VRU SIMULATOR VALIDITY ASPECTS

2nd HCVRU Sim Workshop, 22.2.2023

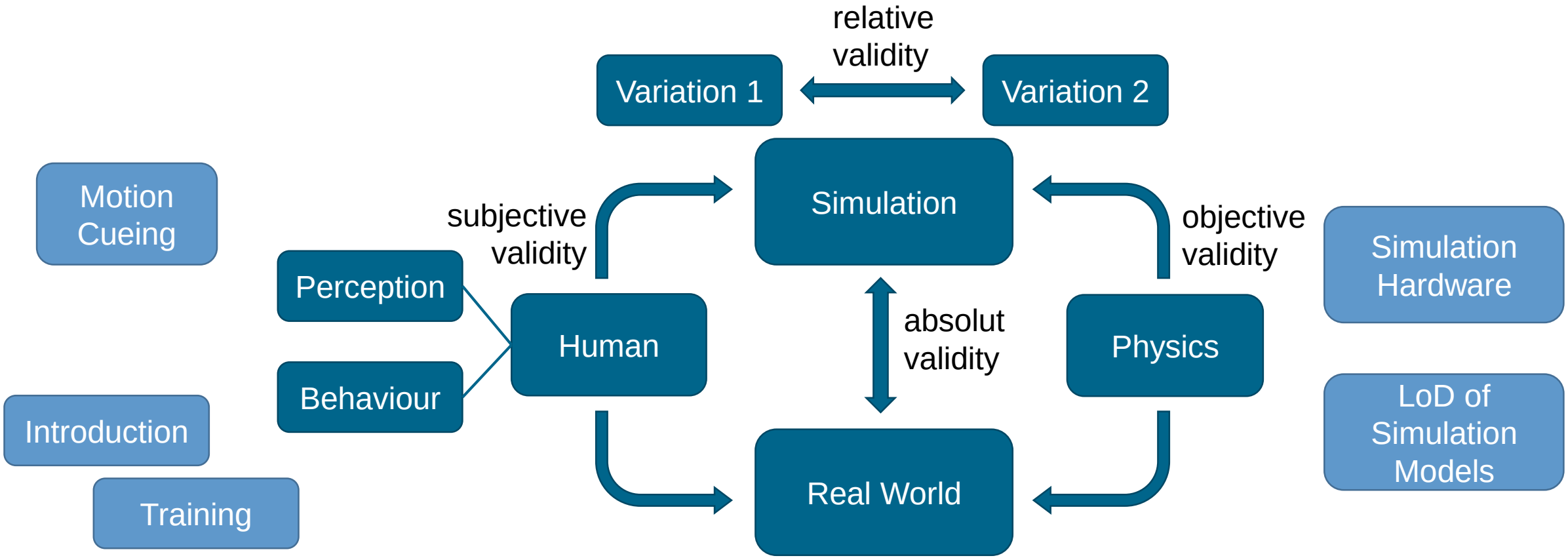
Martin Fischer et al.

DLR

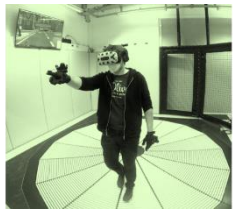
SIMULATION VALIDATION

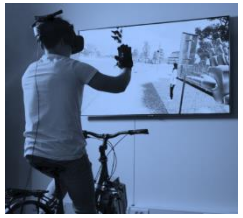
Motivation for Validation

- Reliability – Transfer of simulator study results to real world applications
- Containment – Knowing the limits of the simulator environment



VRU studies





drone acceptance

iUSIM ✓ 2021

LoD visualization & simulation metrics

VALKyRie ✓ 2022

walking behaviour & simulation evaluation

Coala 2023

VR evaluation & effect of display type

VALHaLa ✓ 2023

speed estimation

SPoRe 2023

2024 STADT:up

Interaction behaviour

@City-AF ✓ 2022

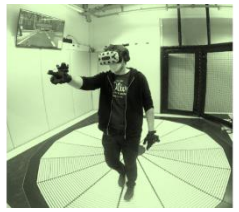
Interaction behaviour

2021 Bike Eval ✓

simulator evaluation & simulation metrics

Bike Eval 2 ✓ 2022

TRAINING

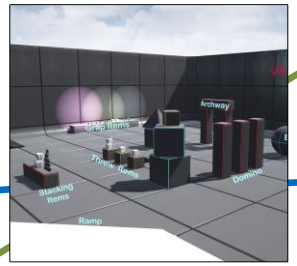


Training Scenarios
Overview

Immersion /
Skill level

Good
Moderate
Poor

Playroom



Story: Tutorial

Supermarket

Story: Shopping Tour

CityPark

Story: Scavenger Hunt

Skill Level for Walking on the Omnideck

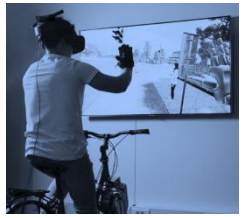
Immersion Level

Main Studie

No.	Task description:
1	Starting point with instructions to read
2	Solve a riddle to choose between two directions
3	Keep environment clean. Dispose some single use coffee cups
4	Cross less traveled street by interacting with a call-by-demand pedestrian traffic light
5	Take a short rest and drink a cola can
6	Scare some crows and make them fly out of the way
7	Climb a longer staircase up
…	

Duration
(min)

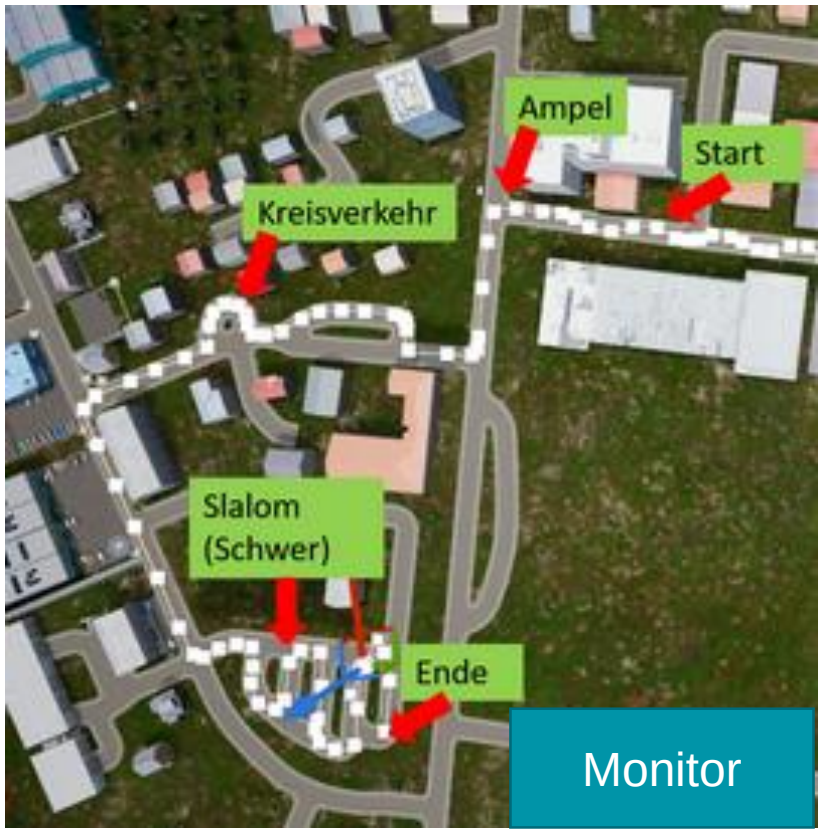
0 5 10 15 20



Cyclist Training Scenarios

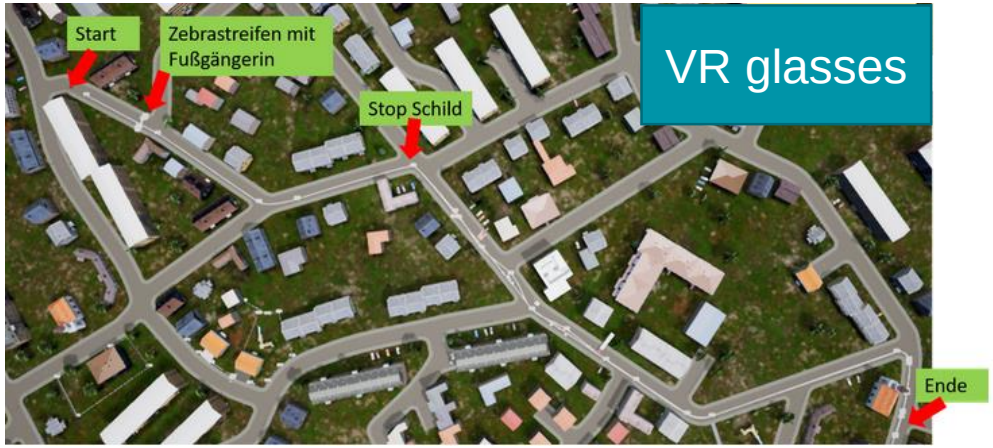
T1) Cyclist should become familiar with

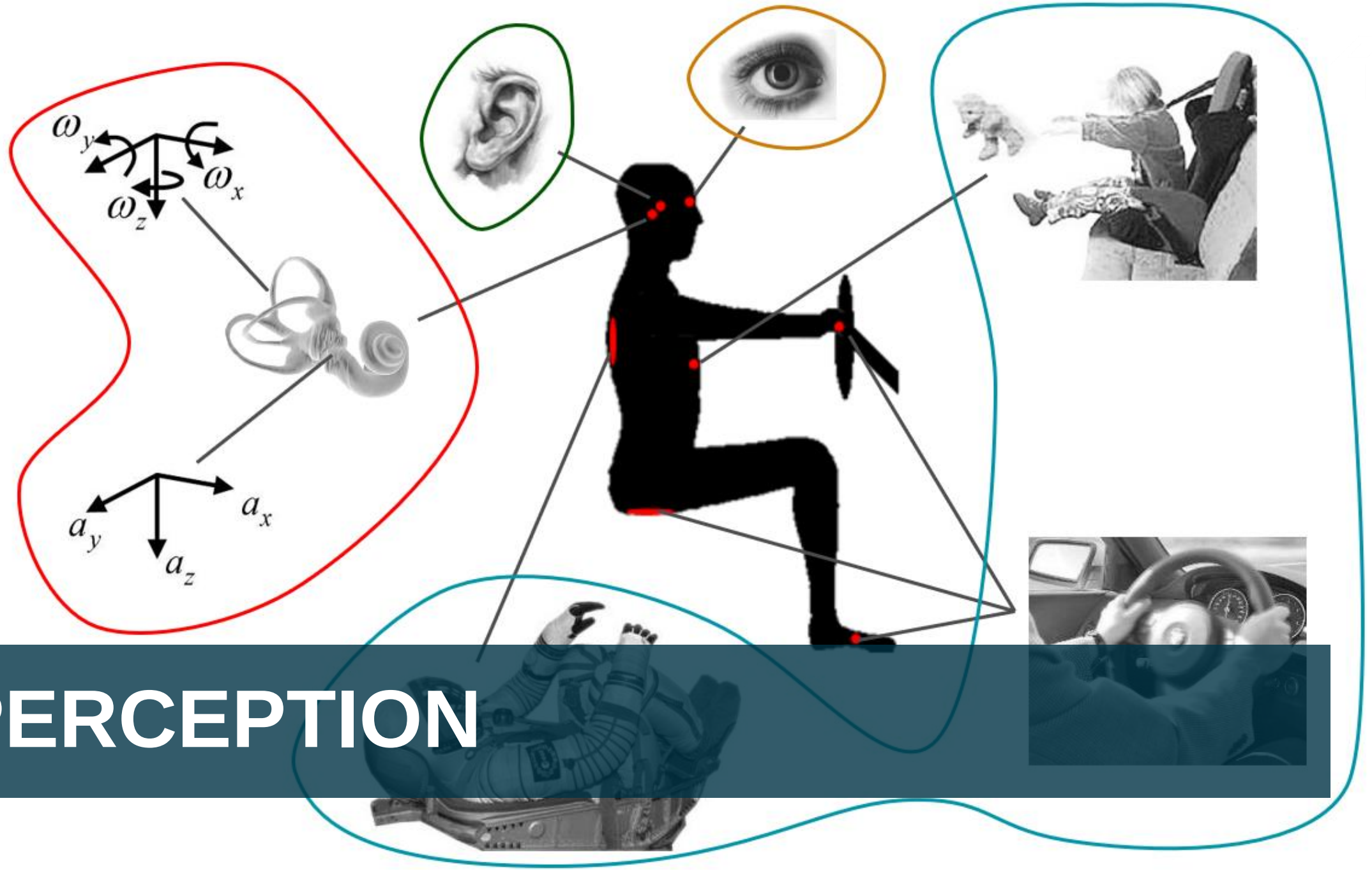
- the **dynamics** of the bicycle when going straight, stopping, braking, accelerating and turning
- the **sensitivity** of the handlebars, the brake and motion platform



T2) Cyclist should become familiar with

- **moving around** in VR





PERCEPTION

VALHaLa Pre-Study on display effects

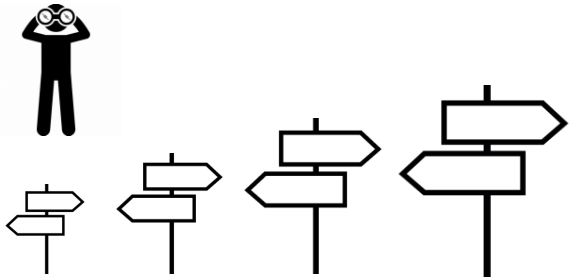
- How good (depending on distance & size) are traffic signs readable?
- Two different variants of display type analysed:

HTC Vive Pro Eye

Triple Display set-up

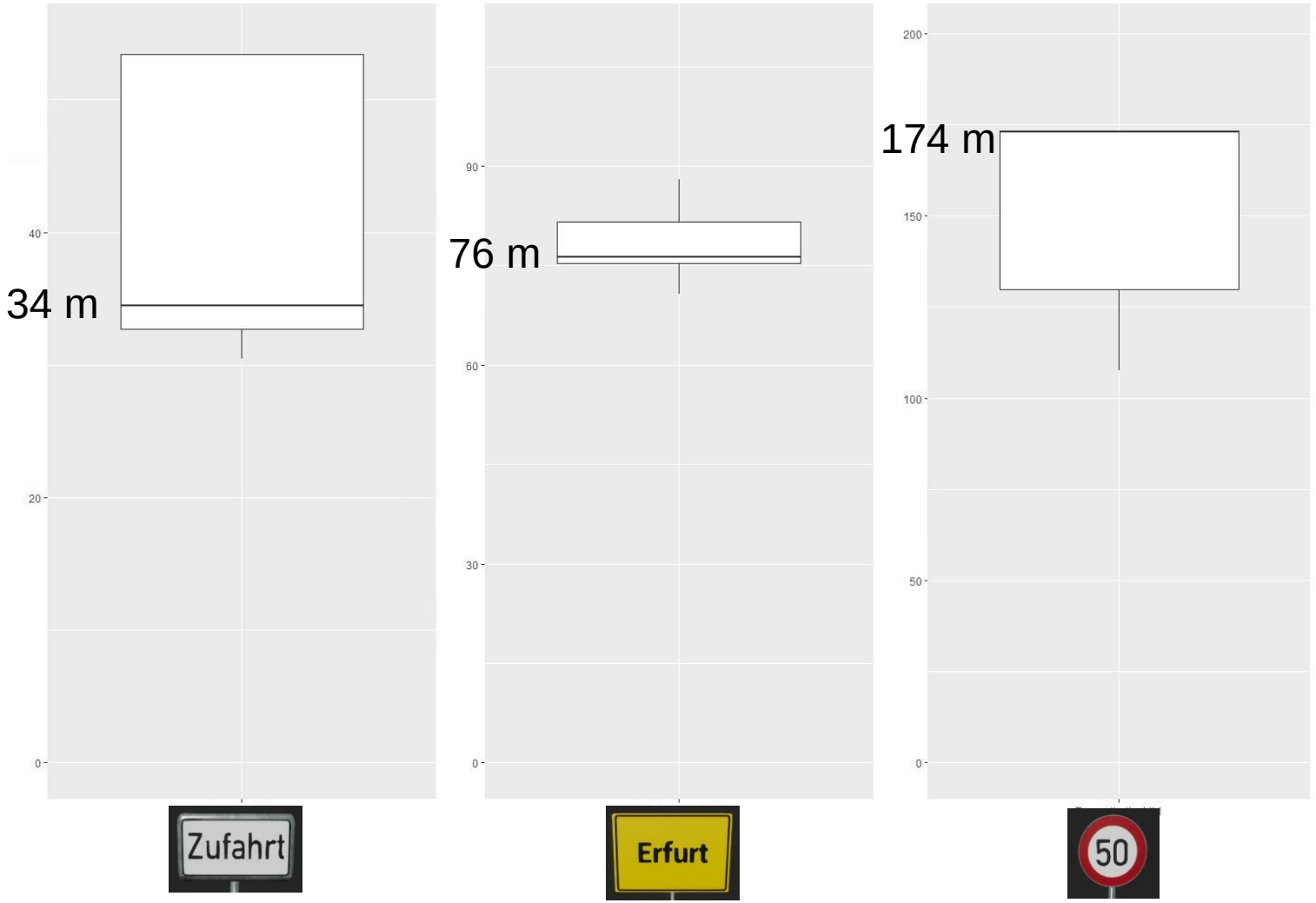
Real world

- Task 1: Moving forward. Press button when traffic sign is readable
- Task 2: Static. Scale size of traffic sign (at a fixed distance) until it is just readable



VALHaLa Pre-Study on display effects

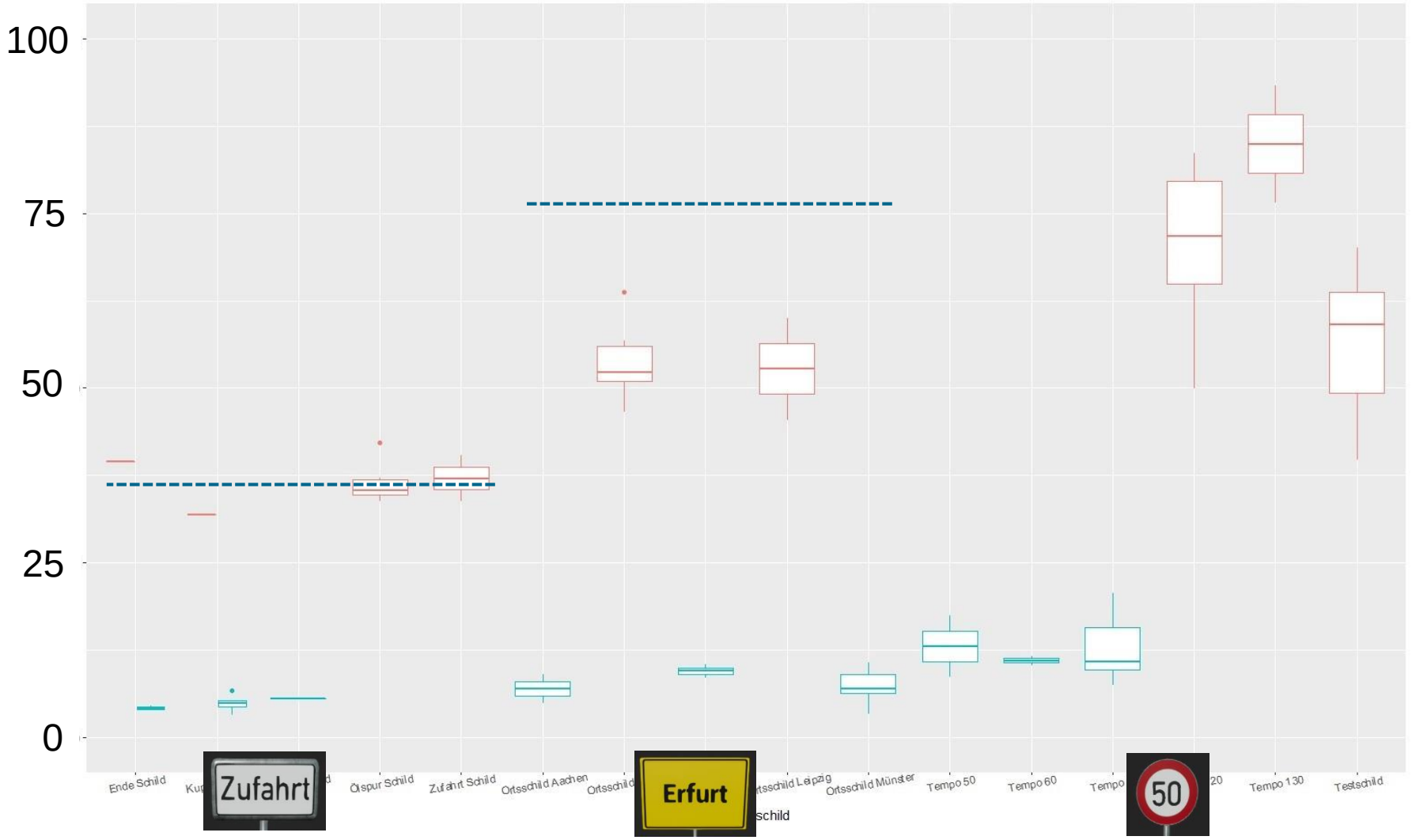
Distance to traffic sign (m)



Real world measurements

VALHaLa Pre-Study on display effects

Distance to traffic sign (m)



Real world measurements

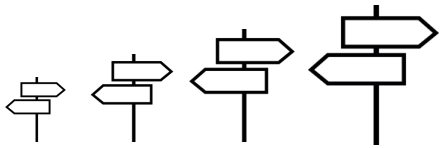
Simulation results

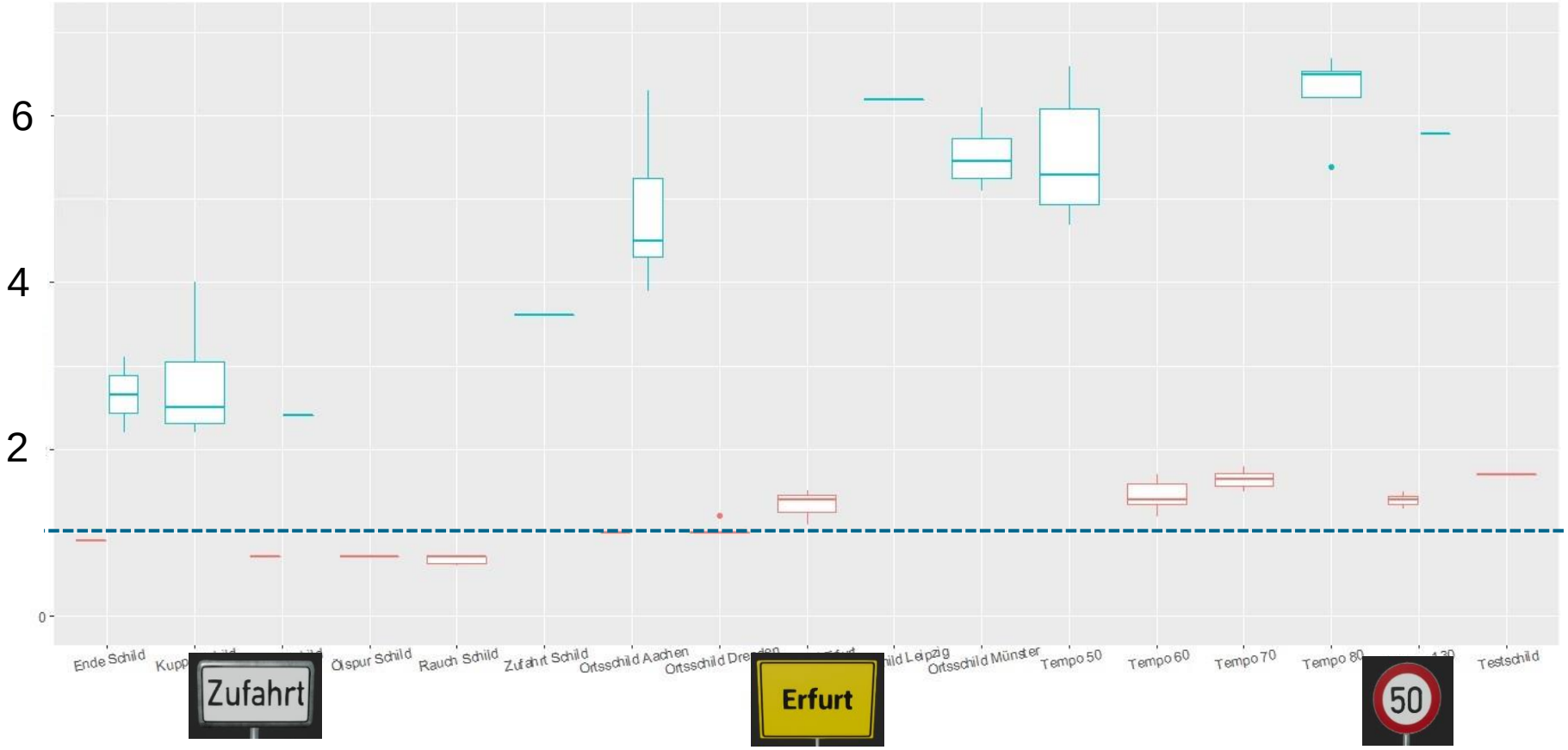
Triple Display set-up

HTC Vive Pro Eye

VALHaLa Pre-Study on display effects

Scaling factor (-)





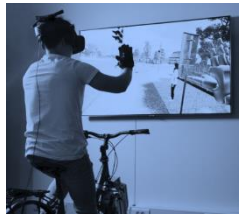
Real world reference

Simulation results

Triple Display set-up

HTC Vive Pro Eye

BIKESIM EVALUATION & VALIDATION

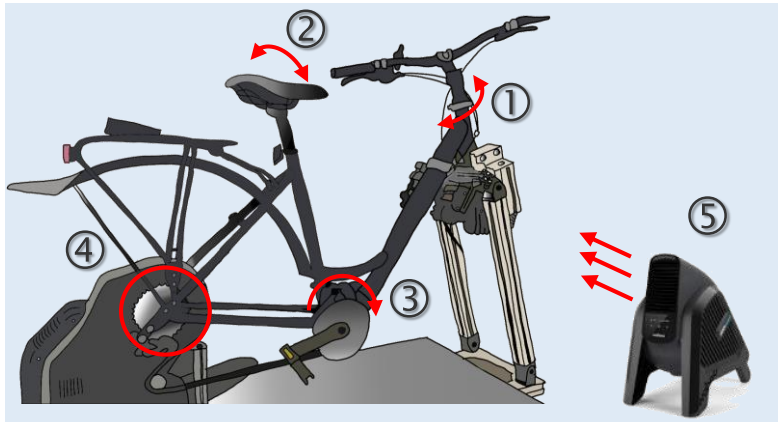


Bike Simulator Evaluation

Bike Eval 1

BikeSim V1.1 Profile B	BikeSim V1.1 Profile A

Bike Eval 2



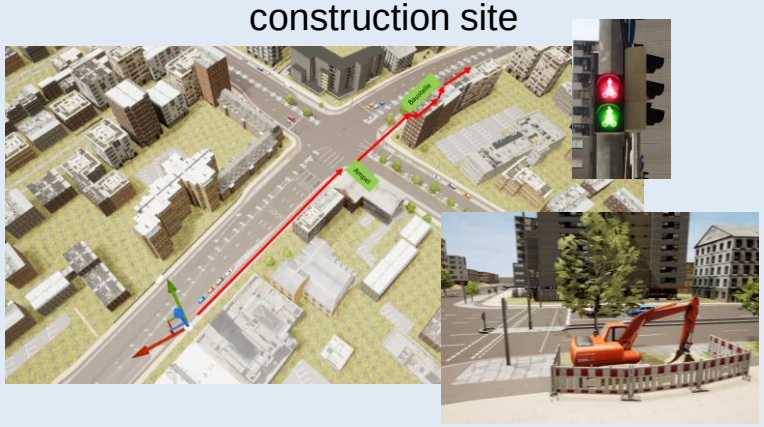
	Feature	BikeSim V1.1 Profile A	BikeSim V2.0 Adapted lateral and longitudinal dynamics (force feedback & haptics)
①	**Steer**	Steering force feedback based on look-up table with **adapted vehicle dynamics steering forces**	Steering force feedback based on **bike physics model**
②	**Lean**	**Force control**	**Position control** (model based approach)
③	**Accelerate**	**Force trainer**	**Speed sensor** rotary controller → high resolution, low latency
④	**Brake**	**Disc brake** at the flywheel **+ Force trainer information**	**Disc brake** at the flywheel **+ Speed sensor information**
⑤	**Headwind**	**Static** headwind	**Dynamic** headwind control based on driving speed

Bike Eval 1

Martinez Garcia, D., Gröne, K., Quante, L., Fischer, M., Thal, S. and Henze, R., 2022. Parameter tuning of a bicycle simulator for a realistic riding behaviour and motion perception, Proceedings of the Driving Simulation Conference 2022 Europe, Driving Simulation Association, Strasbourg, France

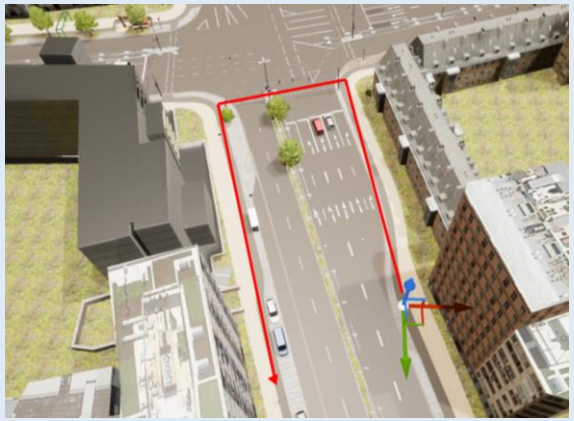
Szenarios

A – Stop at traffic light + drive around construction site

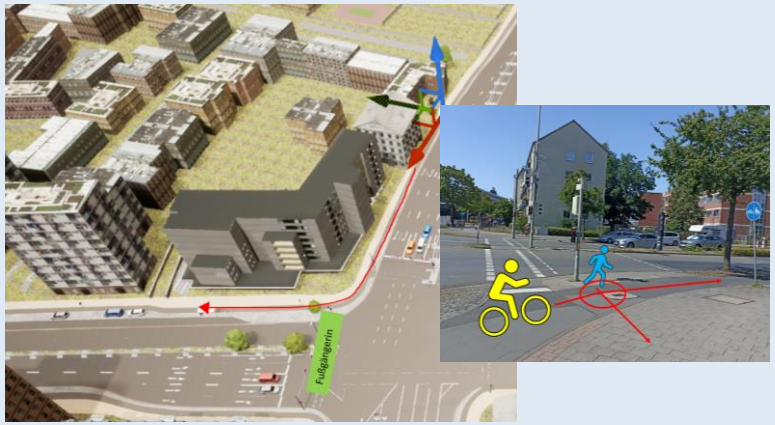


B – Slalom

C – 90° turns at intersection

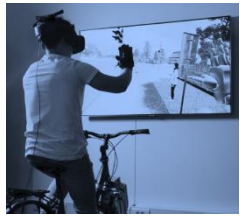


D – Interaction with pedestrian



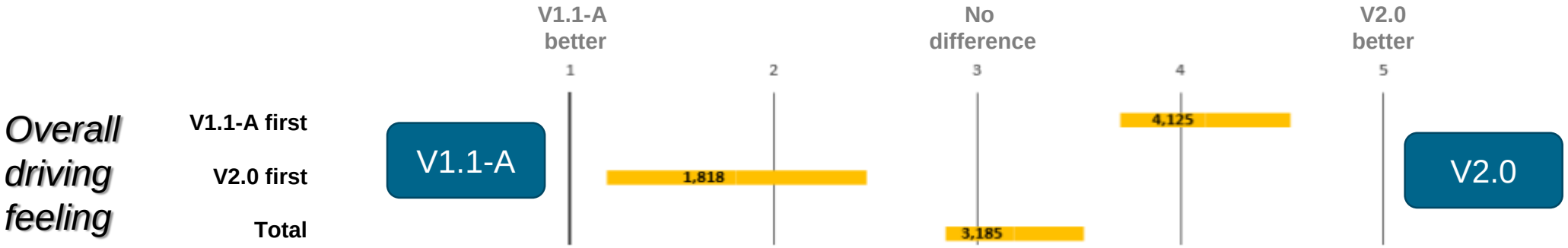
E – Overtaking an e-scooter

F – Turning head

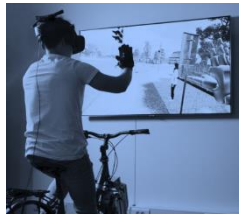


Results – Overall subjective feedback

- Overall feedback (at the end) more depending on order
  - 2nd was rated better

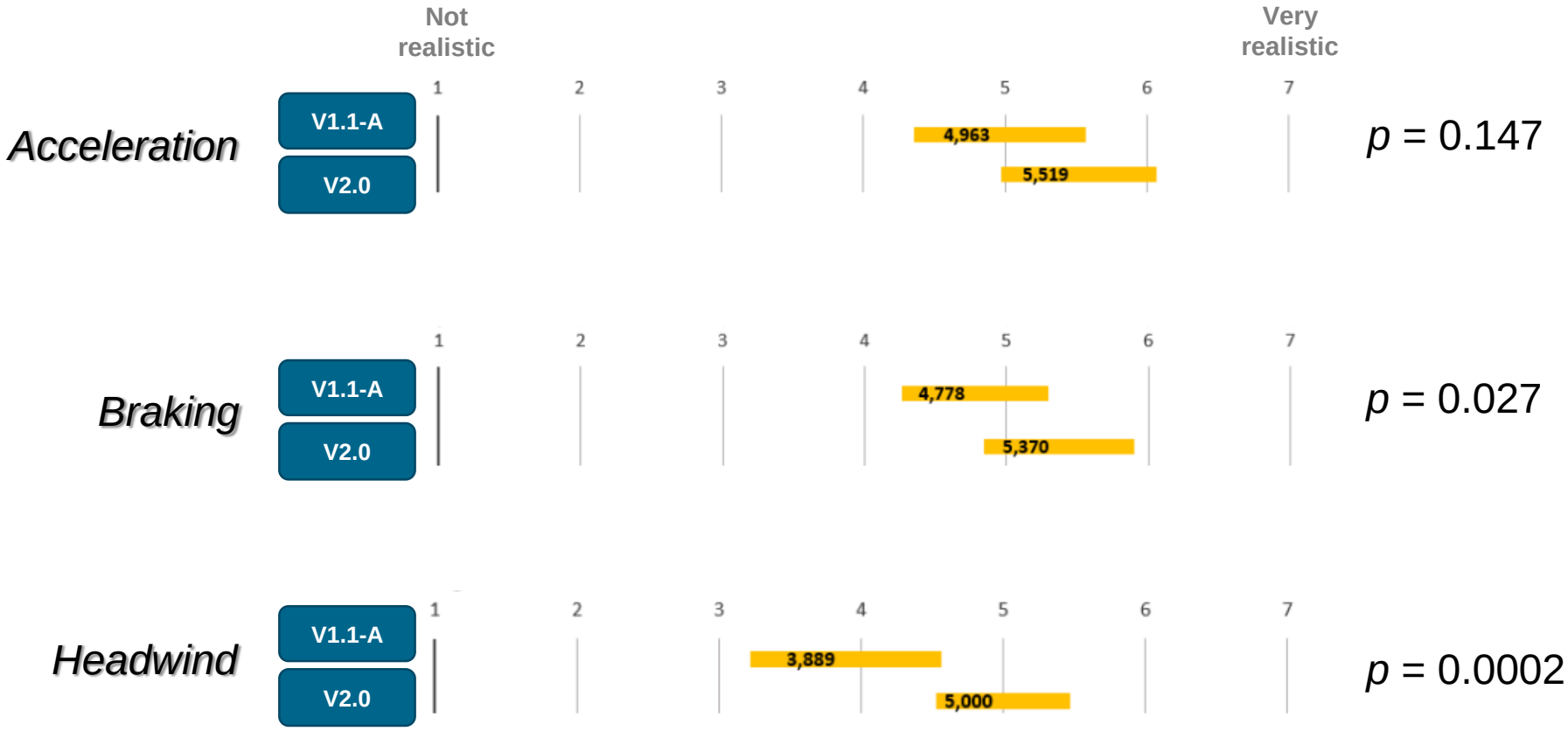


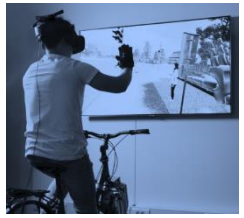
- Conclusion
  - Next study with „inbetween“ instead of „within“ study design
    → each person drives only one set-up



Results – longitudinal dynamics

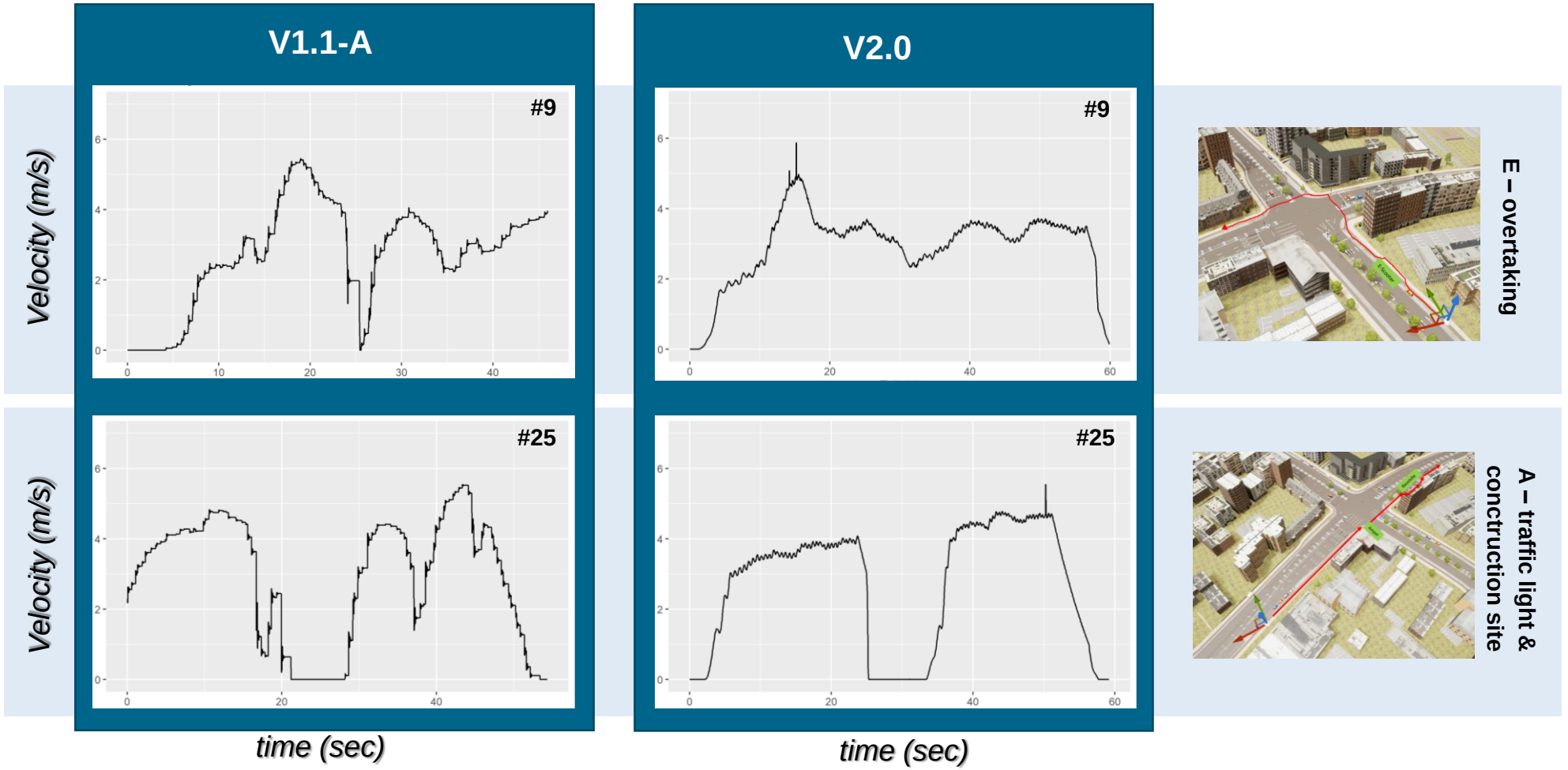
- Overall improvement of longitudinal dynamics was successful





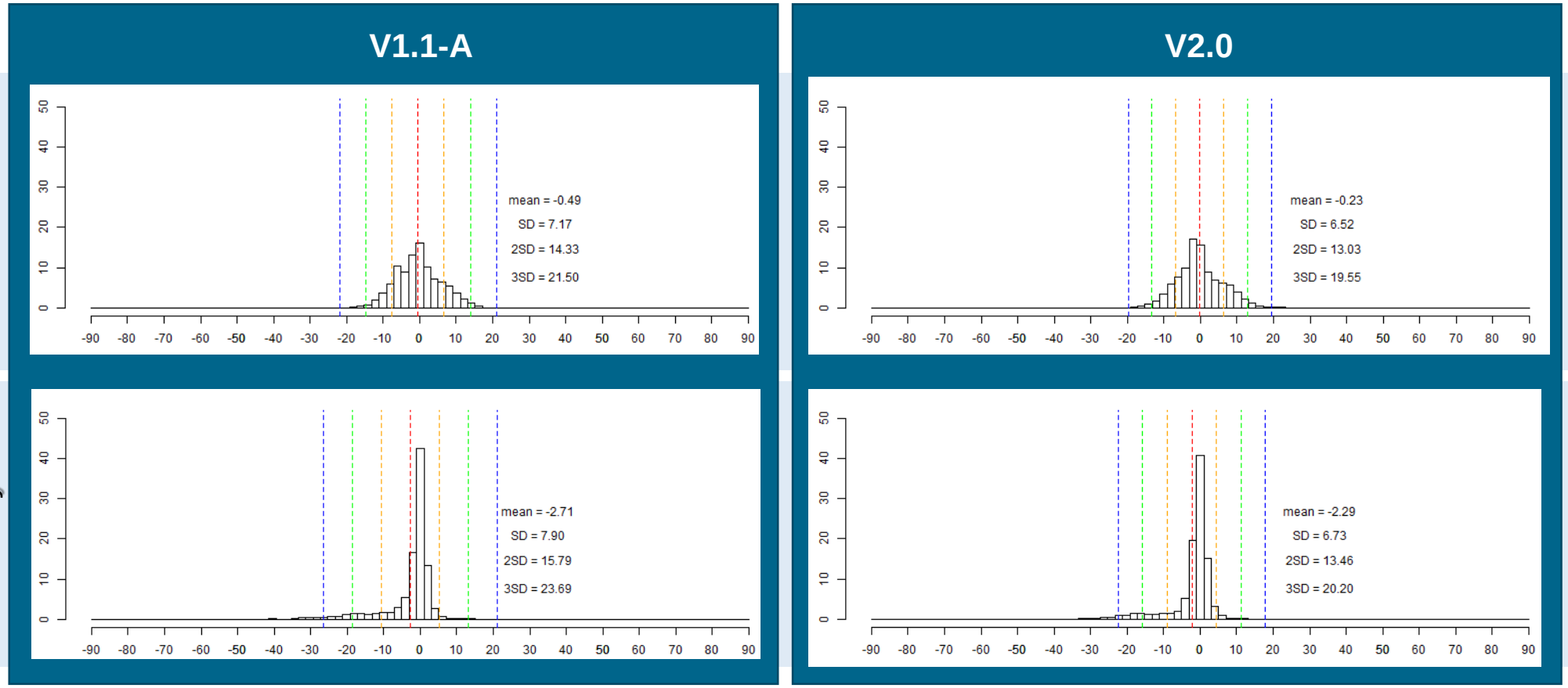
Results – Driving Velocity

- More steady velocity with V2.0

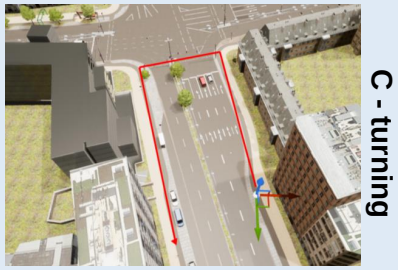


Results – Steering angle

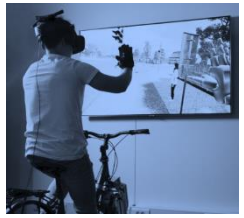
- Different force feedback does not seem to have an influence



B - slalom



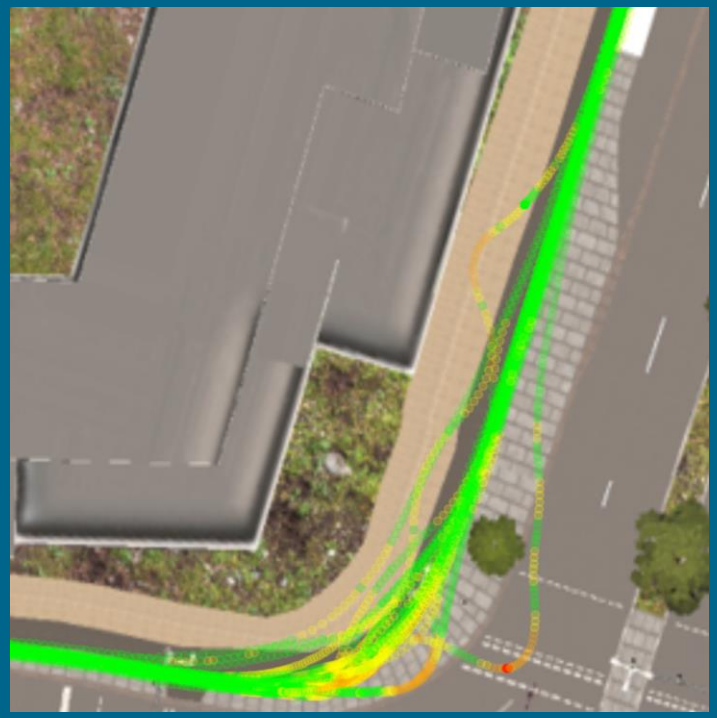
C - turning



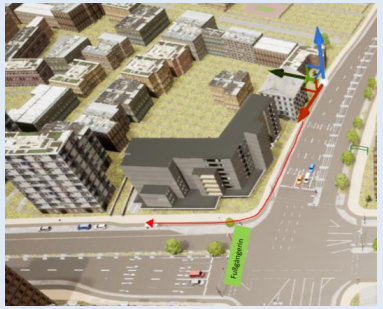
Results – Steering angle

- Some indication of better controlability with V 2.0

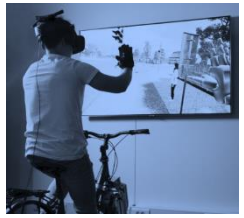
V1.1-A



V2.0

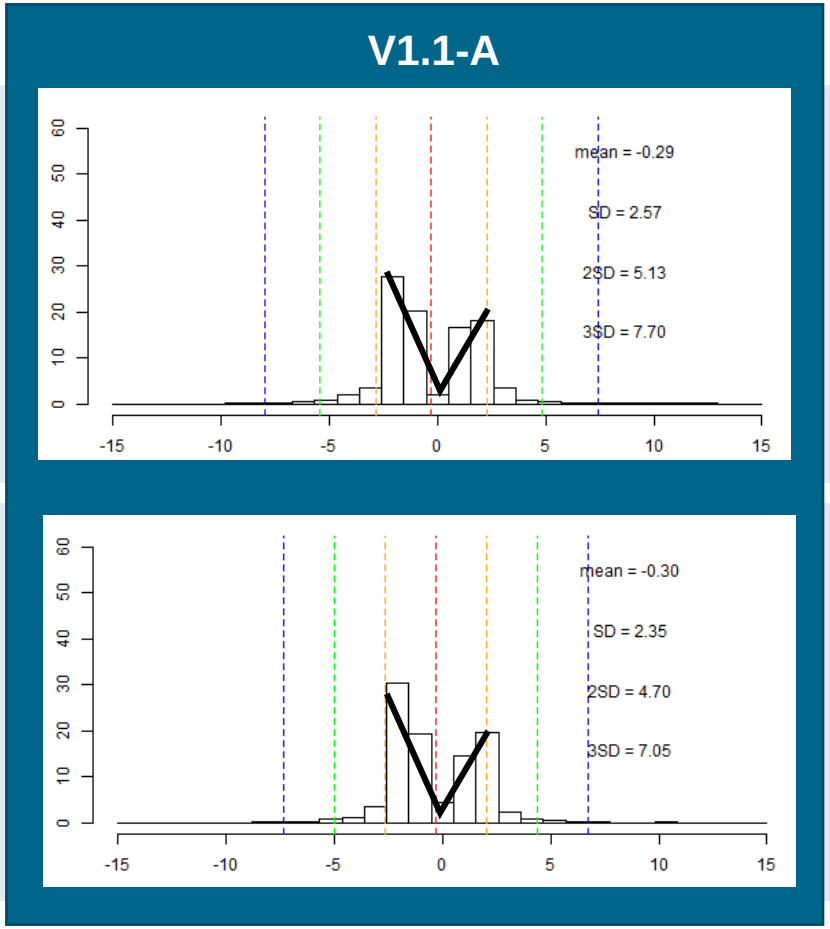


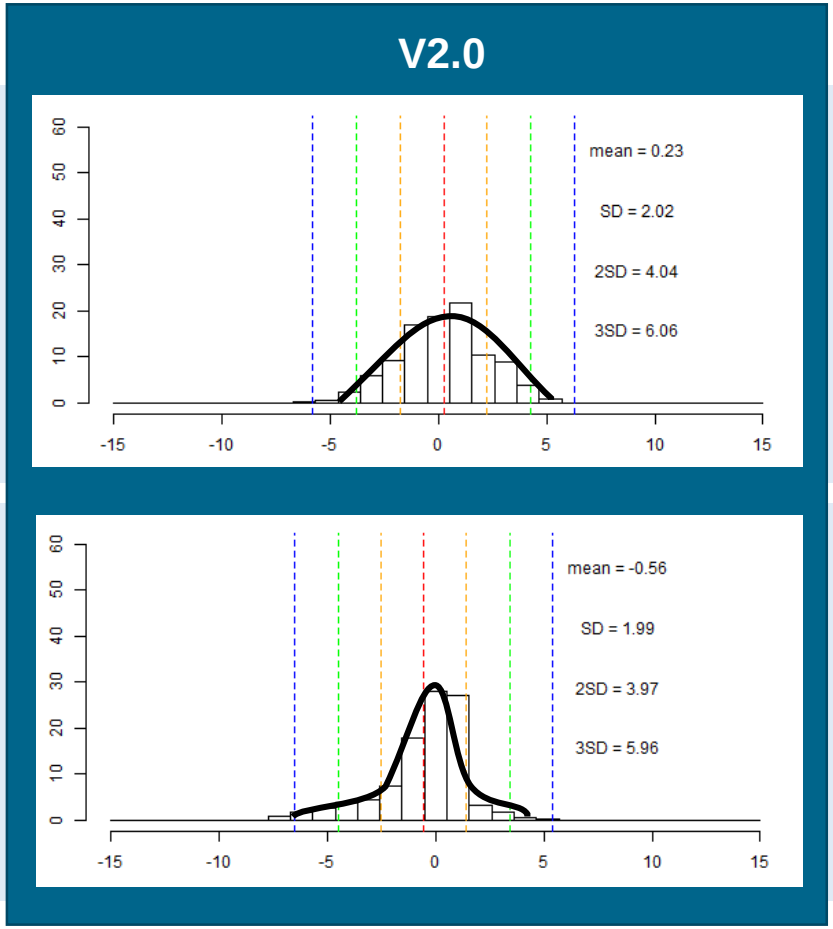
D - Interaction



Results – Lean angle

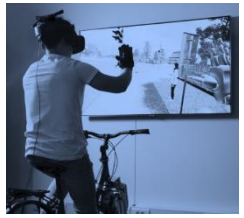
- Clear difference between profiles. More steady distribution with V2.0





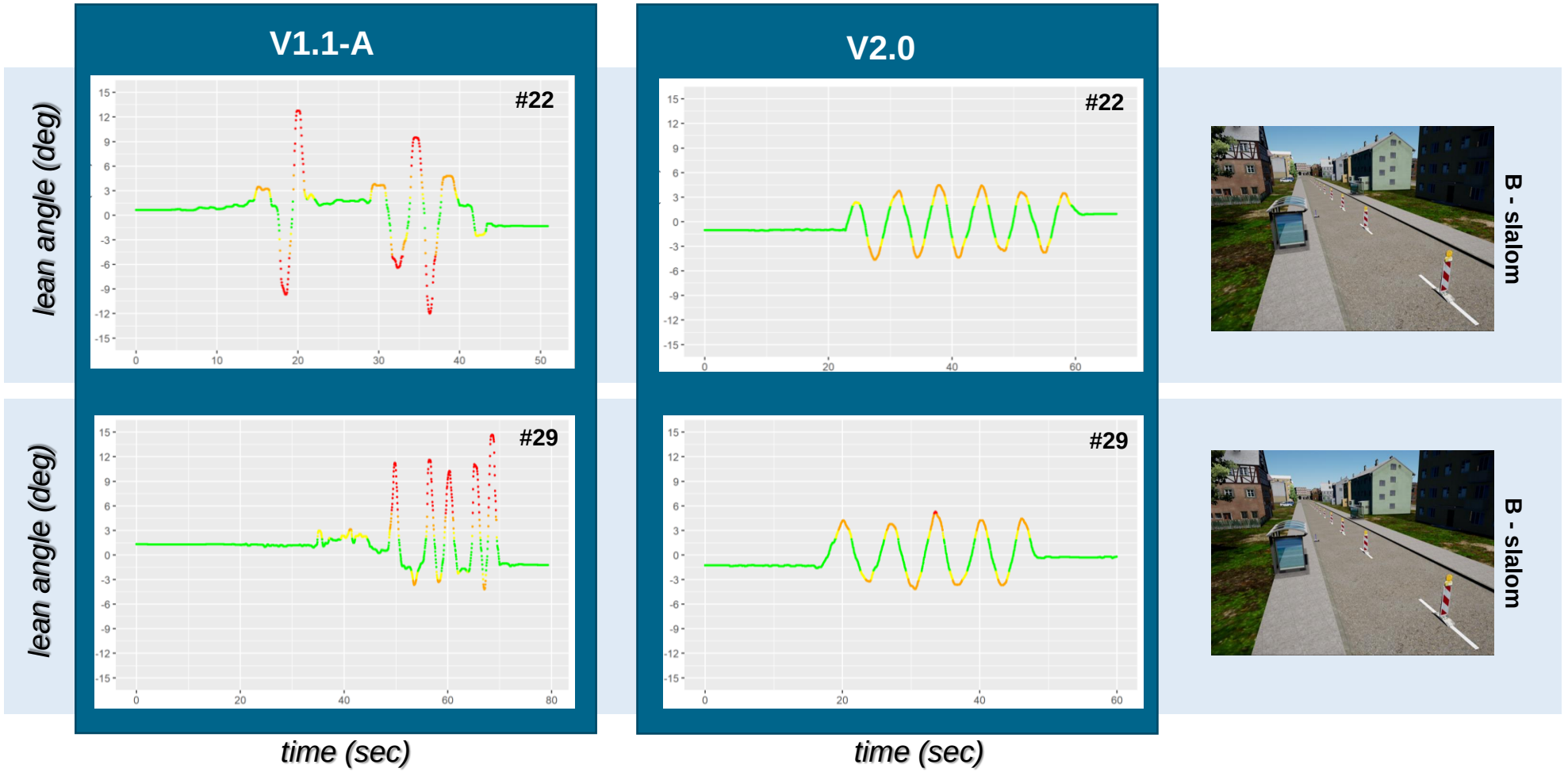
B - slalom

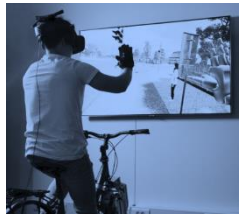
E – overtaking



Results – Lean angle

- More steady driving behaviour with V2.0



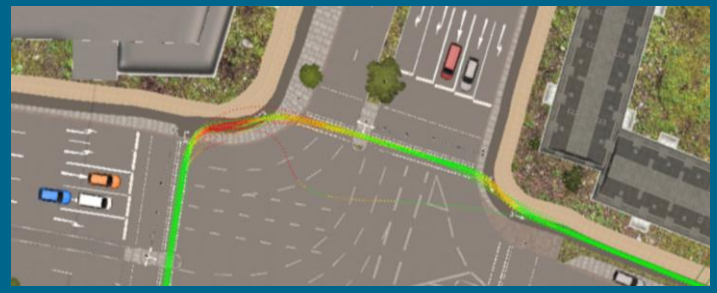


Results – Lean angle

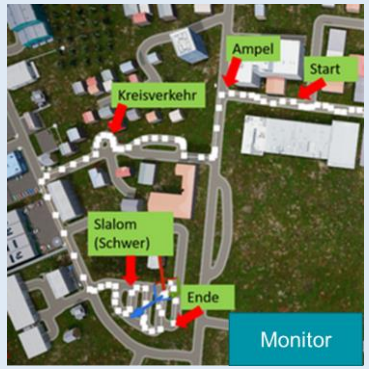
DLR

V1.1-A

V2.0



E – overtaking



Training 1

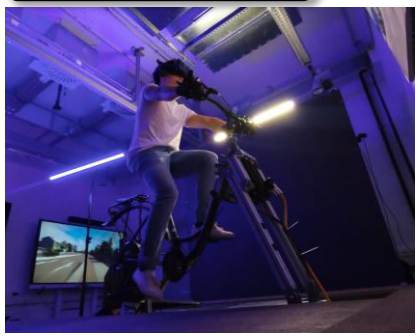
MUSEUM
MUSEUM
CITY TOUR
METRO
URBAN STREET CAFE
METRO
12 MAIN STATION

OUTLOOK

Bike Evaluation – Next Steps

- Validation
  - Real world bicycle driving at the AIM research intersection with the BoReal Bike „BoBBi“
  - Similar scenarios
  - Comparison of BikeEval 2 data to real world data
    - Lean angles
    - Steering angles
    - Velocities
    - Accelerations

Bike Eval 2



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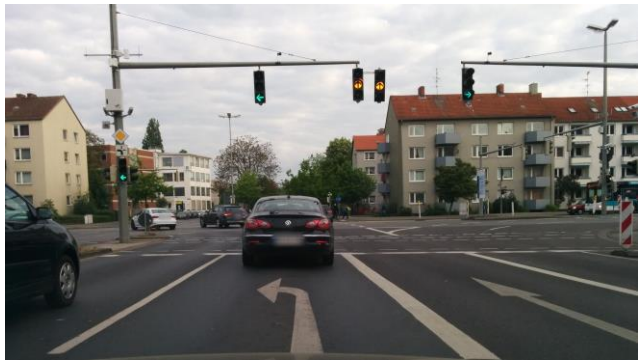


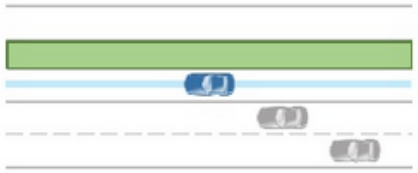
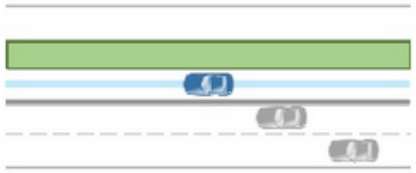
- Further Improvement of lateral dynamics

SPoRe – Speed Perception of Road Users

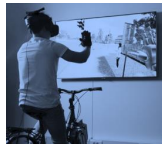
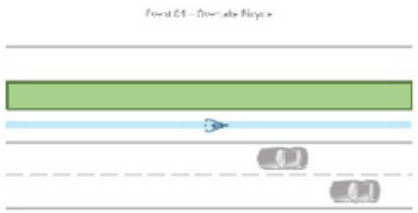
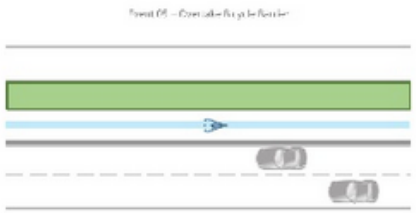
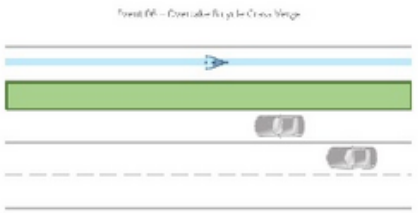
- Goal: Evaluate perceived vs. real speed

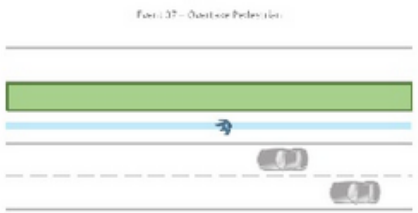
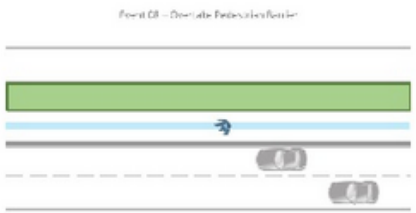
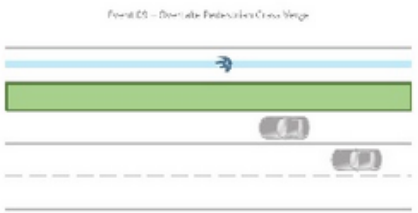
Separation

line | *massive barrier* | *grass strip*

vs.

Study „VALHaLa“ ongoing

Goals

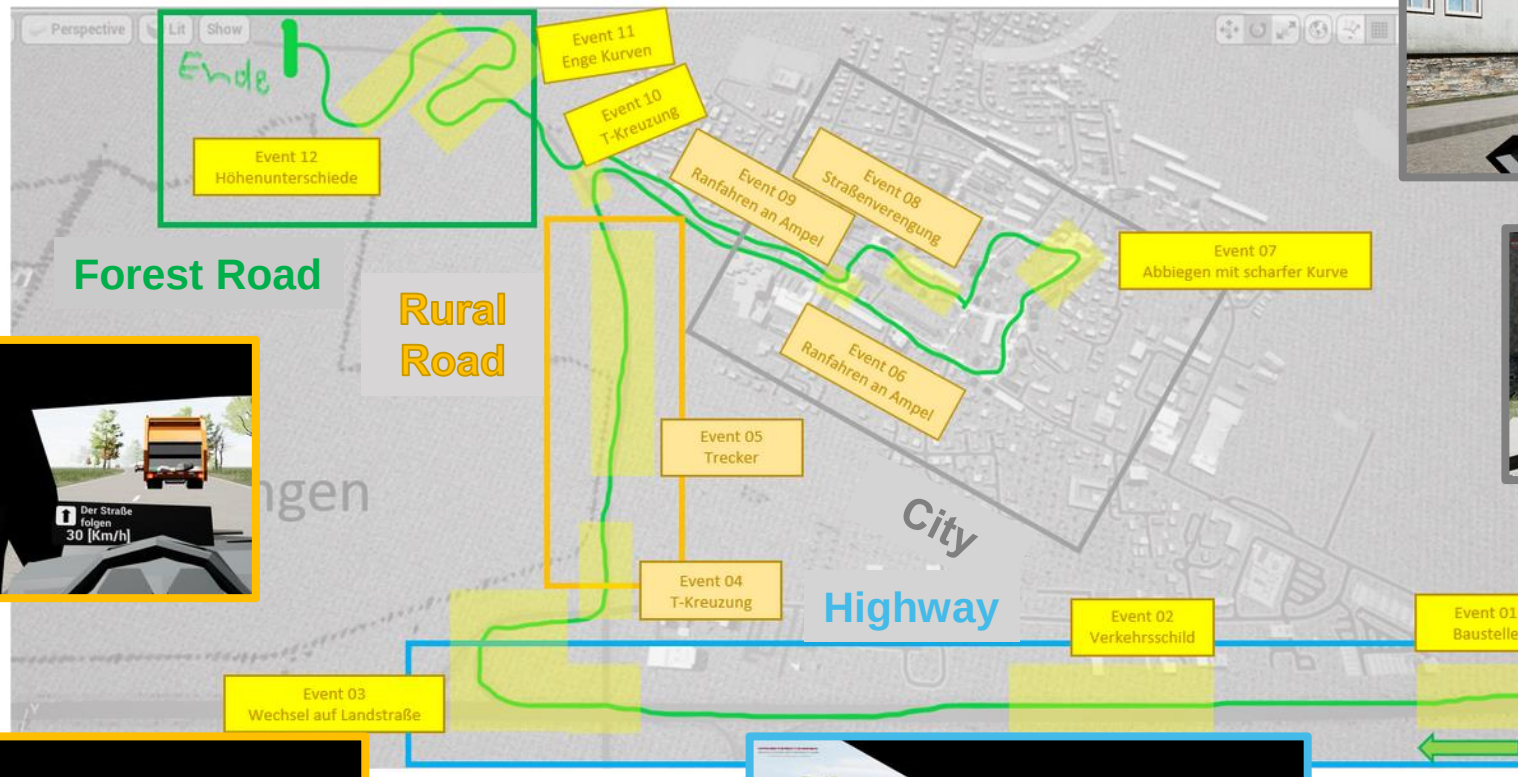
- Investigation of **influence of** the **display form** (monitor vs VR glasses) used on driving behavior in the simulator
- In particular, the influence on **simulator sickness, presence and objective driving data** shall be analysed

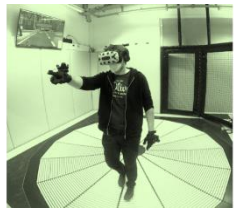
HTC Vive Pro Eye

XTAL 8K

Triple Display set-up

Study „VALHaLa“





Study „Coala“ (planned for 2023)

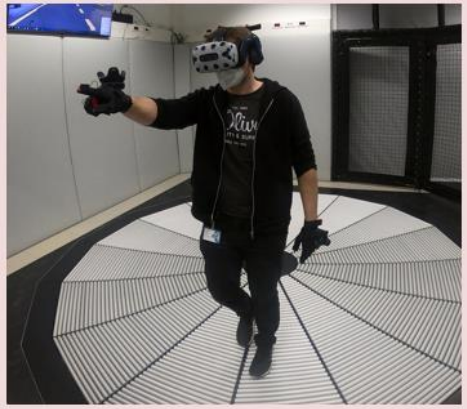
Means of Virtual Walking

Controller

Cyber Shoes

Walk in place

Treadmill



Free walking

Metrics

Quelle: pngwing.com

Simulation Sickness

Performance

Quelle: pngwing.com

Presence

Thank you for
your attention!
DLR
50
QUESTIONS?
ma.fischer@dlr.de