



Motion Parameter Tuning and Evaluation for the DLR Automotive Simulator

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Can this feel like real driving?





Agenda

- Introduction
- Experimental Design
- Experimental Results
- Summary and Conclusions
- Future Tasks



Evaluation strategy

- Quality (of the Motion)
 - Parameter tuning (Classical washout algorithm)
 - First single basic then complex combined manoeuvres
 - New Concepts
 - Simulator Sickness
- Validity
 - Virtual vs. real
 - Objective and subjective evaluation
 - From simple to complex manoeuvres

Technical Equipment

ViewCar



VR-Lab



Simulator



Simulator
limits

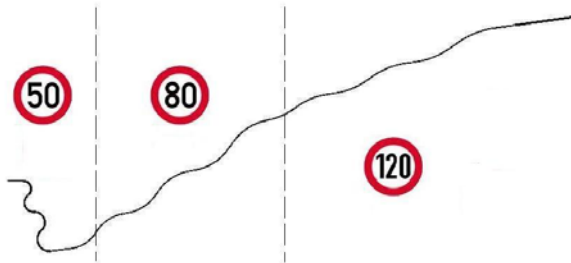
	Position	Acceleration		Position	Acceleration
Surge	±1,5 m	±10 m/s ²	Roll	±21 °	±250 °/s ²
Sway	±1,4 m	±10 m/s ²	Pitch	±21 °	±250 °/s ²
Heave	±1,4 m	±10 m/s ²	Yaw	±21 °	±250 °/s ²

Experimental Design

Track C and B

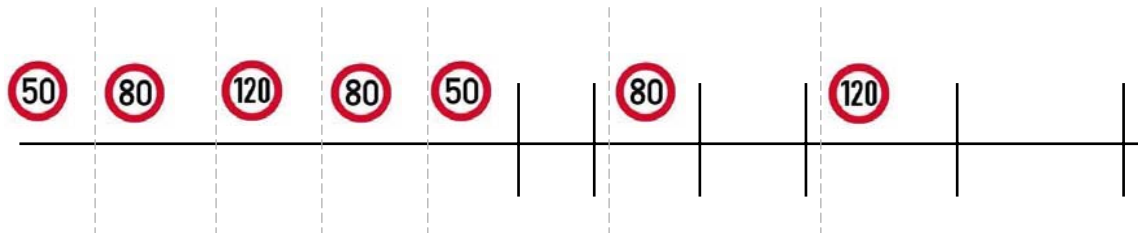
➤ Manoeuvre specific courses

➤ Curve driving (C)



km/h	mph
50	30
80	50
120	75

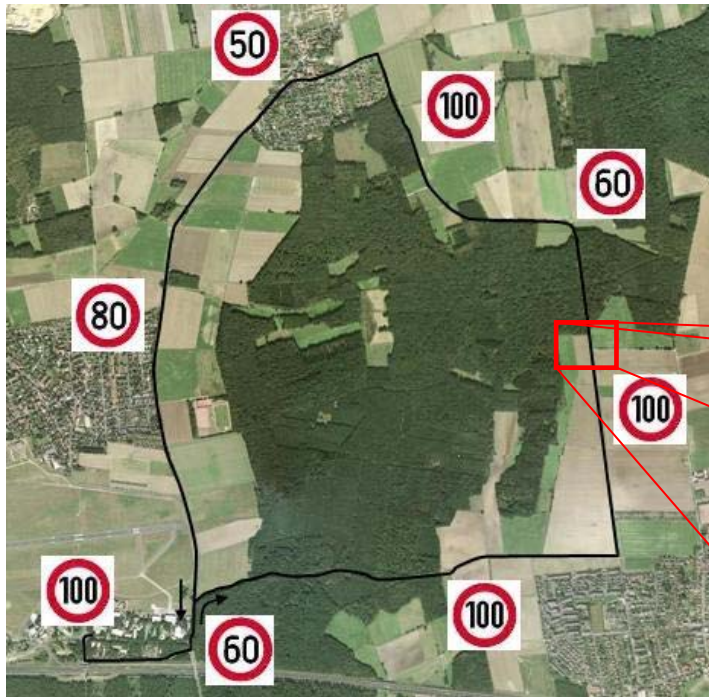
➤ Braking / Accelerating (B)



Experimental Design

Track V and R

- Virtual vs. real driving
- Recording objective parameter



Virtual
(V)



Real
(R)

Experimental Design

Parameter Variation

➤ Acceleration vector for different manouevres

➤ Curve driving:

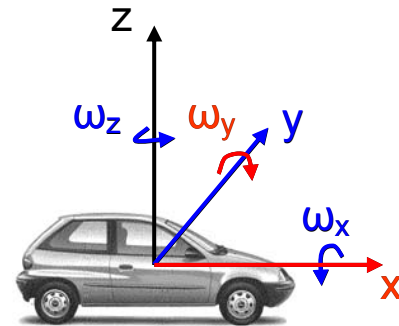
a_y, w_x, w_z

➤ Braking:

a_x, w_y

$$\bar{a} = \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}$$

$$\bar{\omega} = \begin{bmatrix} w_x \\ w_y \\ w_z \end{bmatrix}$$



➤ Here: no common components (DoF).

⇒ Different parameters for tuning

<i>Manoeuvre</i>	<i>Parameter Set-up</i>		
	a	b	c
Curve Driving			
Braking			

1: Original tuning

2: DLR tuning

Experimental Design

Excluding Sequence Effects

Varying the order of ...

1. ...the parameter set

(a, b and c)



12 different set-ups (I-XII)

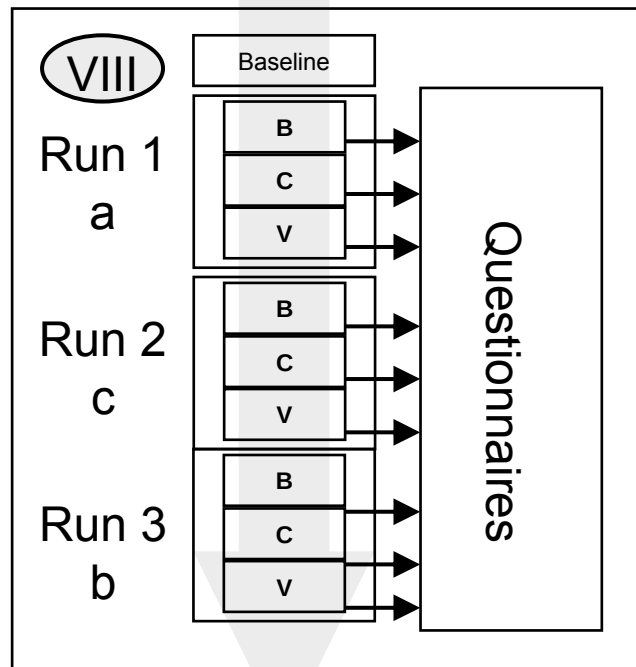
2. ...the first two tracks

(C and B)

		<i>Parameter-set order</i>					
		a – b – c	a – c – b	b – a – c	b – c – a	c – a – b	c – b – a
<i>Track order</i>	C – B – V	I	II	III	IV	V	VI
	B – C – V	VII	VIII	IX	X	XI	XII

Experimental Design

- 12 Subjects (8 male and 4 female aged 25 to 50)
- Virtual drive (Simulator)



Experimental Design

Questionnaires

- How realistic is the feeling of driving?
- How accurately can the car be handled?
- How well do the movements match reality?
- How safe did you feel?

very poor			poor			okay			good			very good		
-1	0	1	-1	0	1	-1	0	1	-1	0	1	-1	0	1

⇒

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
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- Do you recognise any symptoms of simulator sickness?

few...① ② ③ ④ ⑤...many

Experiment Results

- Analytic focus
 - Curve driving
 - Braking
 - Virtual vs. real
 - Simulator sickness
- Data sources
 - Recorded data (objective assessment)
 - Questionnaires (subjective assessment)

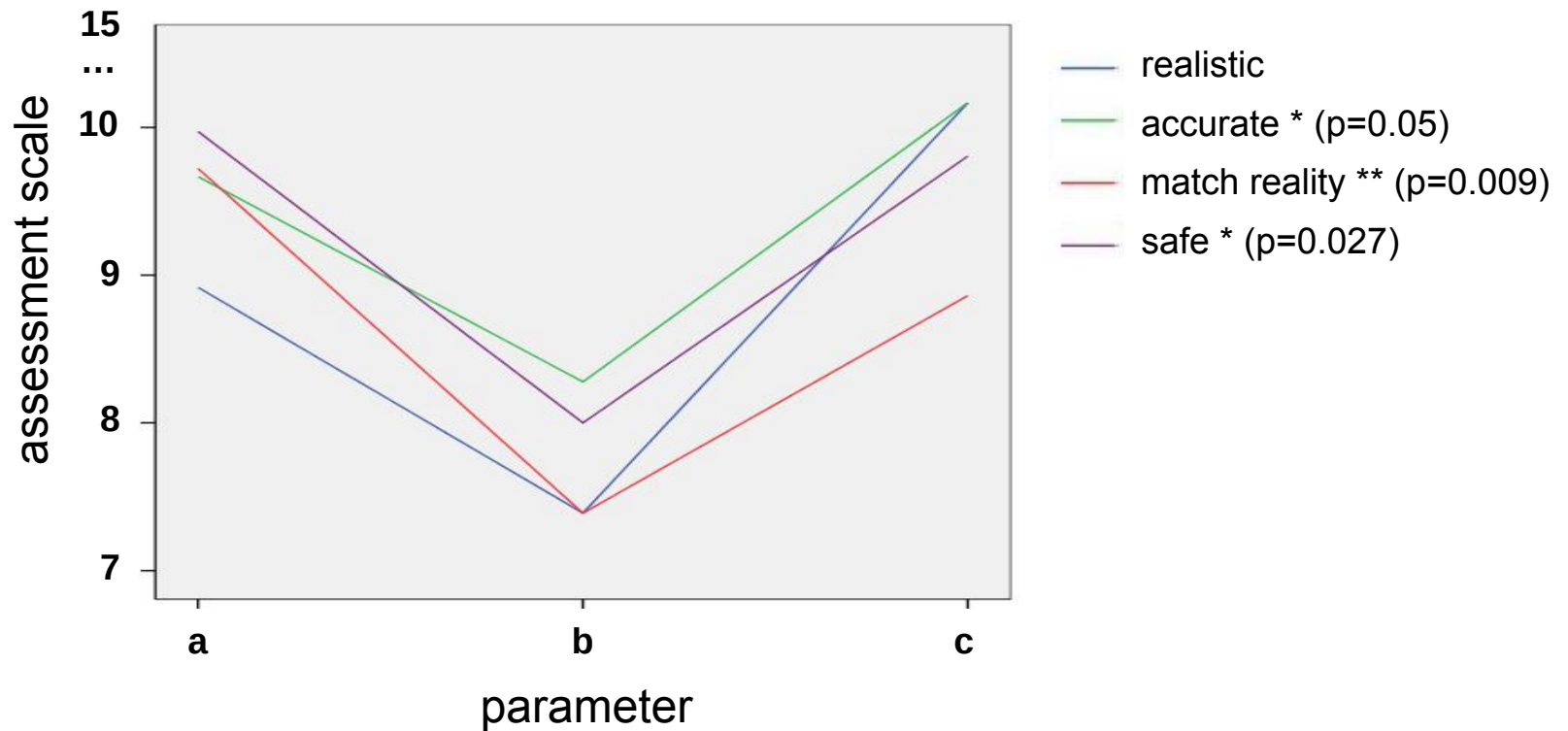
➤ Independent variables

- Parameter set a, b, c
- Track order group B-C-V, C-B-V
- Speed zone 50, 80, 120 [km/h]

	a	b	c
Curve Driving			
Braking			

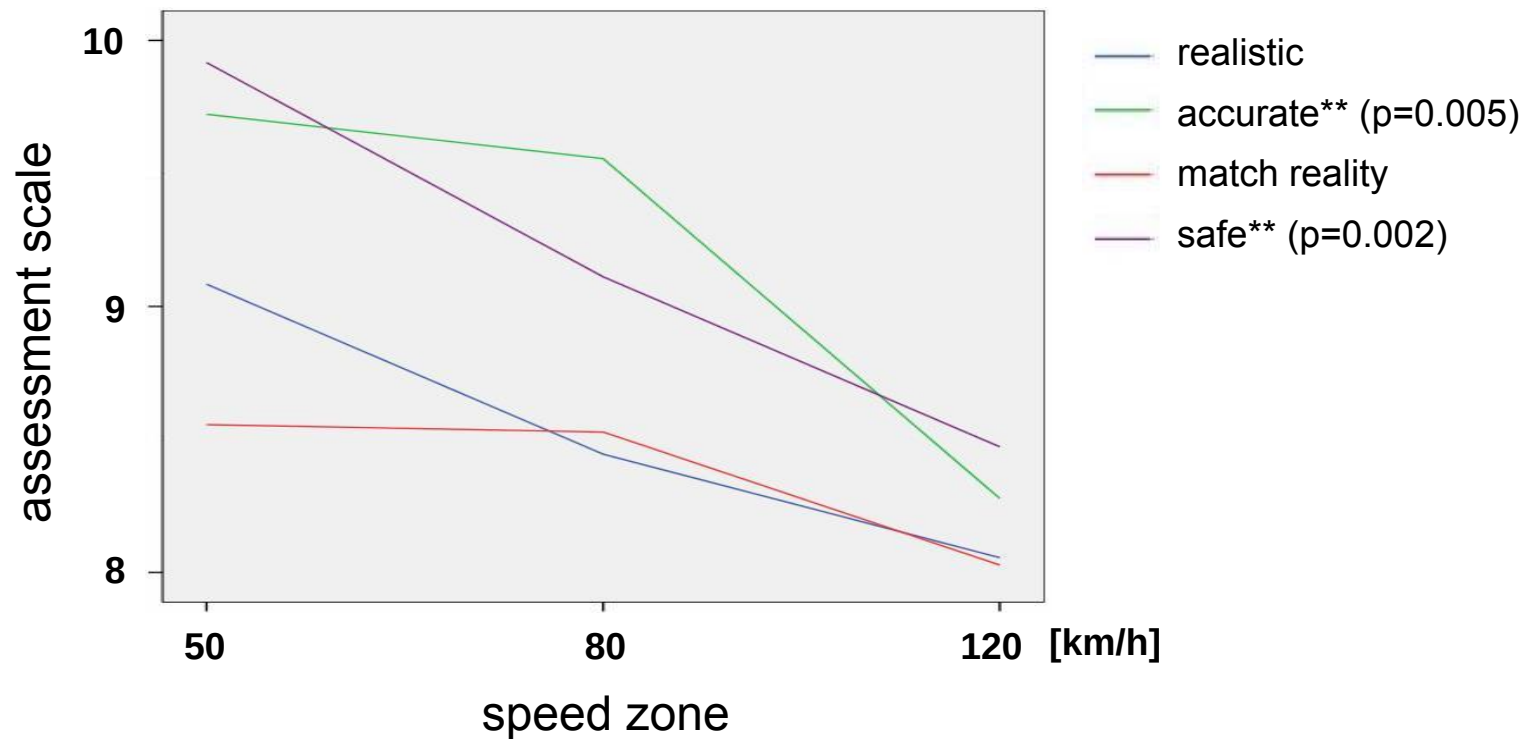
Experiment Results

Braking – main effect parameter



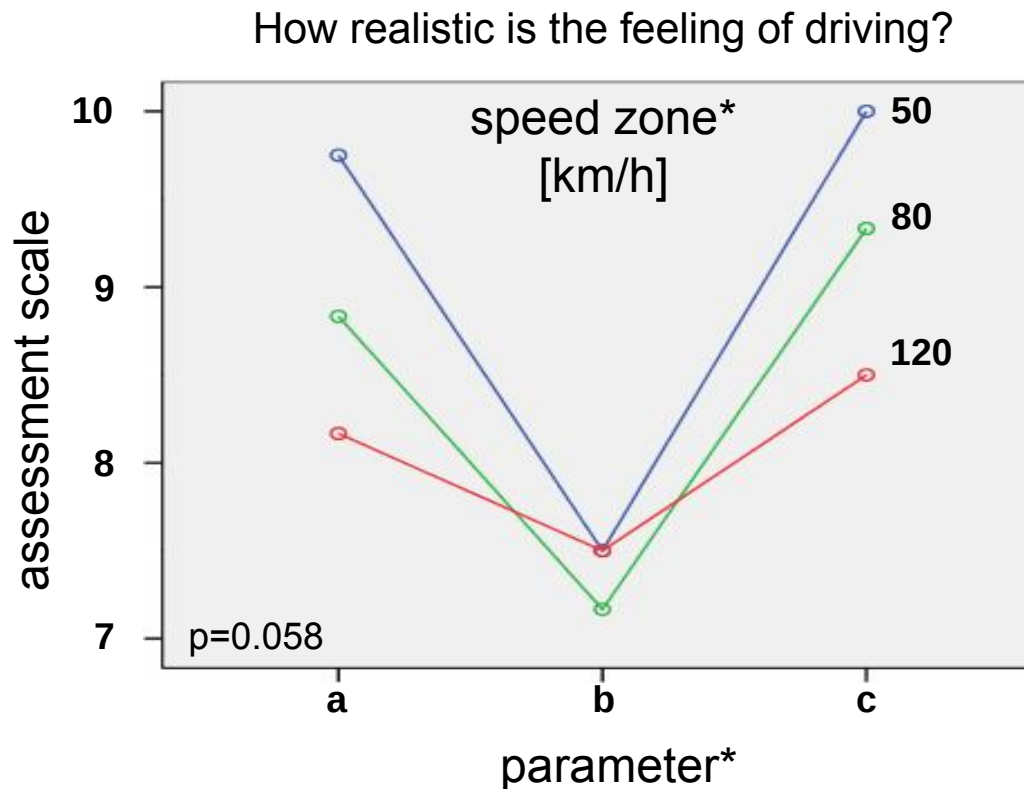
Experiment Results

Braking – main effect speed zone



Experiment Results

Braking – interaction effect parameter-speed zone

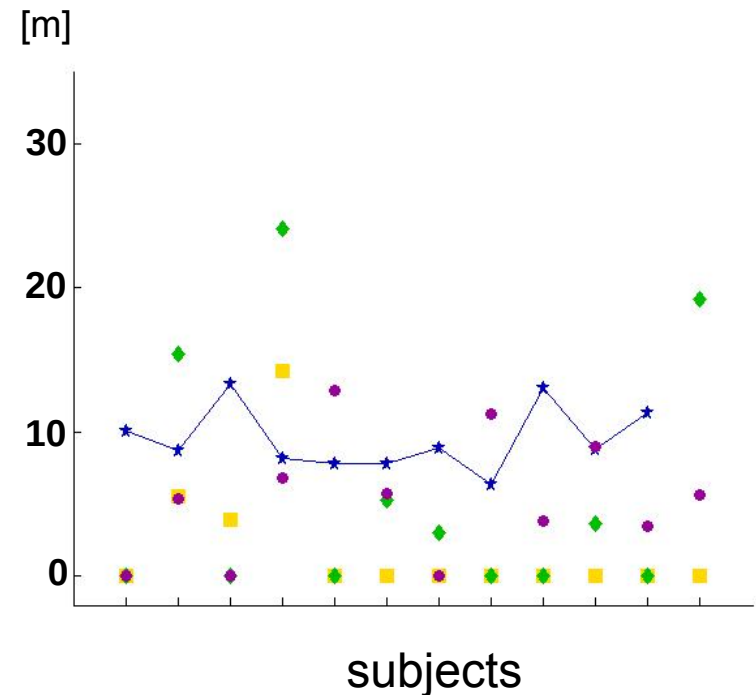
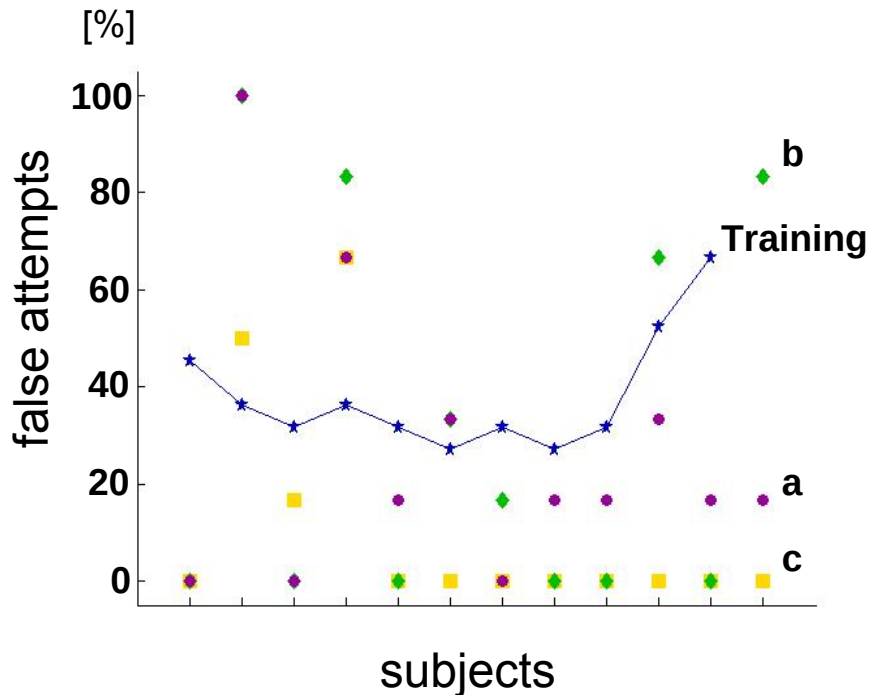


Experiment Results

Braking – accurate stopping ability

➤ task: stop at stopping line

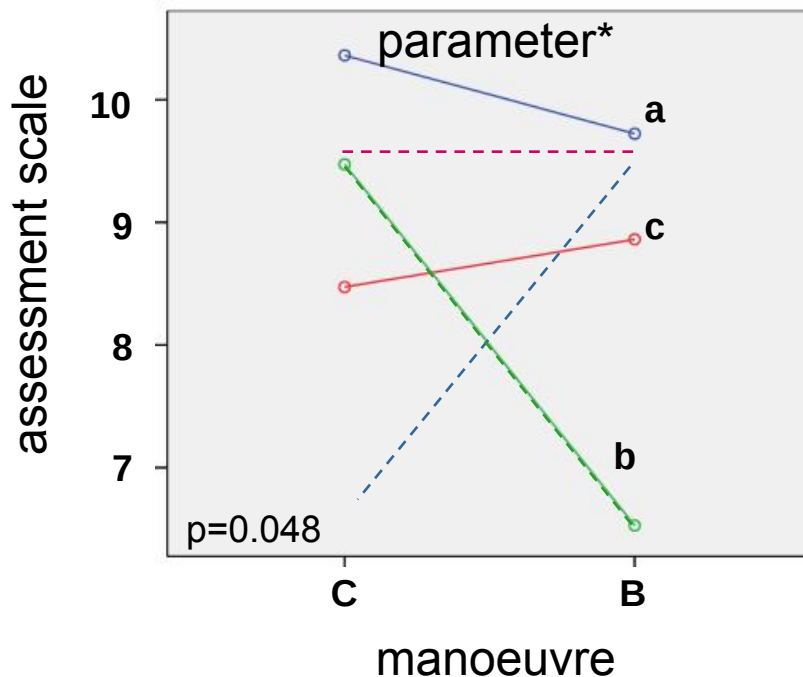
➤ measure: DTI (distance to intersection) → false for $\text{abs}(\text{DTI}) > 3\text{m}$



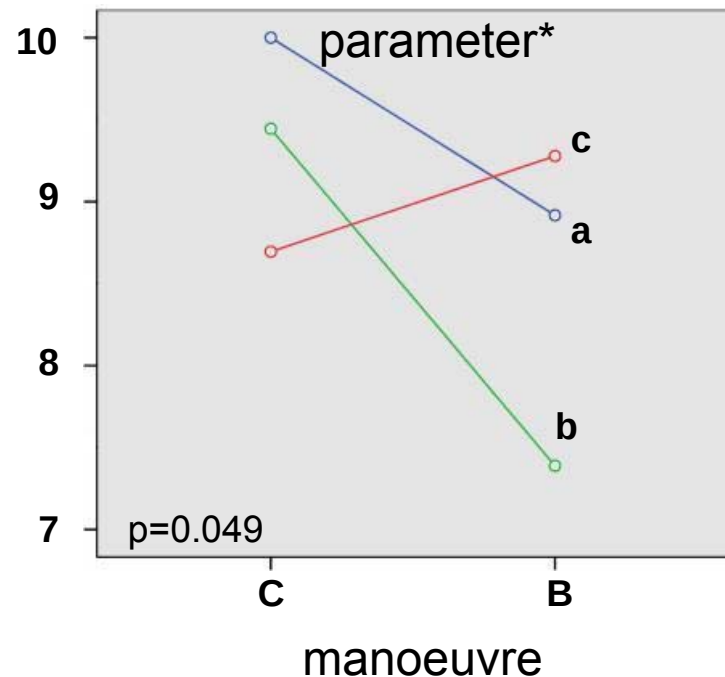
Experiment Results

Curve Driving - main effect parameter

How well do the movements match reality?

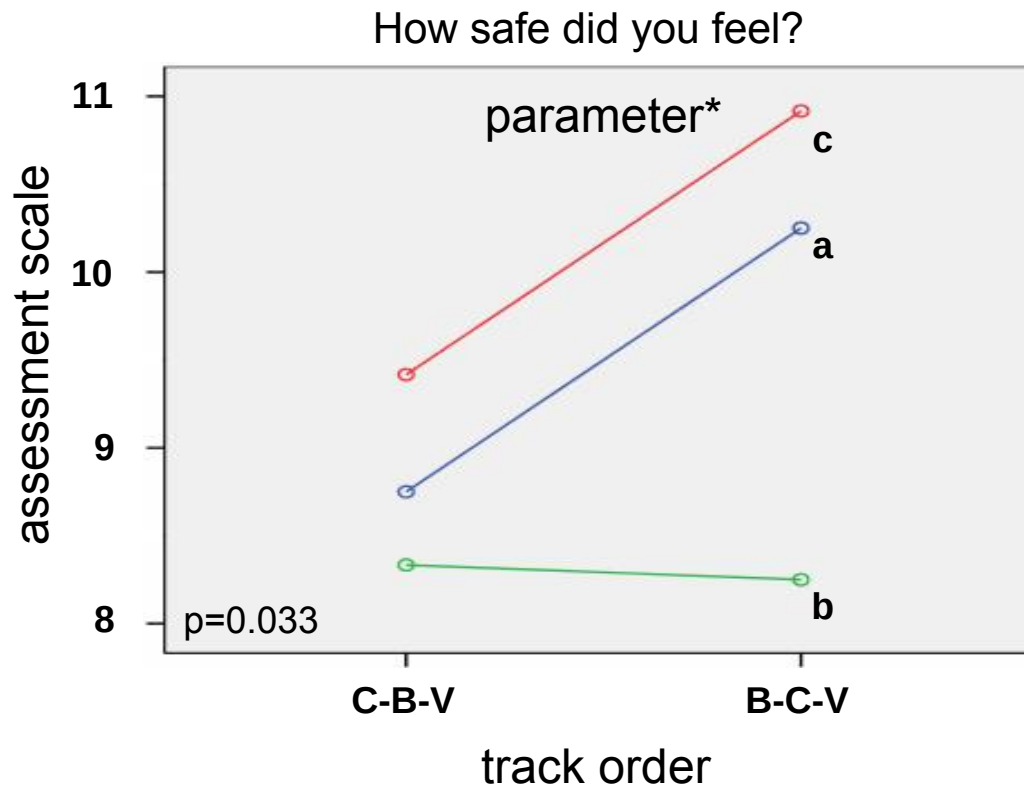


How realistic is the feeling of driving?



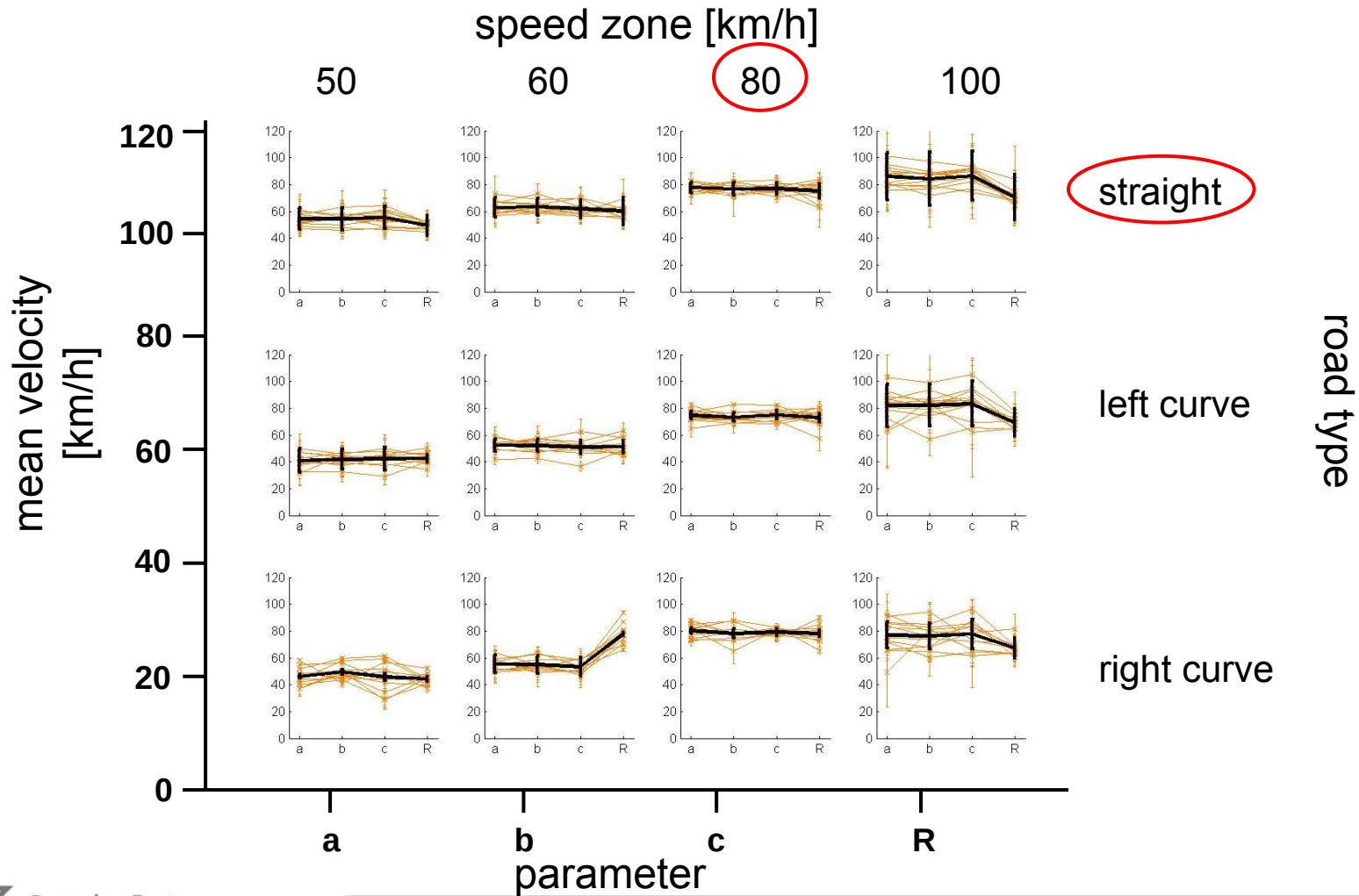
Experiment Results

Virtual - main effect parameter



Experiment Results

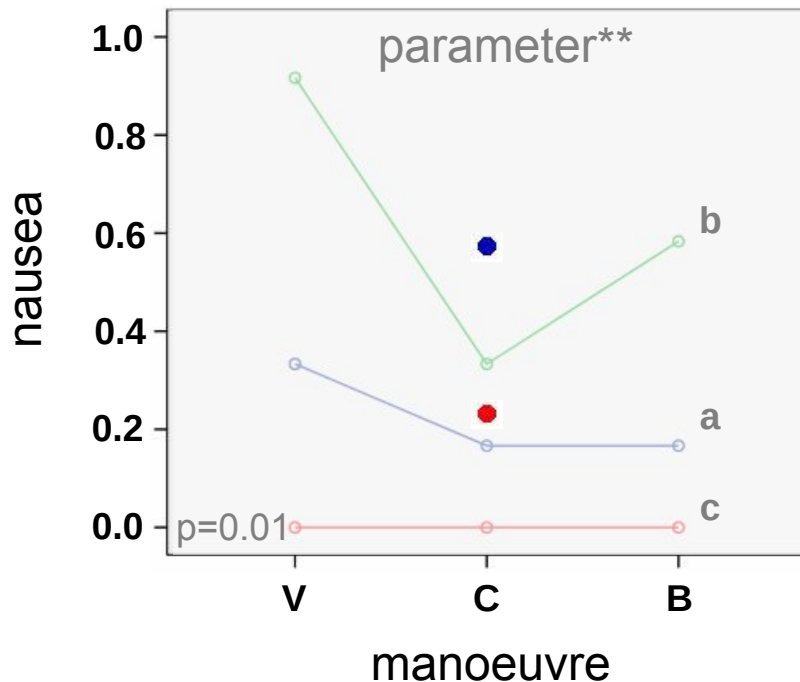
Virtual vs. Real



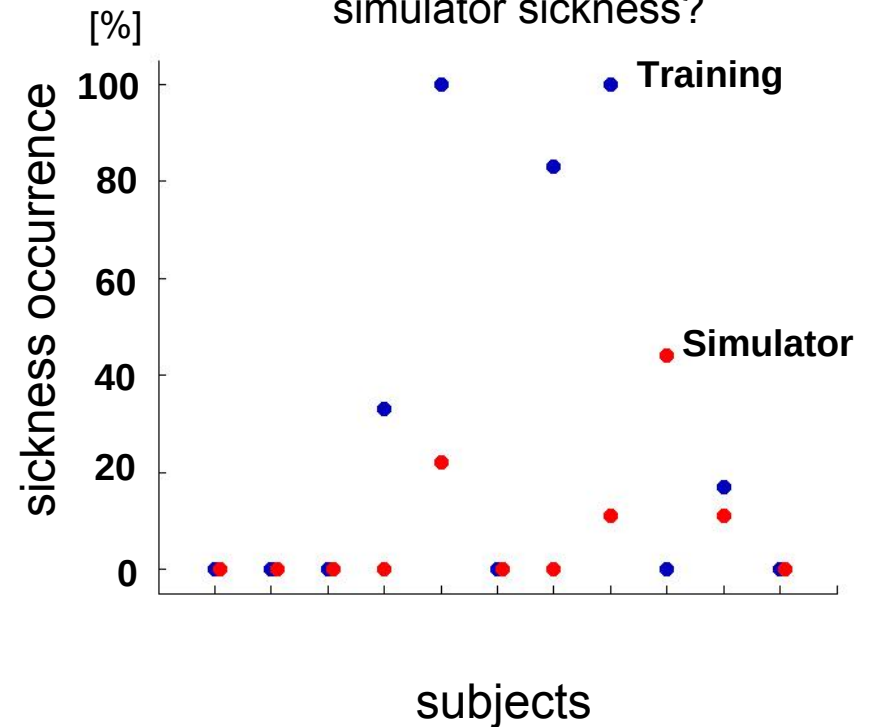
Experiment Results

Simulator Sickness - main effect parameter

Do you recognise any symptoms of simulator sickness?



Do you recognise any symptoms of simulator sickness?



Summary and Conclusion

Parameter Characteristics

	a	b	c
Curve Driving			
Braking			

Summary	
a	best for curving
b	worst for braking
	equally worse for all speed zones
	worst for combined manoeuvres
	most nauseating
c	does not cause nausea
	facilitates very good stopping ability

Conclusions
more motion is better for curving
not suitable for driving
best overall but not as satisfying as expected

Summary and Conclusion

General Characteristics

Summary	Conclusions
the faster the worse	increase overall simulator quality; speed dependant parameters (?)
braking is generally easier with (good) motion response	motion increases realism of simulation
less nausea with motion response	
mean velocity on the virtual and real course is nearly equal	Little hint for comparable driving behaviour

Future Tasks

- Further analysis
 - Lane keeping ability
 - Braking sequence
 - track order effects
- New simulator experiments
 - Enhanced parameter tuning for curving
 - More and combined manoeuvres
(e.g. cornering, double lane change)
 - Motion for high speed driving
 - Evaluation

Can this feel like real driving?

A large yellow robotic arm is shown in a laboratory setting, holding a red car. The arm is complex, with multiple joints and hydraulic cylinders. The car is a small, red, two-wheeled vehicle. The background shows industrial structures and lighting.

➤ Yes, it can!
...not yet, but we're on our way

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