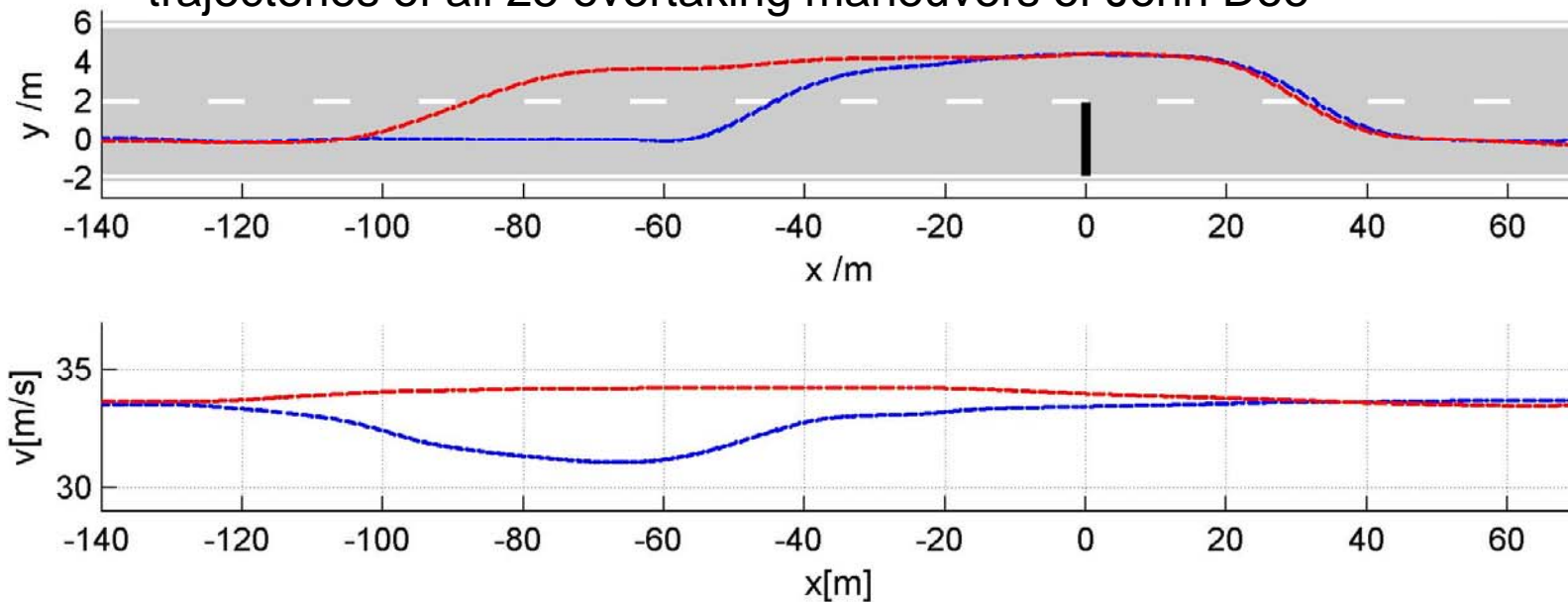trajectories of all 25 overtaking maneuvers of John Doe

Phase 1: How do I drive?

analysis: determination of individual driving styles

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

Max Mustermann fährt in…

30% der Fälle ähnlich dem roten Fahrstil
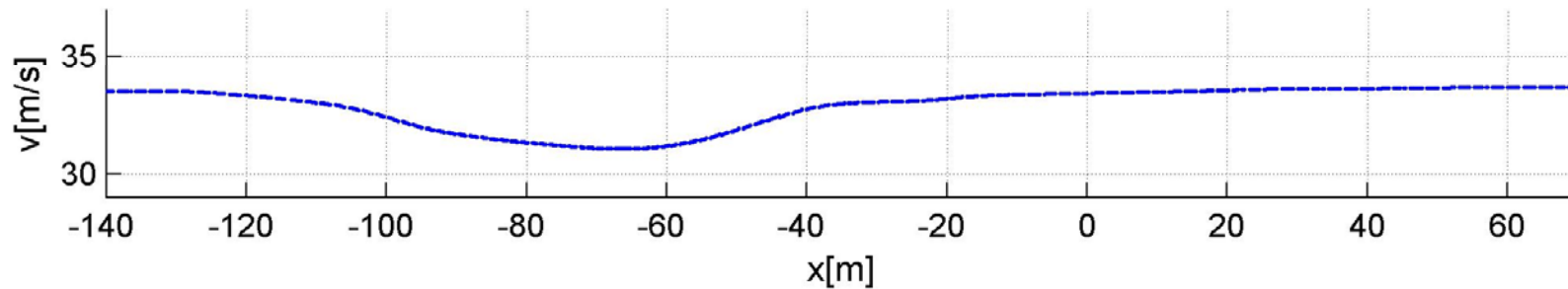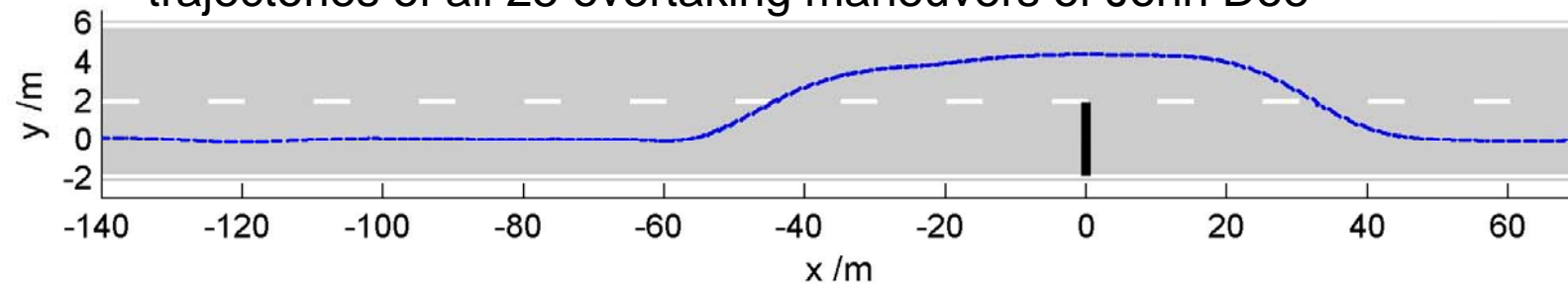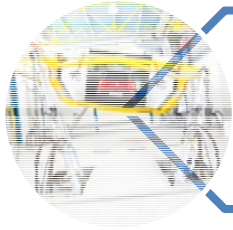70% der Fälle ähnlich dem blauen Fahrstil

DLR

Phase 1: How do I drive?

result 1: representative driving style for one situation

situation B – left lane car with 140 km/h:
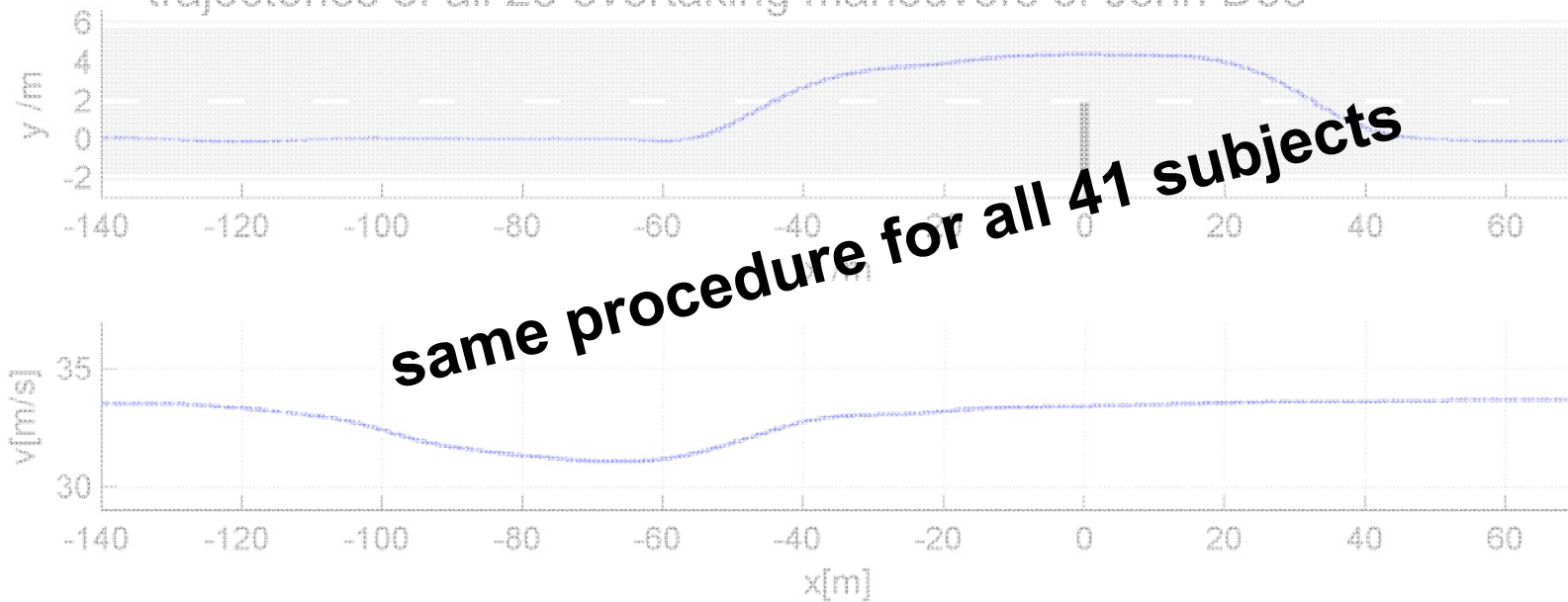trajectories of all 25 overtaking maneuvers of John Doe

Phase 1: How do I drive?

result 1: representative driving style for one situation

situation B — left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

same procedure for all 41 subjects

Phase 1: How do I drive?

result 2: classification of driving styles

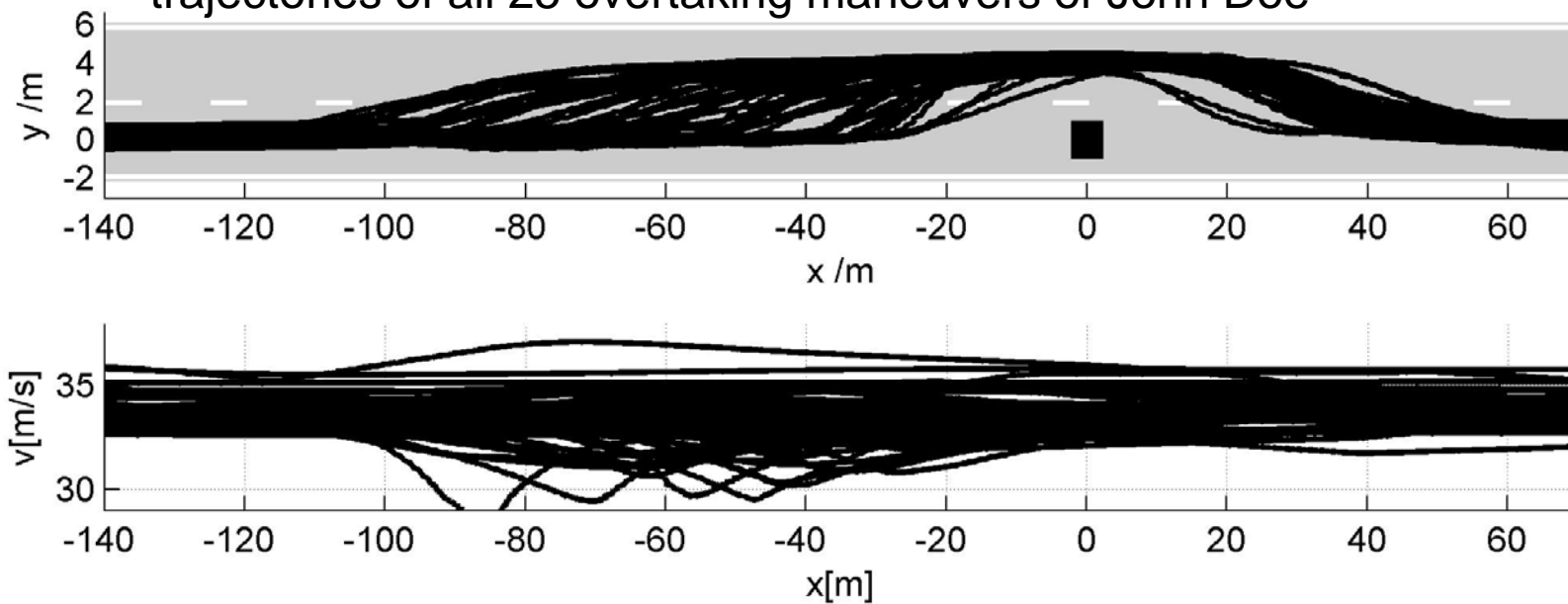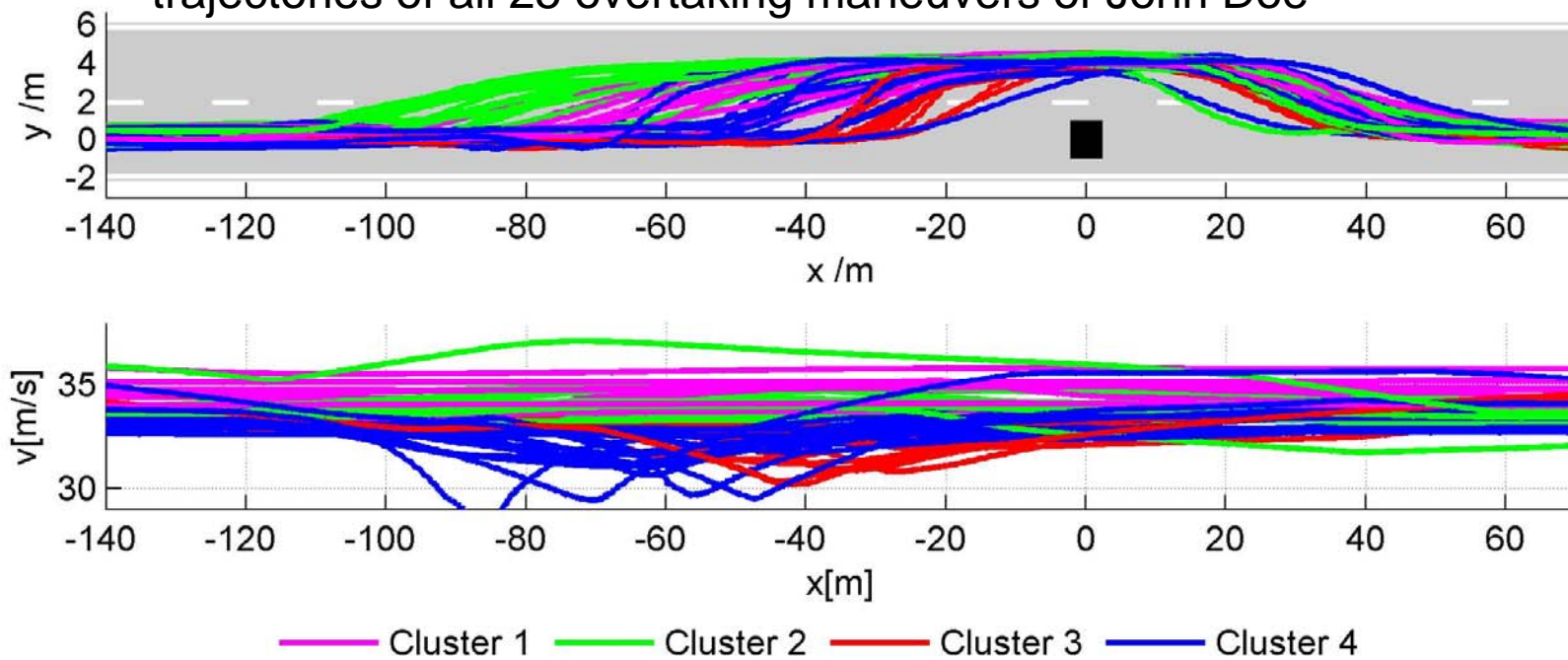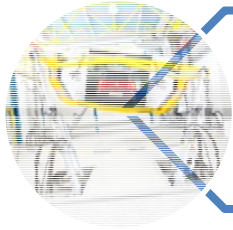situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

Phase 1: How do I drive?

result 2: classification of driving styles

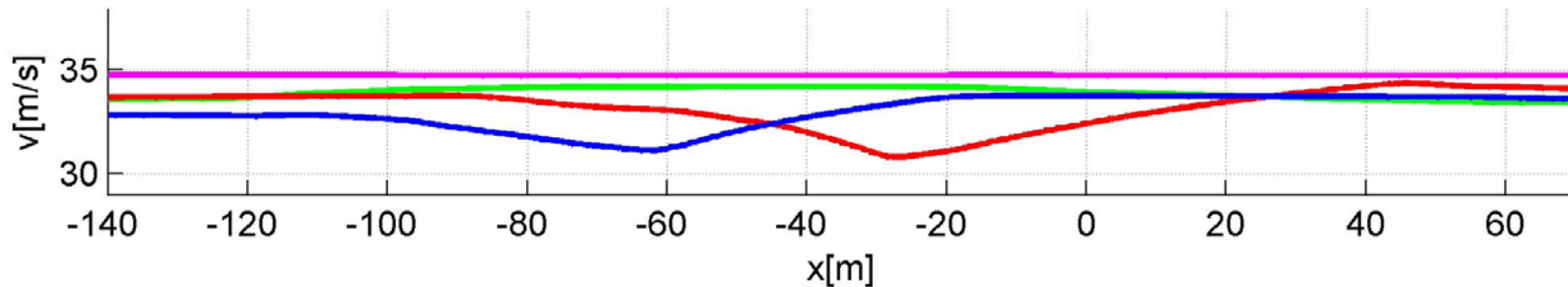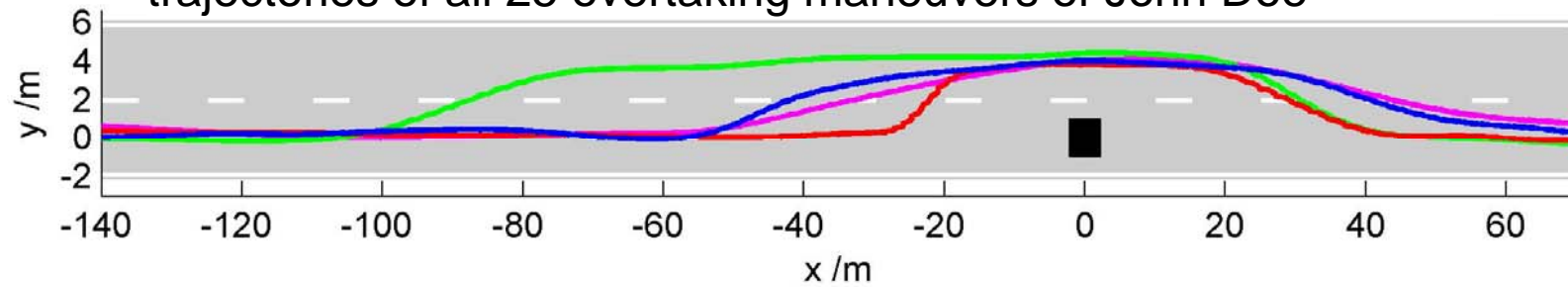situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

Phase 1: How do I drive?

result 2: classification of driving styles

situation B – left lane car with 140 km/h:
trajectories of all 25 overtaking maneuvers of John Doe

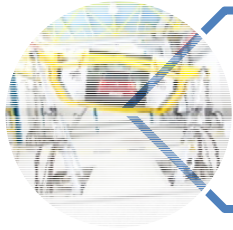| distribution of subjects | 10 | 11 | 6 | 14 |

Phase 2: Should my vehicle drive like me?
procedure for John Doe

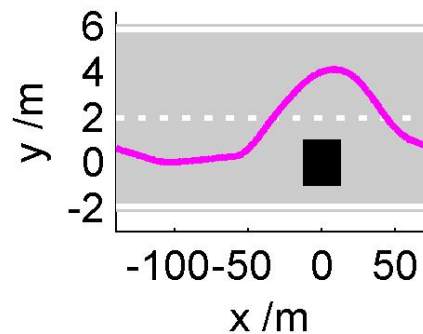It is summer now and John Doe may return for phase 2.

Phase 2: Should my vehicle drive like me?
procedure for John Doe

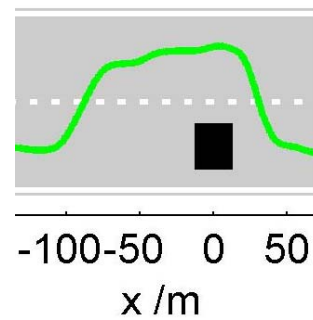input from phase 1: „pool" of driving styles

- driving styles A1-A4, B1-B4, C1-C4
- individual driving style of John Doe for situation A-C

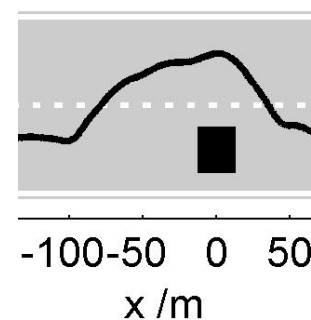**Best-Worst-scaling for preference measurement**

alternative 1:
driving data from B1 (~40 Sek.)

alternative 2:
driving data from B2 (~40 Sek.)

alternative 3:
driving data from John Doe in situation B

$+$ $+$ $=$ 1. trial (~2.5 Min.)
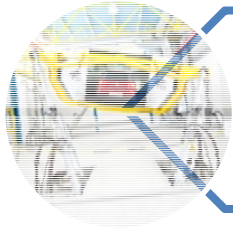
Phase 2: Should my vehicle drive like me?

procedure for John Doe

Automasiertes Überholmanöver:
Situation B - Linke Spur PKW 140 km/h

Phase 2: Should my vehicle drive like me?
procedure for John Doe

evaluation after trial 1:

experimenter: "Which overtaking alternative was best / worst?"

John Doe: "Alternative 1 was best, alternative 2 worst."

Phase 2: Should my vehicle drive like me?
procedure for John Doe

input from phase 1: „pool" of driving styles

- driving styles A1-A4, B1-B4, C1-C4
- individual driving style of John Doe for situation A-C

Best-Worst-scaling for preference measurement

alternative 1:
driving data from B1 (~40 Sek.)
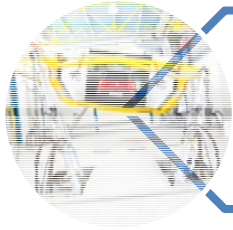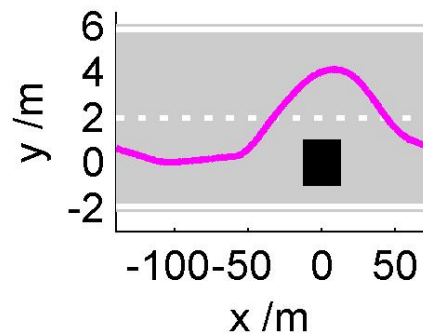
alternative 2:
driving data from B2 (~40 Sek.)

alternative 3:
driving data from John Doe in situation B

+   **+**   **=**   2. trial (~2.5 Min.)

DLR

Phase 2: Should my vehicle drive like me?
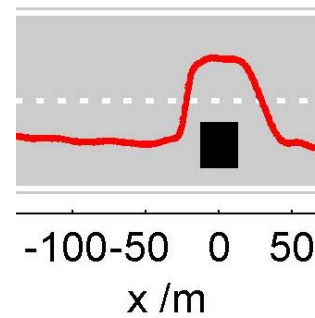### procedure for John Doe

input from phase 1: „pool" of driving styles

- driving styles A1-A4, B1-B4, C1-C4
- individual driving style of John Doe for situation A-C

Best-Worst-scaling for preference measurement

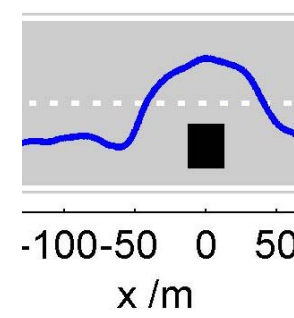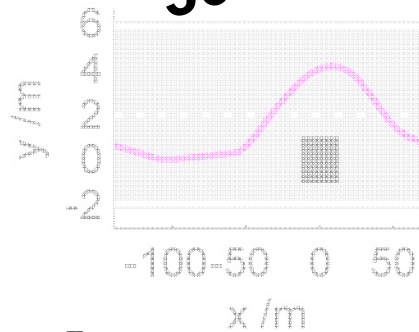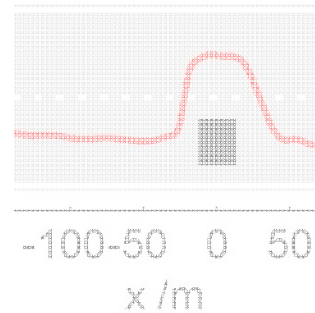**30 trials alltogether, 6 ratings per alternative**

alternative 1:
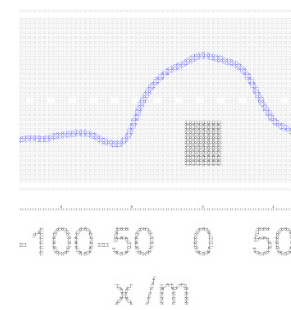driving data from B1 (~40 Sek.)

alternative 2:
driving data from B2 (~40 Sek.)

alternative 3:
driving data from John Doe in situation B

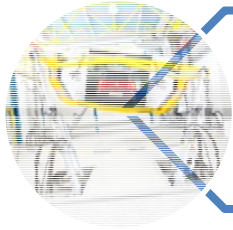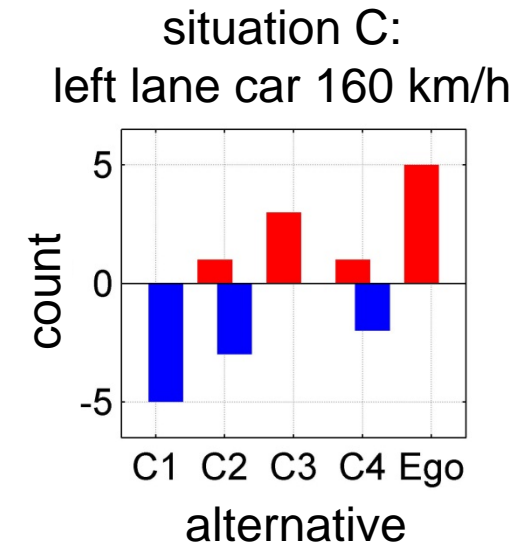2. trial (~2.5 Min.)
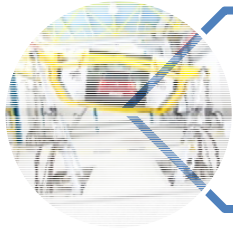
Phase 2: Should my vehicle drive like me?
individual results for John Doe

situation A:
left lane free

situation B:
left lane car 140 km/h

situation C:
left lane car 160 km/h
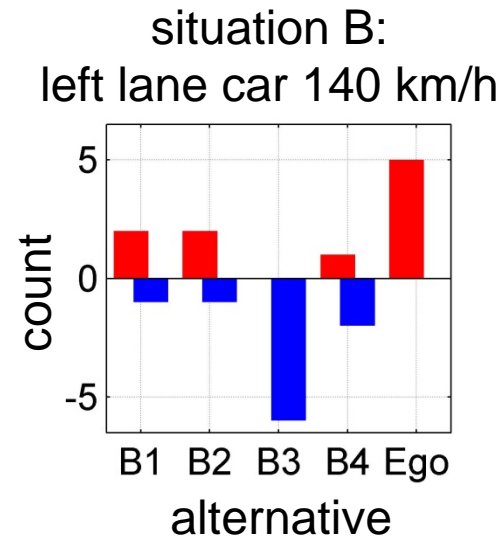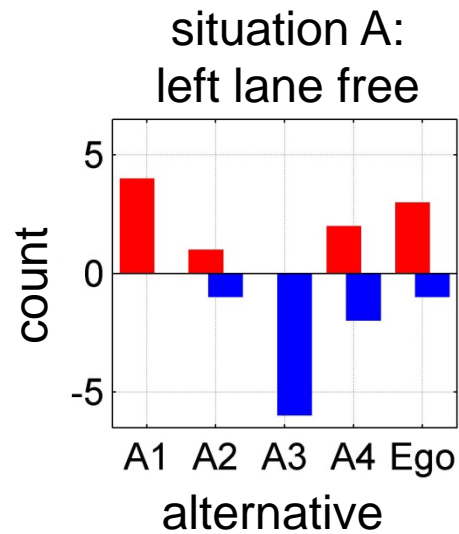
best rating   worst rating

Phase 2: Should my vehicle drive like me?
overall results

situation A:
left lane free

situation B:
left lane car 140 km/h

situation C:
left lane car 160 km/h
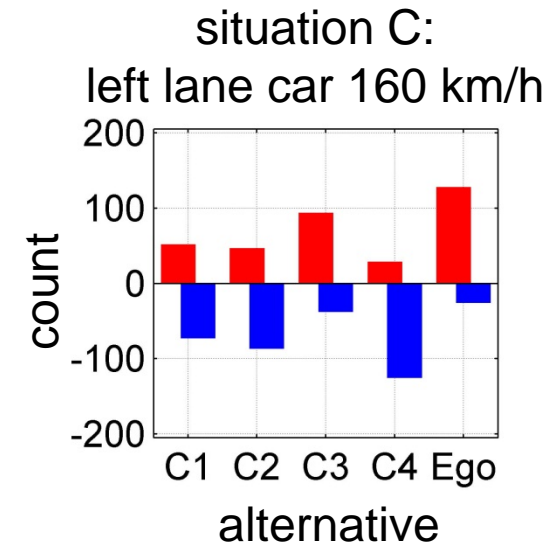
best rating   worst rating

- maximum count = 35 (subjects) x 6 (alternative ratings) = 210

Phase 2: Should my vehicle drive like me?
overall results

situation A:
left lane free

situation B:
left lane car 140 km/h

situation C:
left lane car 160 km/h
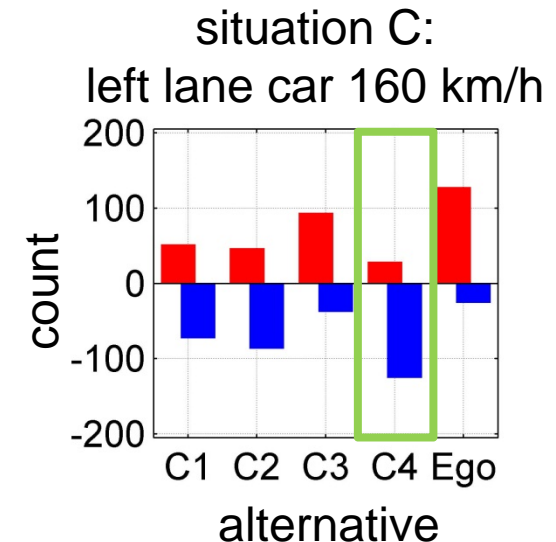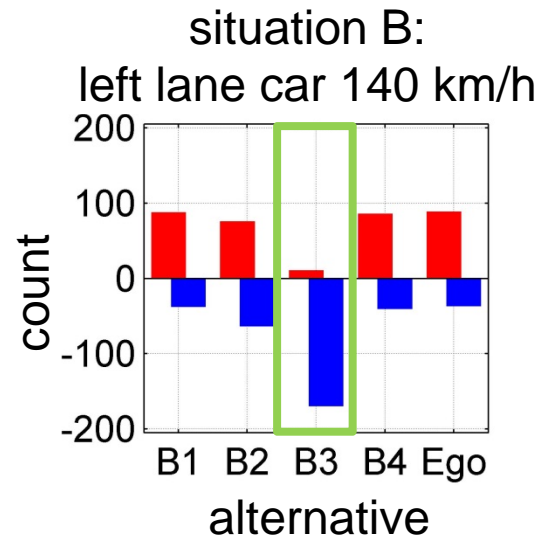
■ best rating   ■ worst rating

- one alternative per condition which was rated significantly worse than others
→ alternatives with more lateral acceleration and less safety distance

Phase 2: Should my vehicle drive like me?
overall results

situation A:
left lane free

situation B:
left lane car 140 km/h

situation C:
left lane car 160 km/h

best rating   worst rating
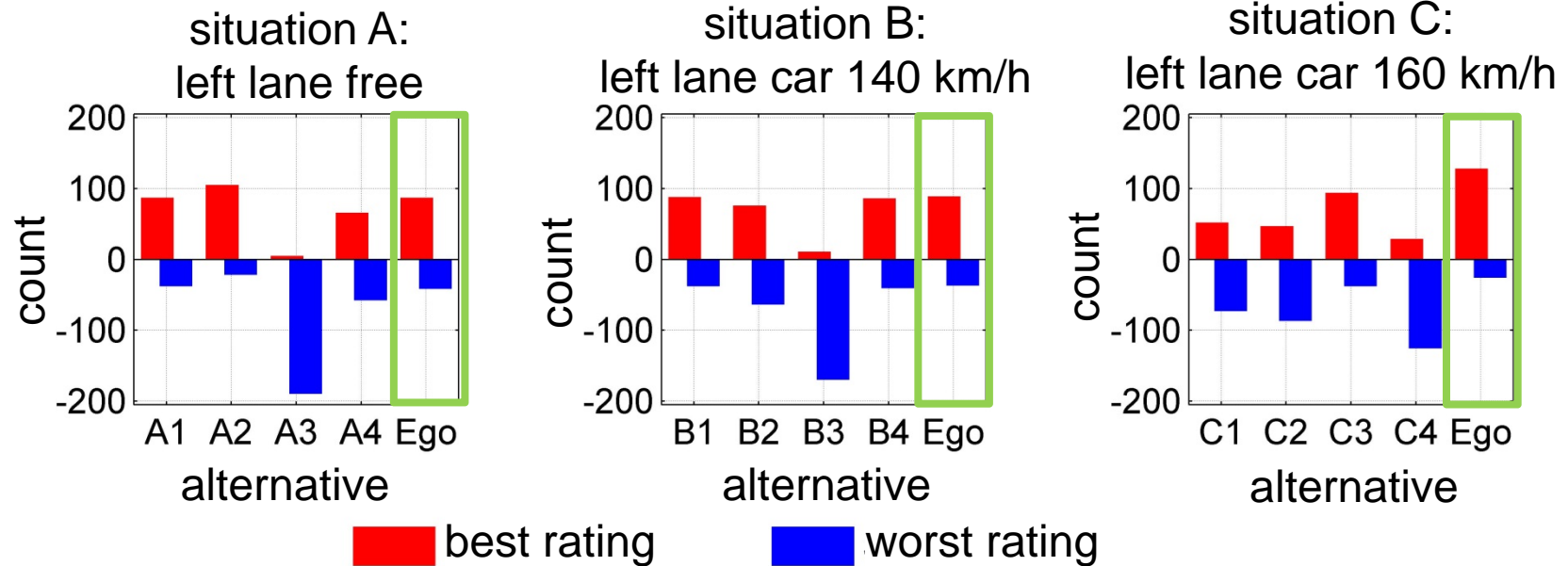
- subjects rate in all 3 conditions their own driving style as positiv
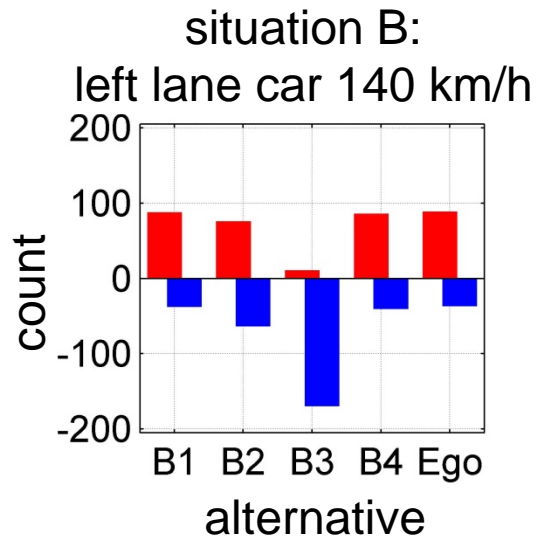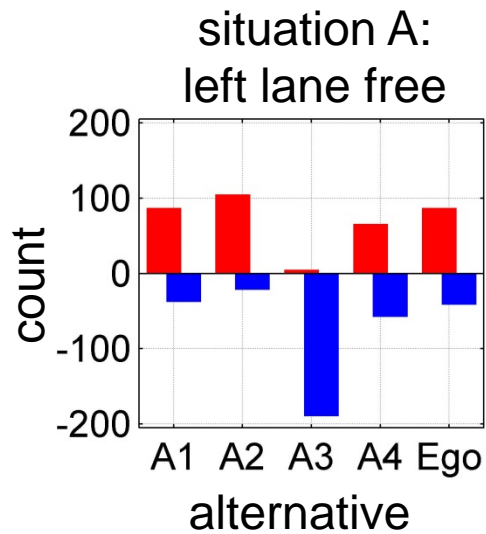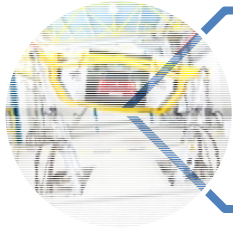- extent of preference varies with situation

Phase 2: Should my vehicle drive like me?
overall results

situation A: left lane free

situation B: left lane car 140 km/h

situation C: left lane car 160 km/h
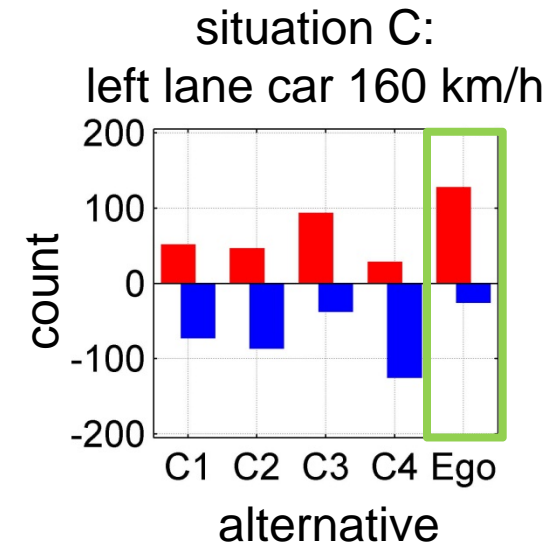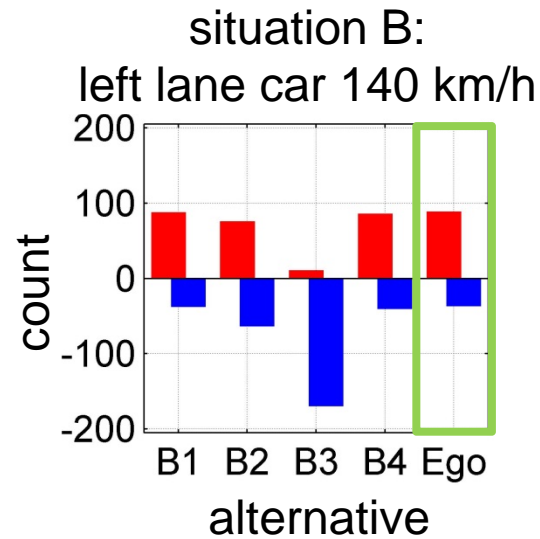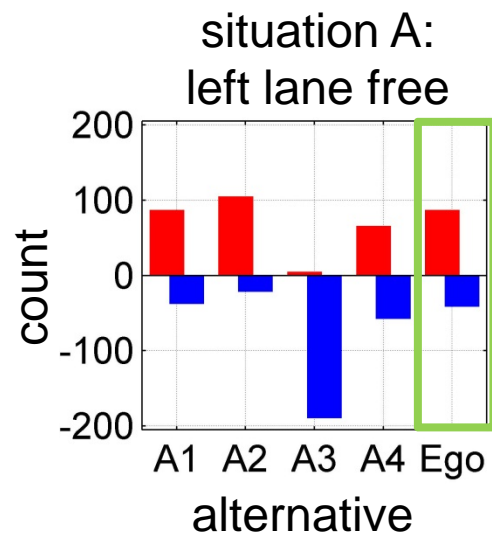
■ best rating   ■ worst rating

- **intermediate result**: my car does not necessarily have to drive like I do
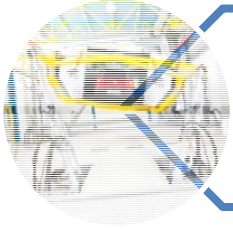
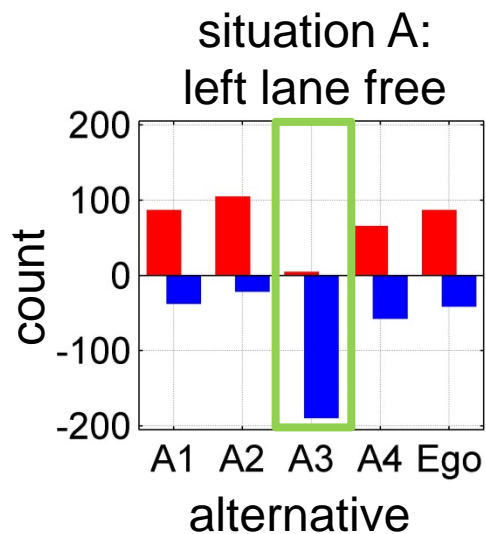**Phase 2: Should my vehicle drive like me?**
further questions and results

1. **Should my automation drive similar to me?**

2. **Can we predict preferences from the manual driving data?**

3. **Which benefit has a driver adaptive alternative compared to a standard profile?**

DLR

Phase 2: Should my vehicle drive like me?
further questions and results

1. **Should my automated car drive similar to me?**

- analysis based on driving style clusters
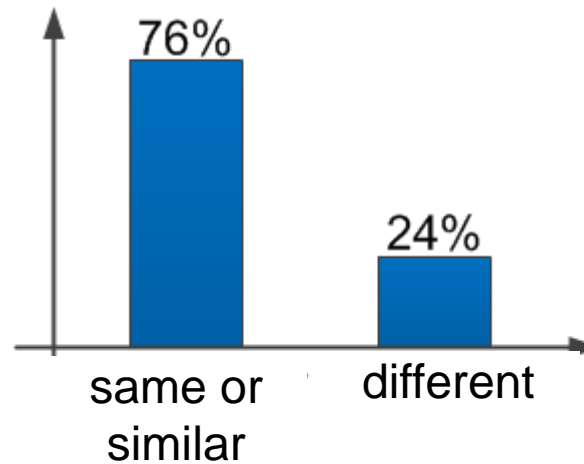
Phase 2: Should my vehicle drive like me?
further questions and results

2. **Can we predict preferences according to manual driving data?**

3. **What benefit has the driver adaptive alternative compared to the baseline?**

1. use standardized measures of Best-Worst-scaling to gain a better understanding of driver preferences
2. define baseline and driver adaptivity

Phase 2: Should my vehicle drive like me?
further questions and results

- definition of standardised measures = Best-Worst-Scores (BWS)

$$\frac{\text{count rating as best alternative} - \text{count rating as worst alternative}}{\text{count of ratings for this alternative}}$$

- example: John Doe rates alternative A2 twice as best alternative and once as worst alternative

-> BWS „Best-Worst" = (2-1)/6 = 1/6

Phase 2: Should my vehicle drive like me?
further questions and results

- definition driver adaptive:

Adaptation of the driving styles based on a predictor function, which estimates the preferred automated driving style based on the manual driving style.

individual manual driving styles

Ego A, Ego B, Ego C

analysis →

set of style cluster

A1- A4
B1- B4
C1- C4

evaluation – Best-Worst-scaling

individually preferred styles

prediction function

driver adaptive

DLR

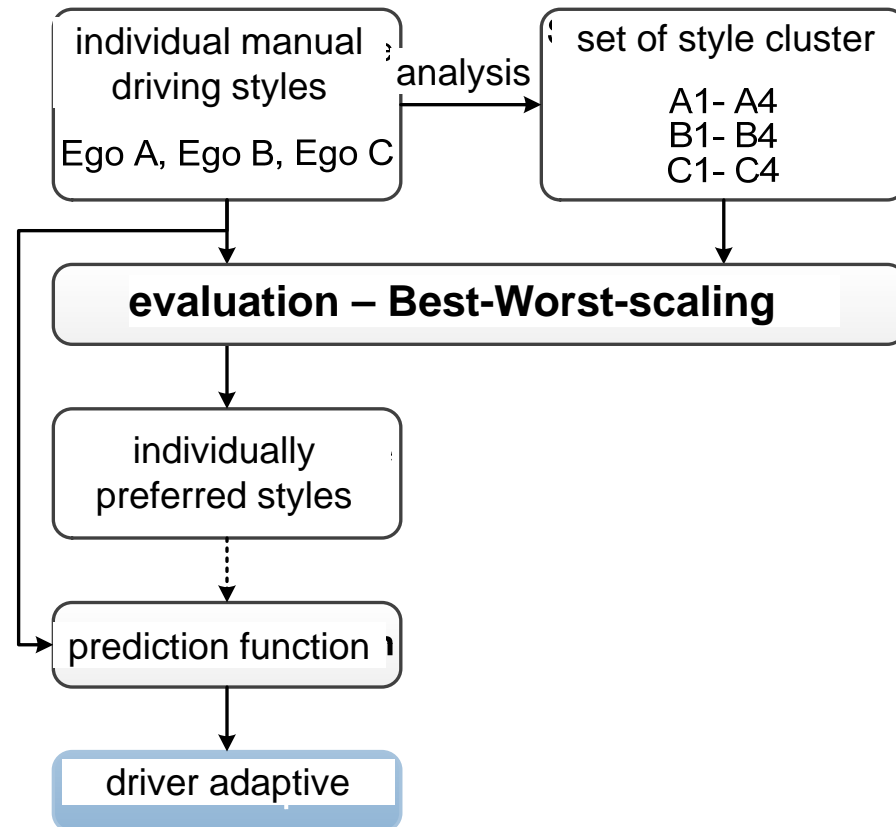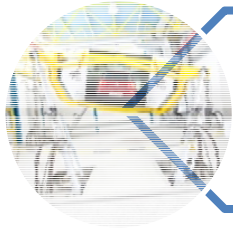## Phase 2: Should my vehicle drive like me?
further questions and results

- <u>definition driver adaptive:</u>

Adaptation of the driving styles based on a predictor function, which estimates the preferred automated driving style based on the manual driving style.

- <u>definition baseline:</u>

The driving style cluster rated best on average for each situation.
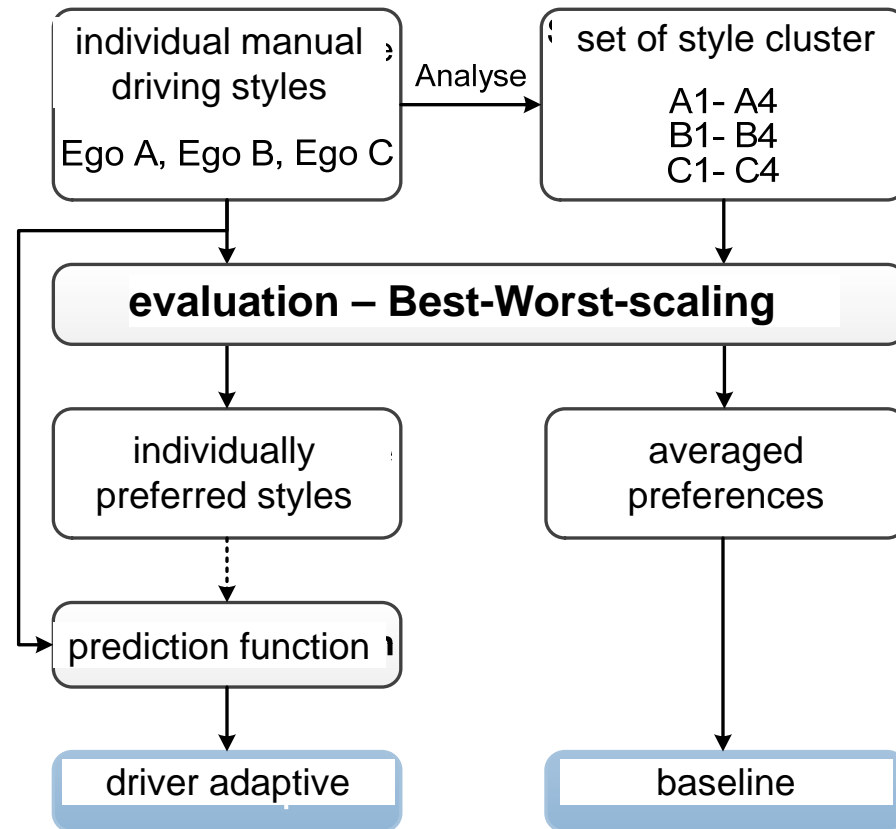
individual manual driving styles	Analyse →	set of style cluster
Ego A, Ego B, Ego C		A1- A4 B1- B4 C1- C4

evaluation – Best-Worst-scaling

individually preferred styles	averaged preferences

prediction function

driver adaptive	baseline

Phase 2: Should my vehicle drive like me?
further questions and results

2. **Can we predict preferences based on manual driving data?**

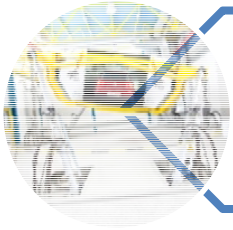3. **Which benefit has the driver adaptive alternative compared to the baseline?**

	baseline: mean standard. „Best-Worst"	driver adaptive: mean standard. „Best-Worst"	increase
situation A	0.41	0.48	17%
situation B	0.23	0.40	74%
situation C	0.23	0.48	110%

Summary and Discussion

Should my car drive like me **or similar**?

- majority prefers an automation driving style similar to their own style

- two limitations:

    - Some subjects prefer an automation style *contrary* to their own style -> interaction with the automation may be necessary

    - Subjects with high lateral accelerations and short safety distances when driving manually prefer large safety distances and lower lateral accelerations

- driver adaptive alternative received higher ratings compared to the unadpated baseline

Thank you for your attention

David.Kaethner@dlr.de
Stefan.Griesche@dlr.de