ETH zürich

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Institut für Werkzeugmaschinen und Fertigung
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icvr
innovation center virtual reality

Impact of Limited Field of View on Human Behaviour in Virtual Reality

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Semester Project
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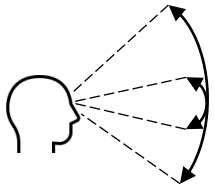
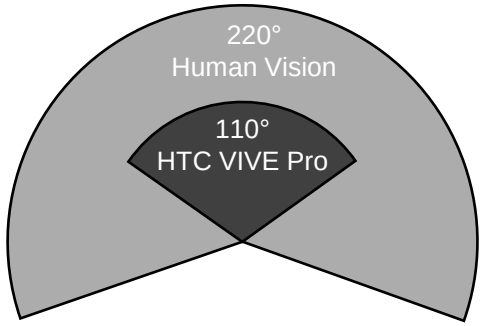
Table of Contents/Agenda

Introduction

Human Field of View (FoV): 200° - 220° *horizontal* [1]

135° *vertical* [1]

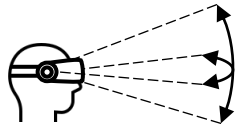


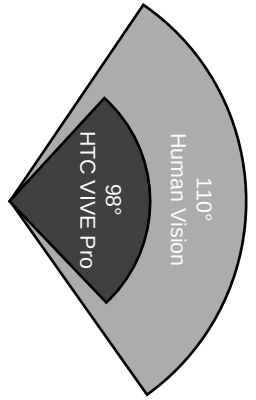


Horizontal FoV comparison

HTC VIVE Pro Head Mounted Display (HMD) Field of View (FoV): 110° *horizontal* [2]

98° *vertical* [2]





Vertical FoV comparison

[1]: Traquair, Harry Moss, 1938. *An Introduction to Clinical Perimetry.* Henry Kimpton.
[2]: Rory Brown, 2019. *HTC VIVE Pro Eye*. VR-Compare.com.

Related Work

State of the Art FoV Research

- Effects of limited FoV on user behaviour in general:
  - Passing obstacle courses with limited FoV leads to slower pace and more head movements [1][2][3][4]
  - Restricted FoV in search task affects performance negatively in ***either*** reality ***or*** VR [5][6][7]
  - FoV restrictions affects balance negatively in VR [8]

- Research of FoV in VR focused on effects regarding VR sickness
  - Artifically limit FoV to combat VR sickness [9]

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[1]: Toet et al., 2008. *Locomotion Through a Complex Environment With Limited Field-of-View.* Perceptual Motor Skills
[2]: Toet et al., 2008. *Effects of field-of-view restriction on manoeuvring in a 3-D environment.* Ergonomics.
[3]: Jansen et al., 2011. *Human locomotion through a multiple obstacle environment: strategy changes as a result of visual field limitation.* Experimental Brain Research.
[4]: Jansen et al., 2010. *Obstacle Crossing With Lower Visual Field Restriction: Shifts in Strategy.* Journal of Motor Behavior.
[5]: Ragan et al., 2015. *Effects of Field of View and Visual Complexity on Virtual Reality Training Effectiveness for a Visual Scanning Task.* IEEE.
[6]: Grinyer et al., 2022. *Effects of Field of View on Dynamic Out-of-View Target Search in Virtual Reality.* IEEE.
[7]: Polys et al., 2006. *Effects of Information Layout, Screen Size, and Field of View on User Performance in Information-Rich Virtual Environments*. Computer Animations & Virtual Worlds.
[8]: Been-Lirn Duh et al., 2001. *Effects of Field of View on Balance in an Immersive Environment*. IEEE.
[9]: Adhanom et al., 2020. *The Effect of a Foveated Field-of-view Restrictor on VR Sickness*. IEEE.

Related Work

State of the Art & Goal of the project

- Trajectory and movement comparisons between reality and VR (in rehabilitation reserach):
  - Reaching [1]
  - Walking [2]
  - Reach to Grasp & Transport (Device Assembly) [3]

- Comparison of Visual Search between Physical Environments and VR [4]

⟶ Only limited research on comparing user behaviour in reality and VR with regards to limited FoV

Goal: Compare user behaviour in reality and VR given restricted FoV with regards to head movement trajectories and speed in a user study

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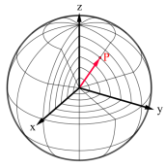
[1]: Viau et al., 2004. *Reaching in reality and virtual reality: a comparison of movement kinematics in healthy subjects and in adults with hemiparesis.* Journal of NeuroEngineering and Rehabilitation.
[2]: Cirio et al. 2013. *Kinematic Evaluation of Virtual Walking Trajectories***.** IEEE.
[3]: Arlati et al. 2022. *Kinematics of aimed movements in ecological immersive virtual reality: a comparative study with real world.* Virtual Reality.
[4]: Van den Oever et al., 2022. *Comparing Visual Search between Physical Environments and VR.* ISMAR.

Methods

Test Conditions

Reality	Reality with restricted FoV	Virtual Reality
Normal FoV (220° h, 110° v)	Limited FoV (110° h, 98° v)	Limited FoV (110° h, 98° v)

Tracking & Data Collection



Head Trajectory Tracking

Using Unity tracker script: Location and orientation

Angular Rotation & -Velocity

Derived from orientation change over time

Time to target

Identify movements ($V_a > 5\ \frac{deg}{s}$) and use Unity tracker script timer

Questionnaire:

Demographics, task load, cognitive absorption, simulation sickness, sense of presence

Methods

Tracking in Reality

Goal: Track user’s head trajectories & restrict the user’s FoV in reality

Methods

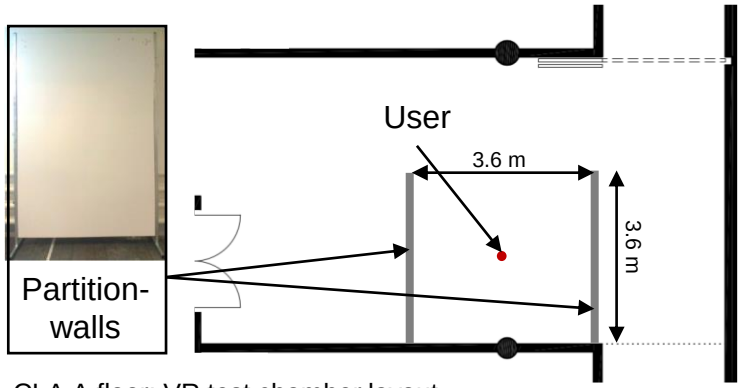
User Study Design

Test conditions:

Used Devices:

Methods

User Study Design



CLA A floor: VR test chamber layout

Rendering of virtual CLA A floor test chamber

Methods

User Study Design: Guided Task

Initial position:

User is standing on a marked spot inside a square room

Focus Target Design:

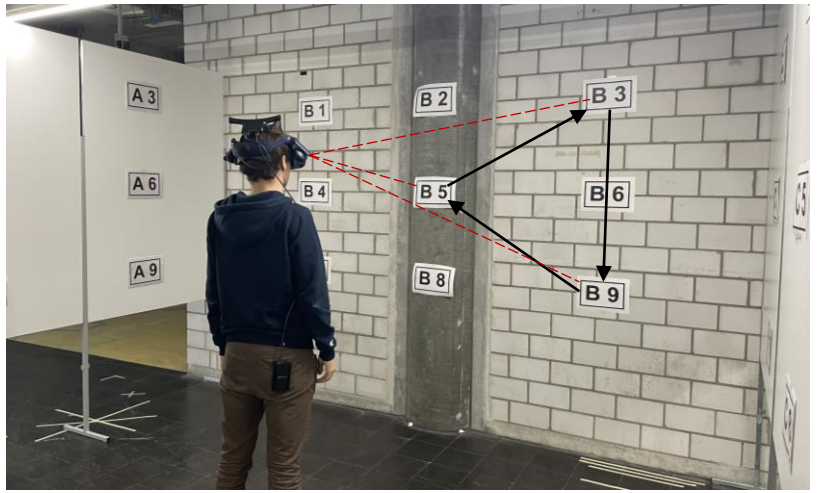
Square Cards designated with a letter-number combination, logically ordered and numbered in 3x3 pattern.

Task:

User is tasked to look at the card with the letter-number combination given by the test conductor

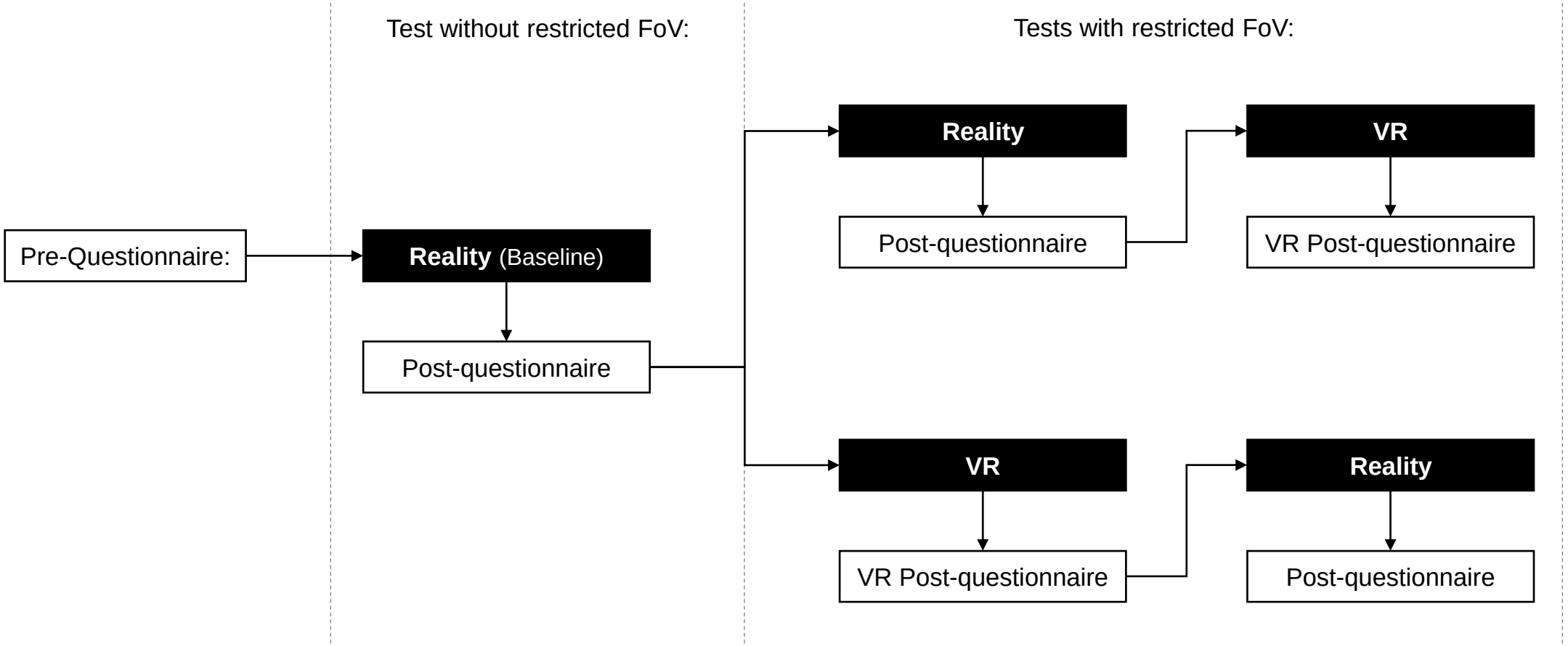
Goal:

Trigger and track comparable head movements



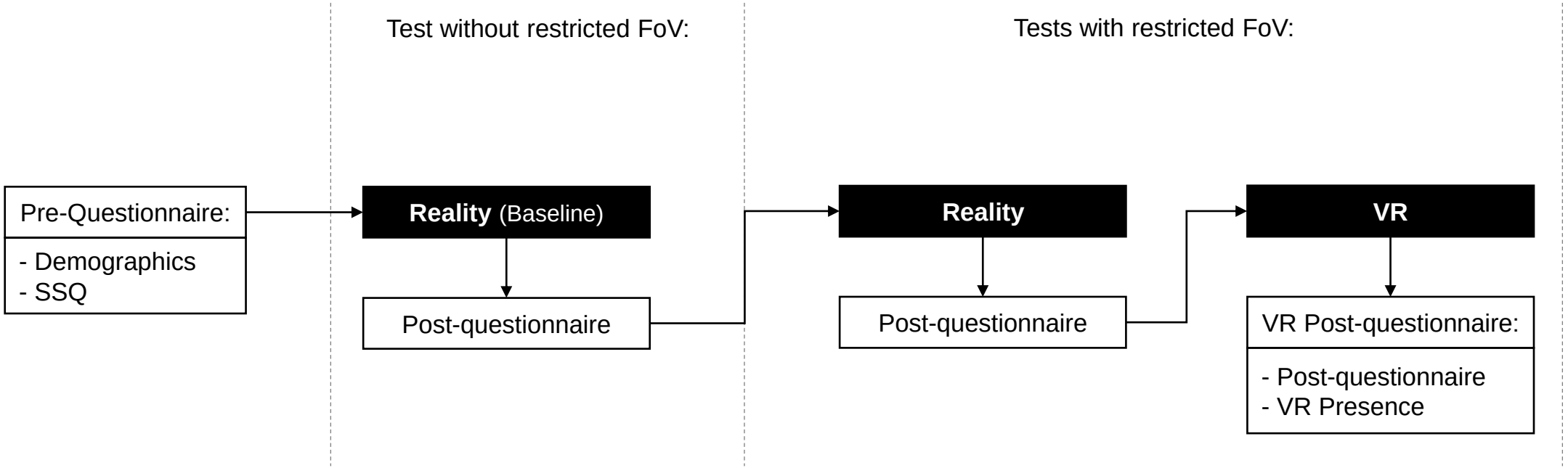
Methods

User Study Procedure



Methods

User Study Procedure



Test sub-tasks:

1. Environment Familiarisation
2. Calibration
3. Guided task

Post-questionnaire:

1. SIM-TLX Questionnaire
2. SSQ
3. Cognitive Absorption

Methods

User Study

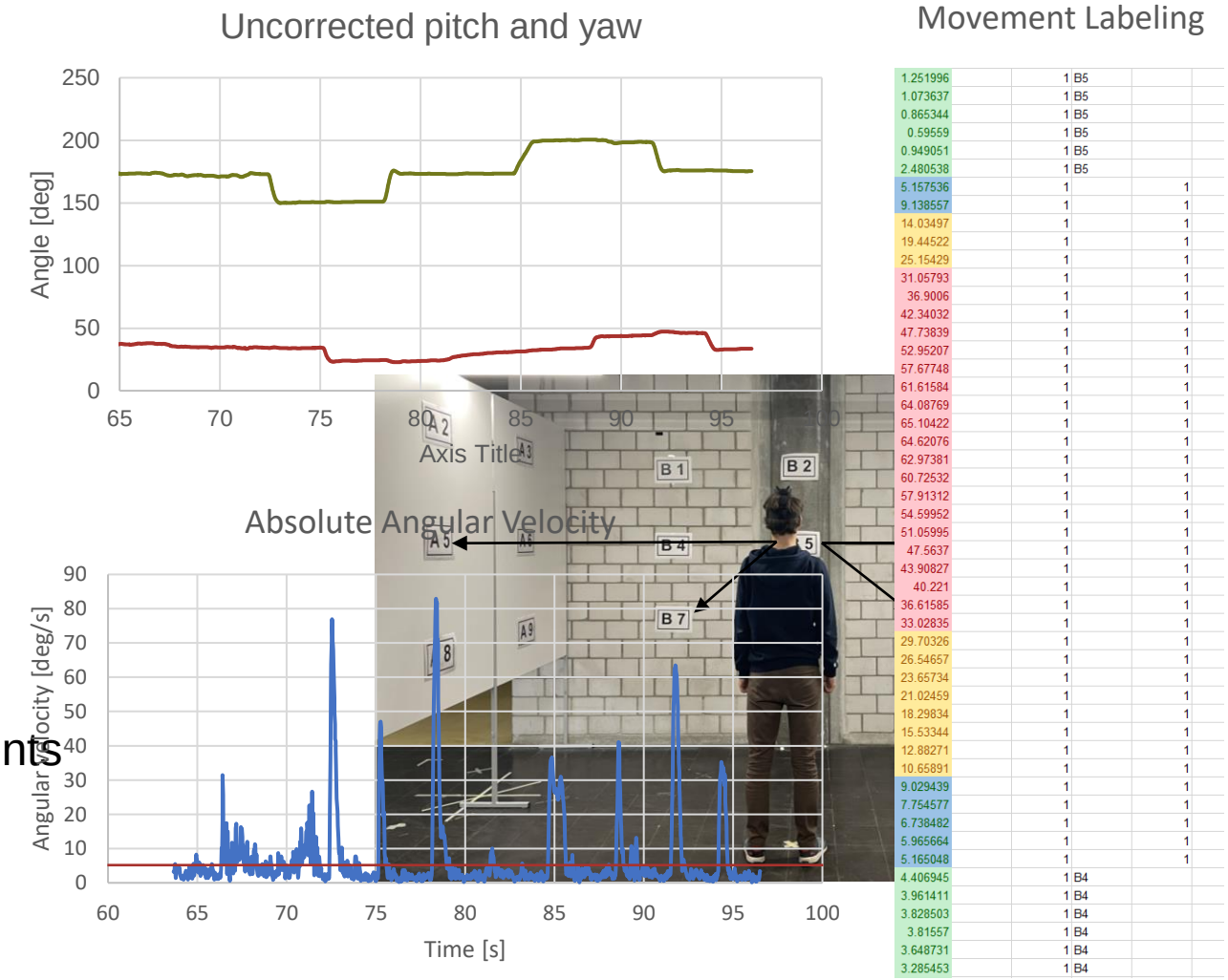
- 31 participants
  - Average age: 24
  - 13 females, 18 males
  - Mostly students

- Captured data:
  - 93 data sets
  - 689’976 lines of trajectory data
  - 28’289’016 individual data points

Methods

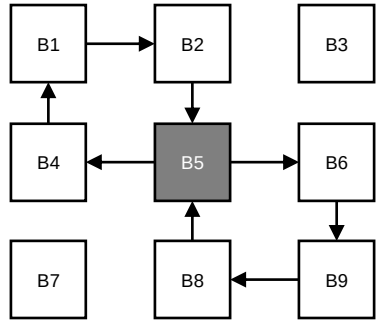
Data Tidying & Analysis

- Data Transformation
  - Data is transformed from quaternions
  - Spherical coordinates and velocity
- Data Labelling
  - Identification of movement
  - Manual labelling of movements
- Data Tidying
  - Filtering of data for the selected movements
    - B5 -> B6, B5 -> B7/B9, B5 -> A5/C5



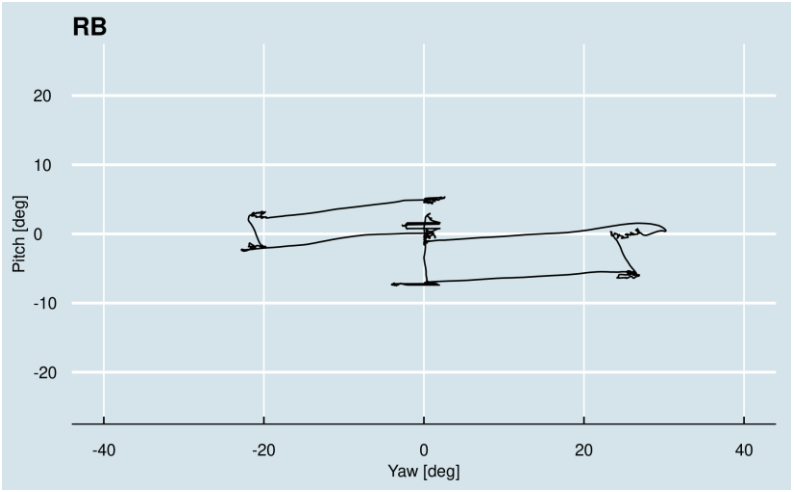
Results

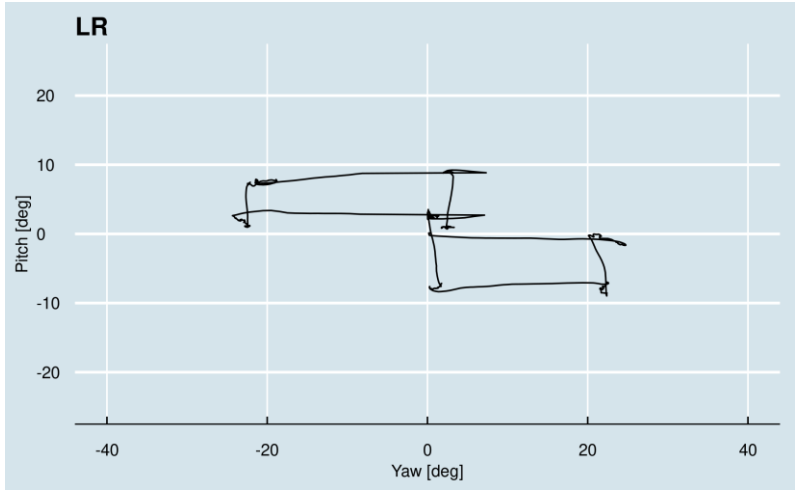
Head Trajectories

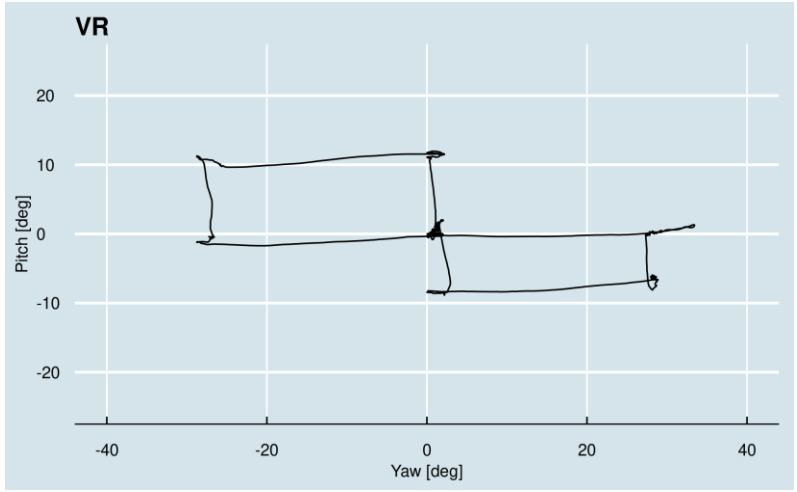


Looking order:

B5 → B6 → B9 → B8 → B5 → B4 → B1 → B2 → B5

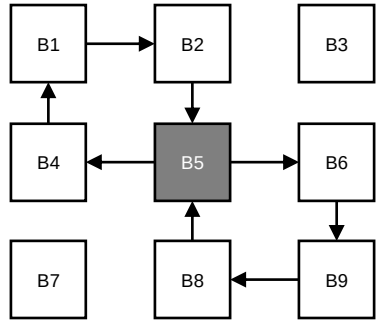


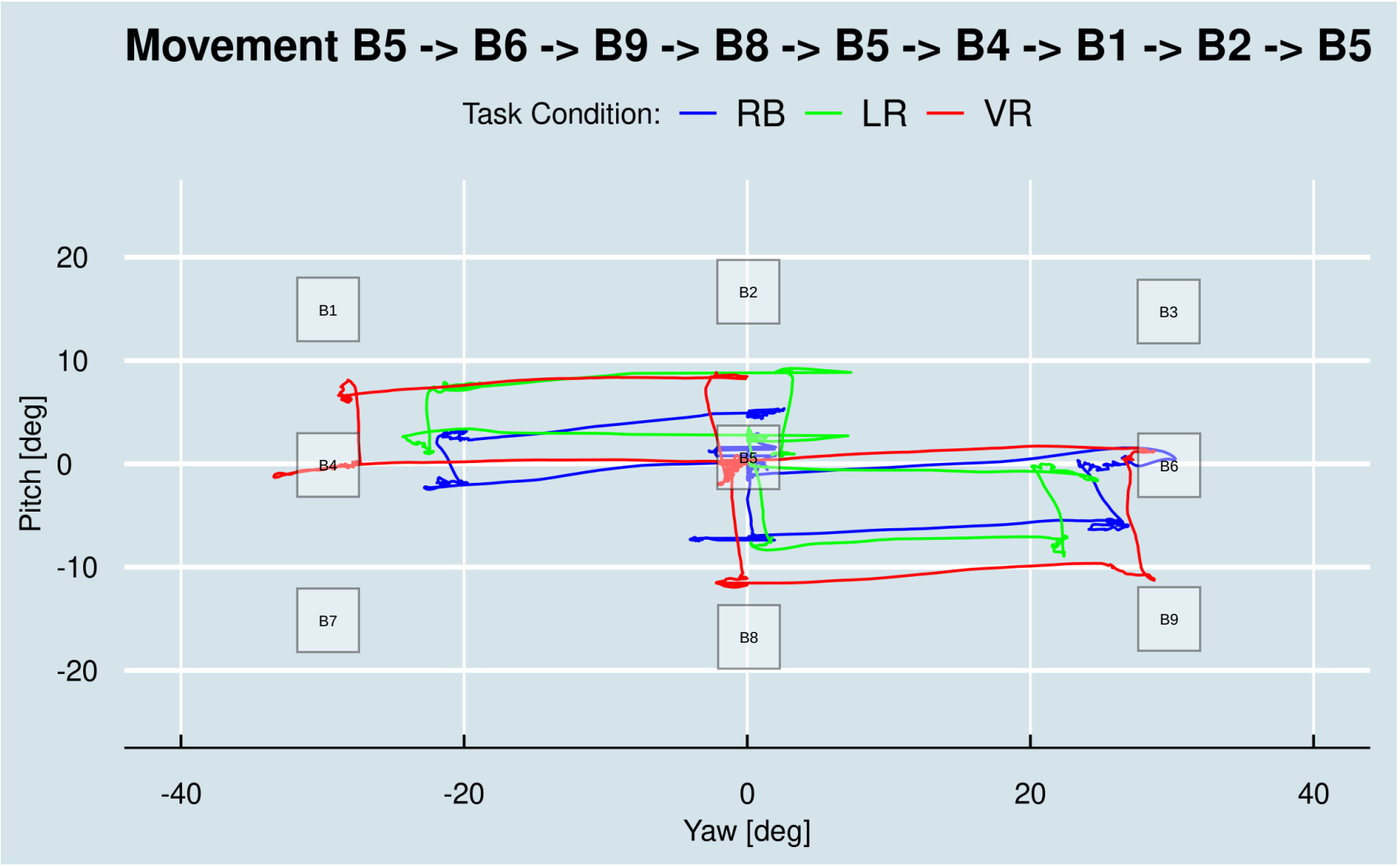




Results

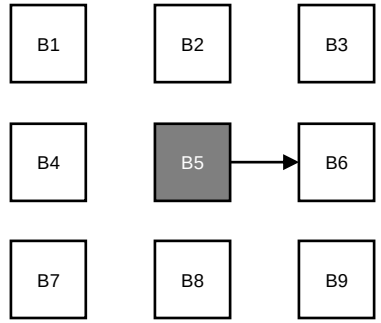
Head Trajectories



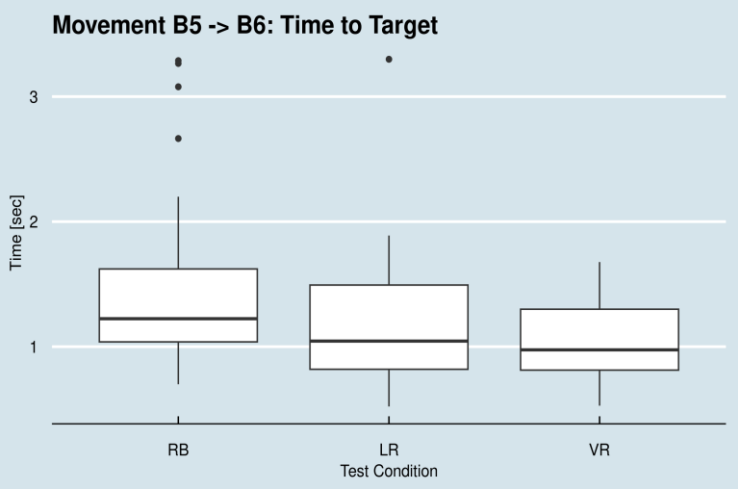


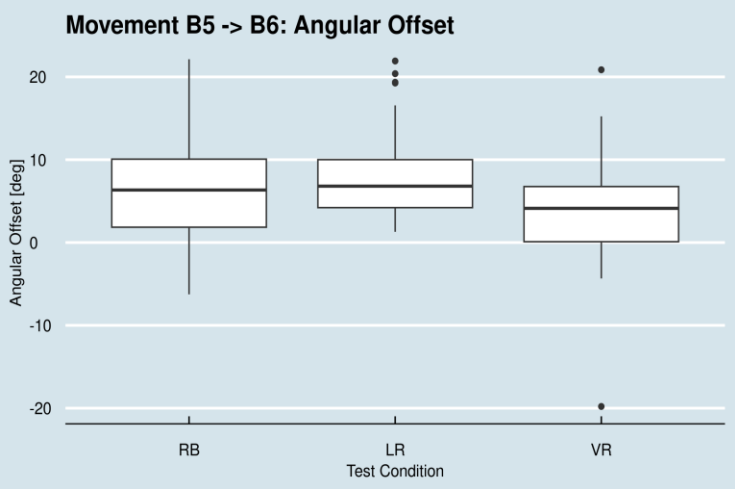
Results

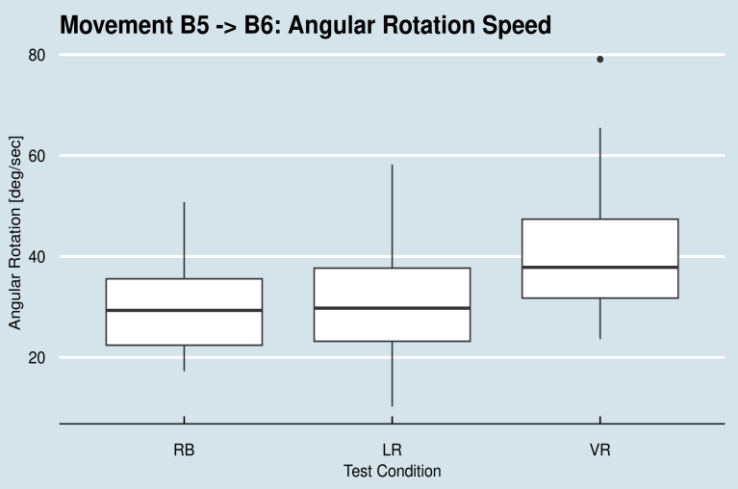
Movement B5 -> B6



Test Condition	RB	ΔRB.LR	LR	ΔLR.VR	VR	ΔRB.VR
Mean Time to Target [sec]	1.481	0.295	1.187	0.128	1.058	0.423
Mean Angular Offset [deg]	6.307	-2.072	8.385	4.842	3.961	2.77
Mean Angular Rotation Speed [deg/sec]	29.916	-1.18	30.678	-10.472	40.516	-9.292

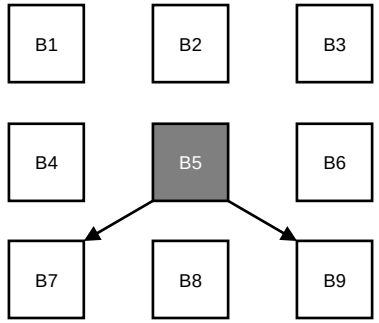




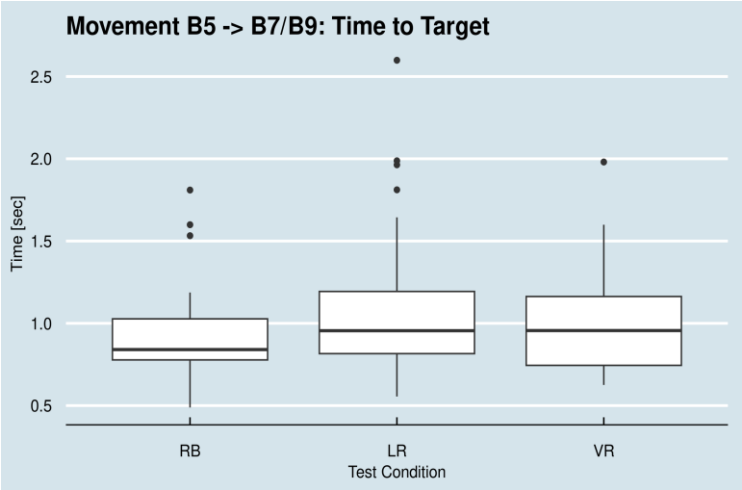


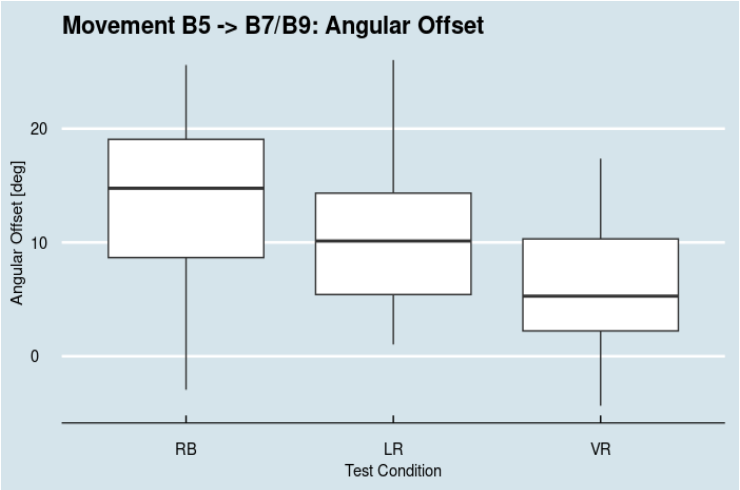
Results

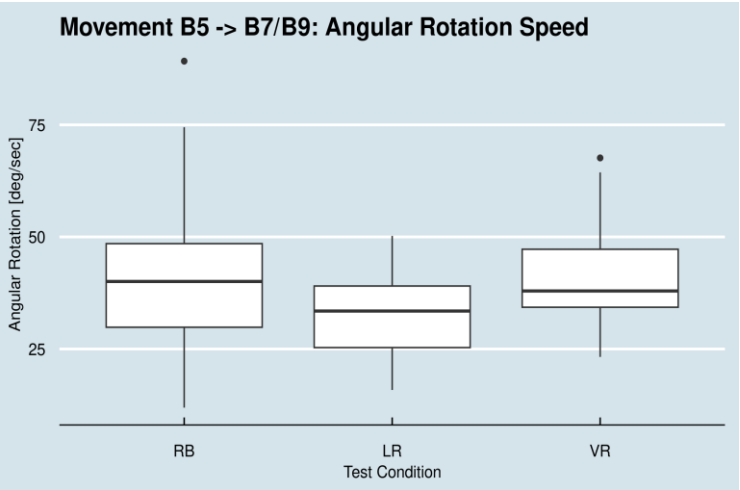
Movement B5 -> B7/B9



Test Condition	RB	ΔRB.LR	LR	ΔLR.VR	VR	ΔRB.VR
Mean Time to Target [sec]	0.927	-0.174	1.088	-0.075	0.993	0.098
Mean Angular Offset [deg]	13.536	2.937	10.758	8.882	5.926	5.946
Mean Angular Rotation Speed [deg/sec]	33.994	6.962	33.095	-1.162	40.763	-8.124

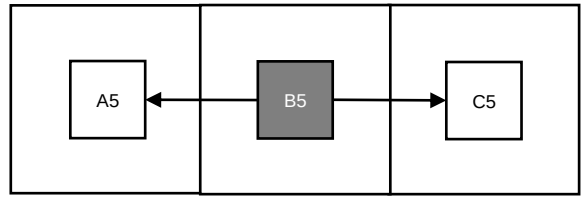




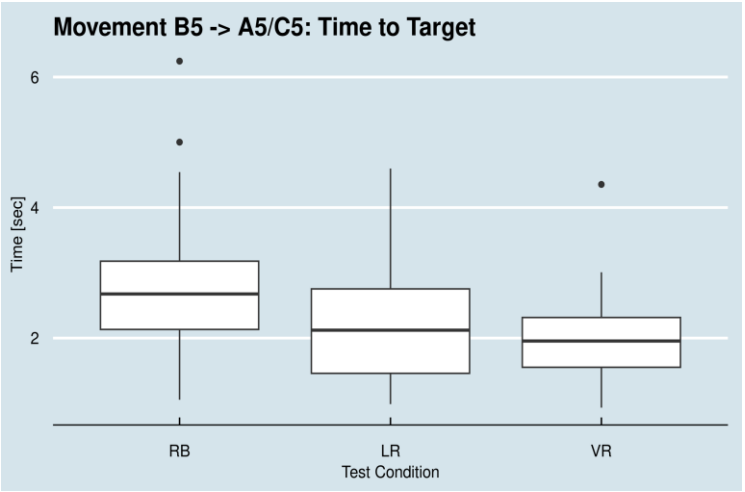


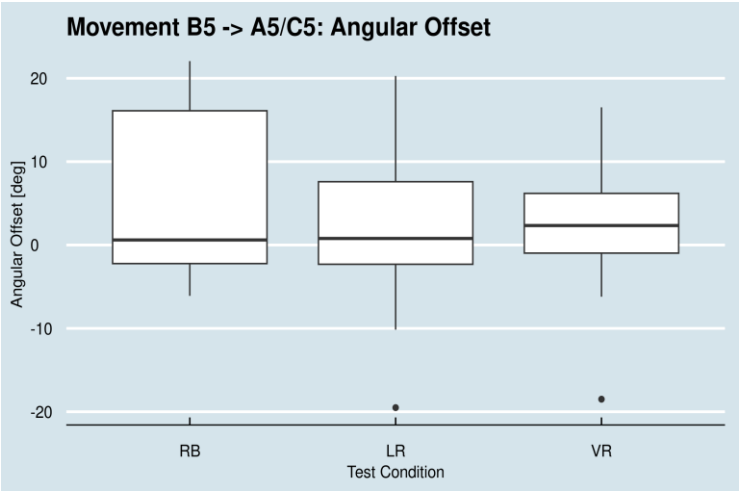
Results

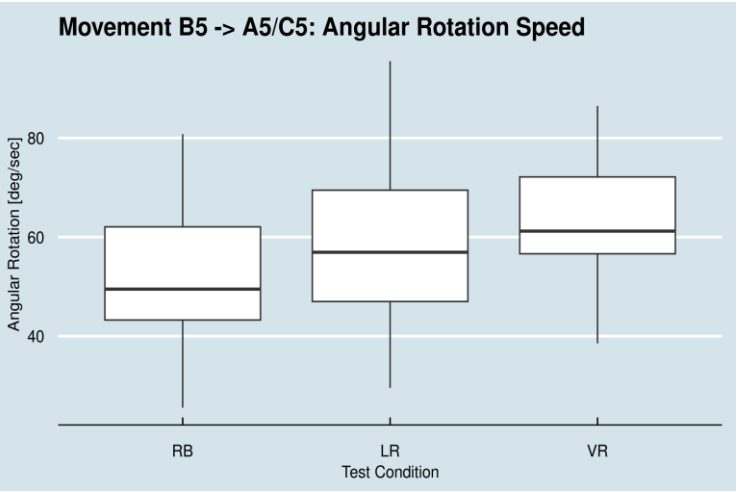
Movement B5 -> A5/C5



Test Condition	RB	ΔRB.LR	LR	ΔLR.VR	VR	ΔRB.VR
Time to Target [sec]	2.818	0.582	2.235	0.204	2.031	0.787
Angular Offset [deg]	5.308	3.2	2.519	0.957	2.517	4.157
Angular Rotation Speed [deg/sec]	52.017	-7.321	59.919	-3.286	63.136	-10.608

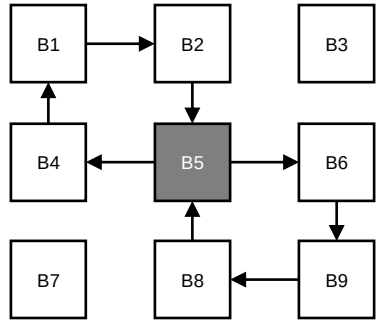


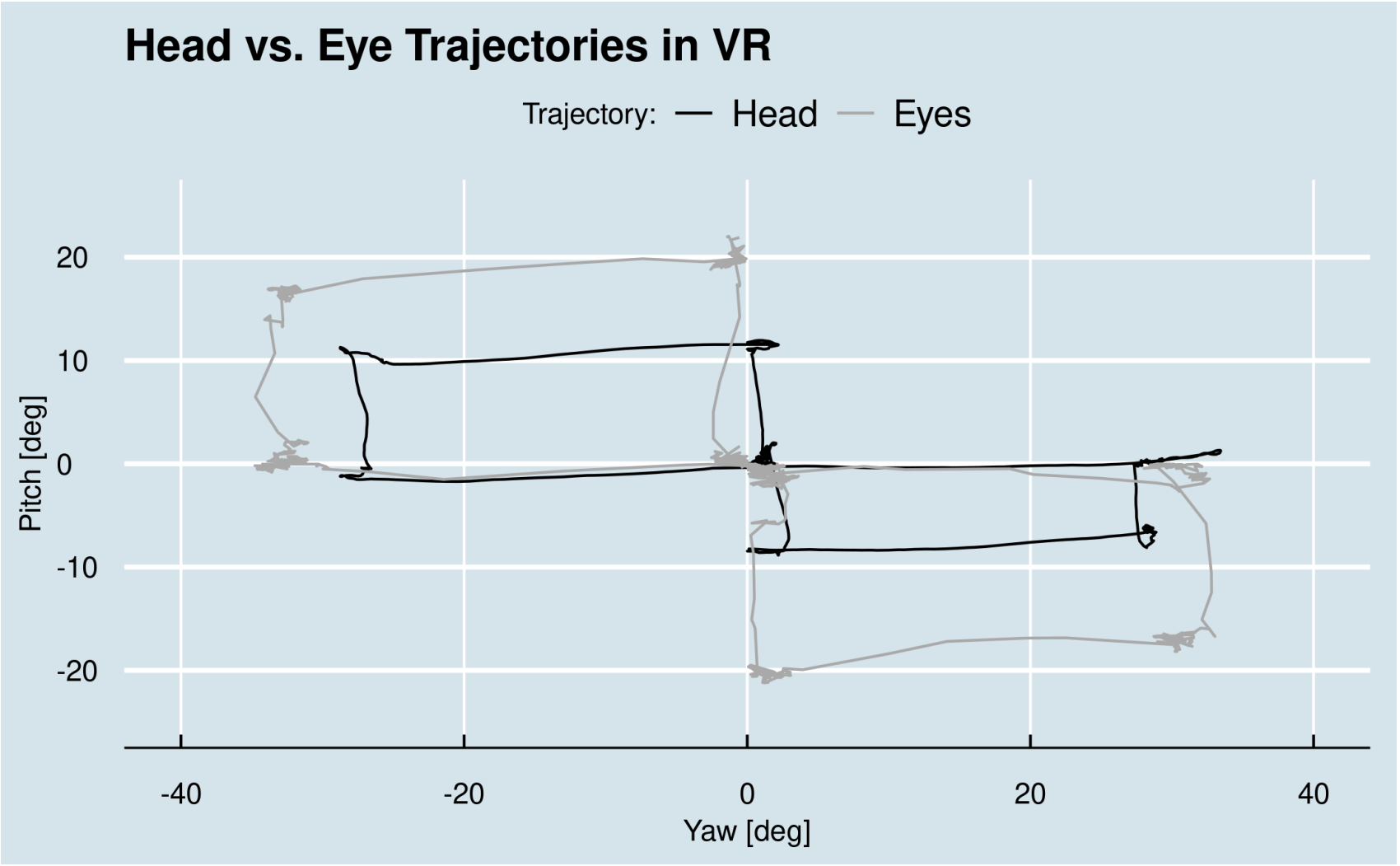




Results

Head and Eye Trajectories





Discussion

Limitations

- System limitations:
  - Recorded orientation sometimes unreliable (possible interference of partition walls)
  - Random change of coordinate systems of VIVE Tracker
  - Tracking Script Design:
    - Quaternions / Euler Angles and not vectors were recorded
    - Manual calibration and labelling of movements in data analysis
  - Some recorded data returns values after analysis which do not make sense
- Head movements are very individual and difficult to identify, categorise and measure.
  - Head movements are connected to eye movements

Conclusion

- Head movements are highly individual and can differ greatly
  - Difference between individual users higher compared to differences between RB, LR and VR
- Head trajectory nearly always offset short of target point
  - Head movements are linked to eye movements
  - Slightly more offset & more compensated with eye movements in reality compared to VR
- Angular offset higher in reality compared to VR
  - Lower after movement to target outside of FoV
- Given limitations, difficult to draw definitive conclusion

Outlook

- Analysis of eye trajectories and head trajectories in combination
  - Eye tracking recorded only VR, but not analysed
  - Eye trajectories and head trajectories in relation

- Tracking script could be improved to receive more reliable data

- Analysis of more head movement trajectories to further solidify conclusion
  - Statistical Bayesian analysis of results

- Further data analysis
  - Overshoot of target by users
  - Acceleration & Deceleration
  - Difference of pitch / yaw movements

Thank you for your attention!

Rework Conclusions

Reword Outlook

Questions?

Results

Further Observations

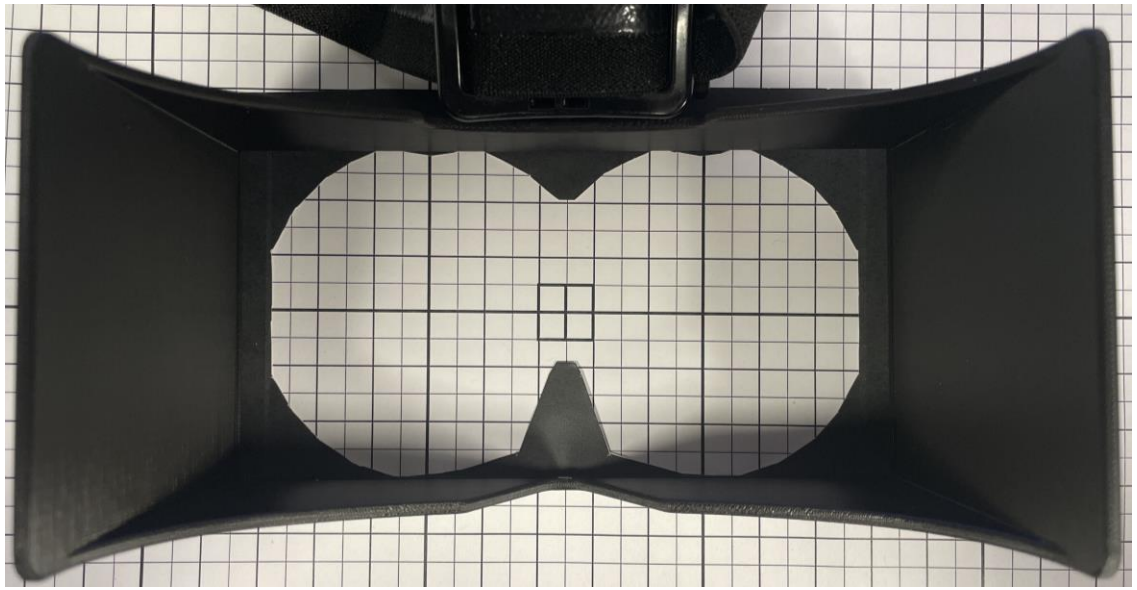
- For the task condition order of RB -> VR -> LR:
  - Five users independently mentioned mediocre to severe discomfort during the LR test

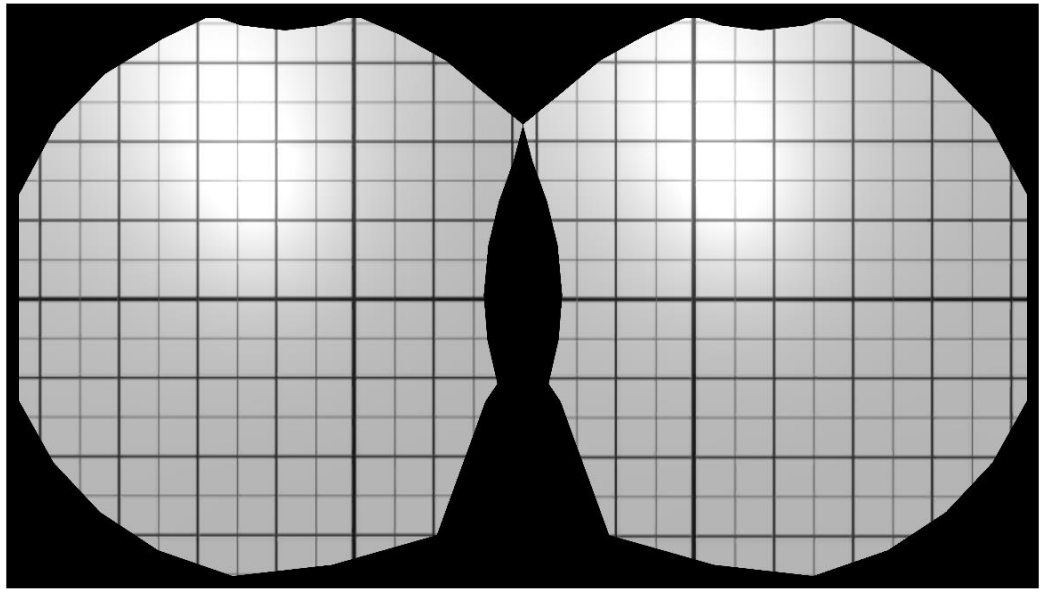
- FoV restriction was messing with their felt perception of reality
- While they did know they are in reality, the limited FoV and the lack of seeing their own body, as they said, made them feel as if they were in VR again, which really messed with their mind.
- FoV was one of the defining factors of perceiving as being in VR for them

Methods

FoV Restriction Device Validation

Goal: Validation of the occlusion mesh for the FoV restriction device

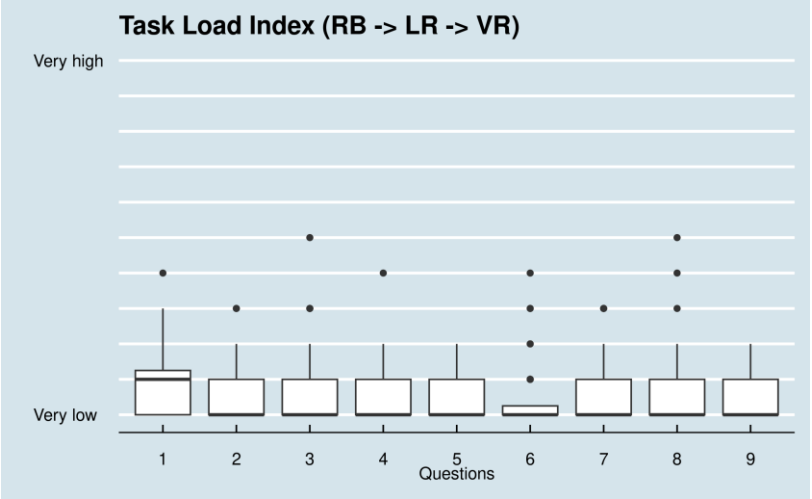


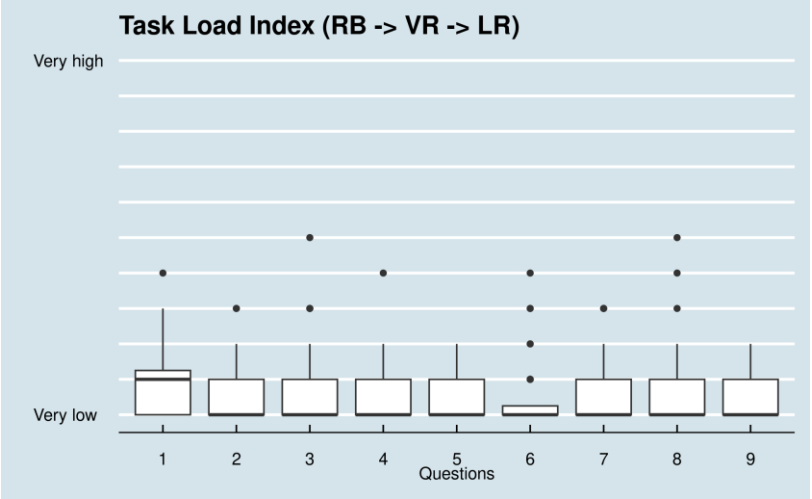


Results

Task Load Index

1. How mentally fatiguing was the task?
2. How physically fatiguing was the task?
3. How hurried or rushed did you feel during the task?
4. How insecure, discouraged, irritated, stressed and annoyed were you?
5. How complex was the task?
6. How stressed did you feel while performing the task?
7. How distracting was the task environment?
8. How uncomfortable/irritating were the visual and auditory aspects of the task?
9. How difficult was the task?

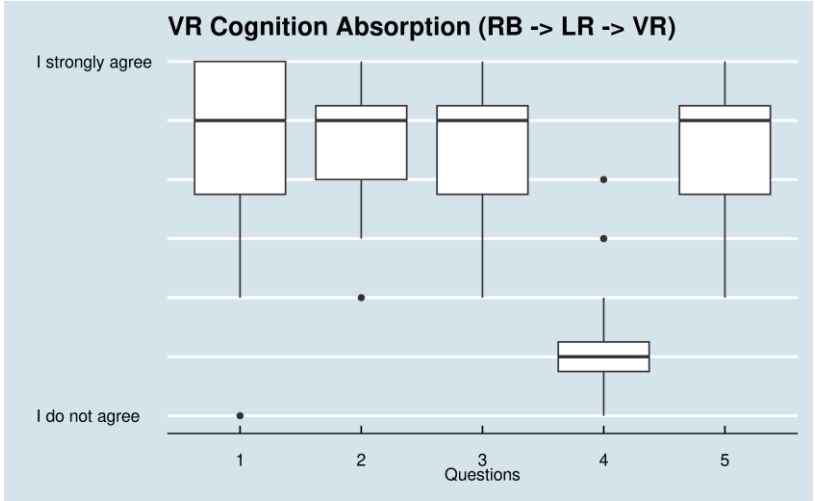


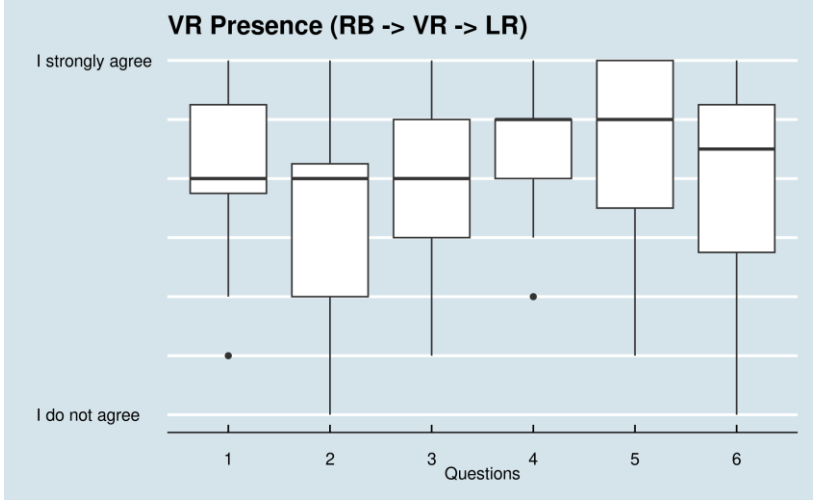


Results

Cognitive Absorbtion

1. While using the VR equipment, I was able to block out most other distractions.
2. While using the VR equipment, I was absorbed in what I was doing.
3. While using the VR equipment, I was immersed in the task I was performing.
4. While using the VR equipment, I got very easily distracted by events unrelated to the task.
5. While using the VR equipment, my attention did not get diverted very easily.

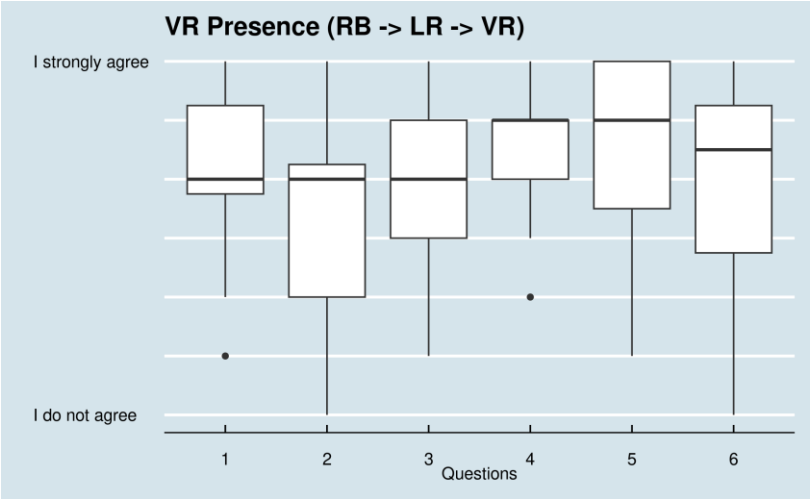


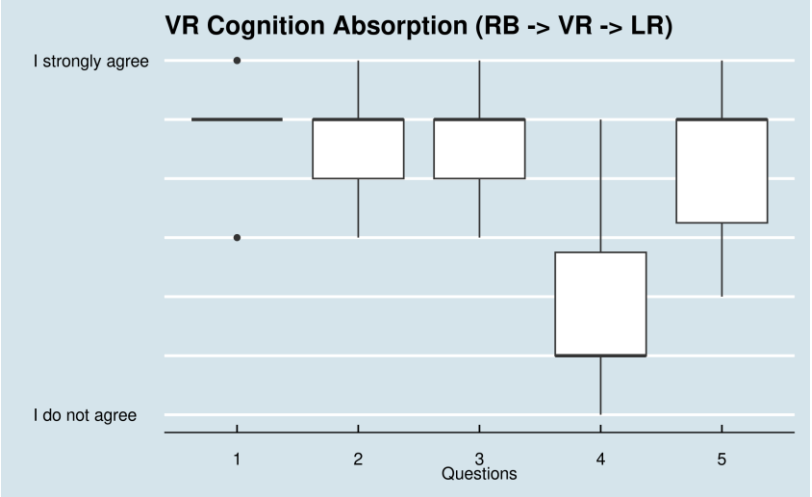


Results

VR Presence

- Sense of being in the training room, on the following scale, where 7 represents your normal experience of being in a place. I had a sense of being in the training room:
- To what extent were there times during the experience when the training room was reality for you?
- When you think back, do you think of the training room more as images that you saw, or more as a place that you visited?
- During the time of the experience, which was strongest, the sense of being in the training room, or being somewhere else?
- Consider your memory of being in the training room: How similar in terms of the structure of memory is this to the structure of memory of other places that you have been today? (…) Do you think of the training room as a place in a way similar to other places that I have been to today?
- During the experience, did you often think to yourself that you were actually present in the test chamber?





Methods

User Study Design: Looking Order

Looking task order (RB-LR-VR)

1 R baseline:

- ☐ B5 -> B6 -> B9 -> B8 -> B5 -> B4 -> B1 -> B2 -> B5
- ☐ B5 -> B3 -> B1 -> B9 -> B3 -> B7 -> B1 -> B5 -> B7 -> B9 -> B5
- ☐ B5 -> A5 -> C5 -> B5 -> C2 -> B8 -> A2 -> A8 -> B2 -> C8 -> B5
- ☐ B5 -> B4 -> A4 -> C6 -> B6 -> B5

2 LR:

- ☐ B5 -> B4 -> B1 -> B2 -> B5 -> B6 -> B9 -> B8 -> B5
- ☐ B5 -> B7 -> B9 -> B5 -> B3 -> B1 -> B9 -> B3 -> B7 -> B1 -> B5
- ☐ B5 -> C5 -> A5 -> B5 -> C2 -> B8 -> A2 -> A8 -> B2 -> C8 -> B5
- ☐ B5 -> B6 -> C6 -> A4 -> B4 -> B5

3 VR

- ☐ B5 -> B6 -> B9 -> B8 -> B5 -> B4 -> B1 -> B2 -> B5
- ☐ B5 -> B9 -> B7 -> B5 -> B3 -> B1 -> B9 -> B3 -> B7 -> B1 -> B5
- ☐ B5 -> C2 -> B8 -> A2 -> A8 -> B2 -> C8 -> B5 -> A5 -> C5 -> B5
- ☐ B5 -> B4 -> A4 -> C6 -> B6 -> B5

Looking task order (RB-VR-LR)

1 R baseline:

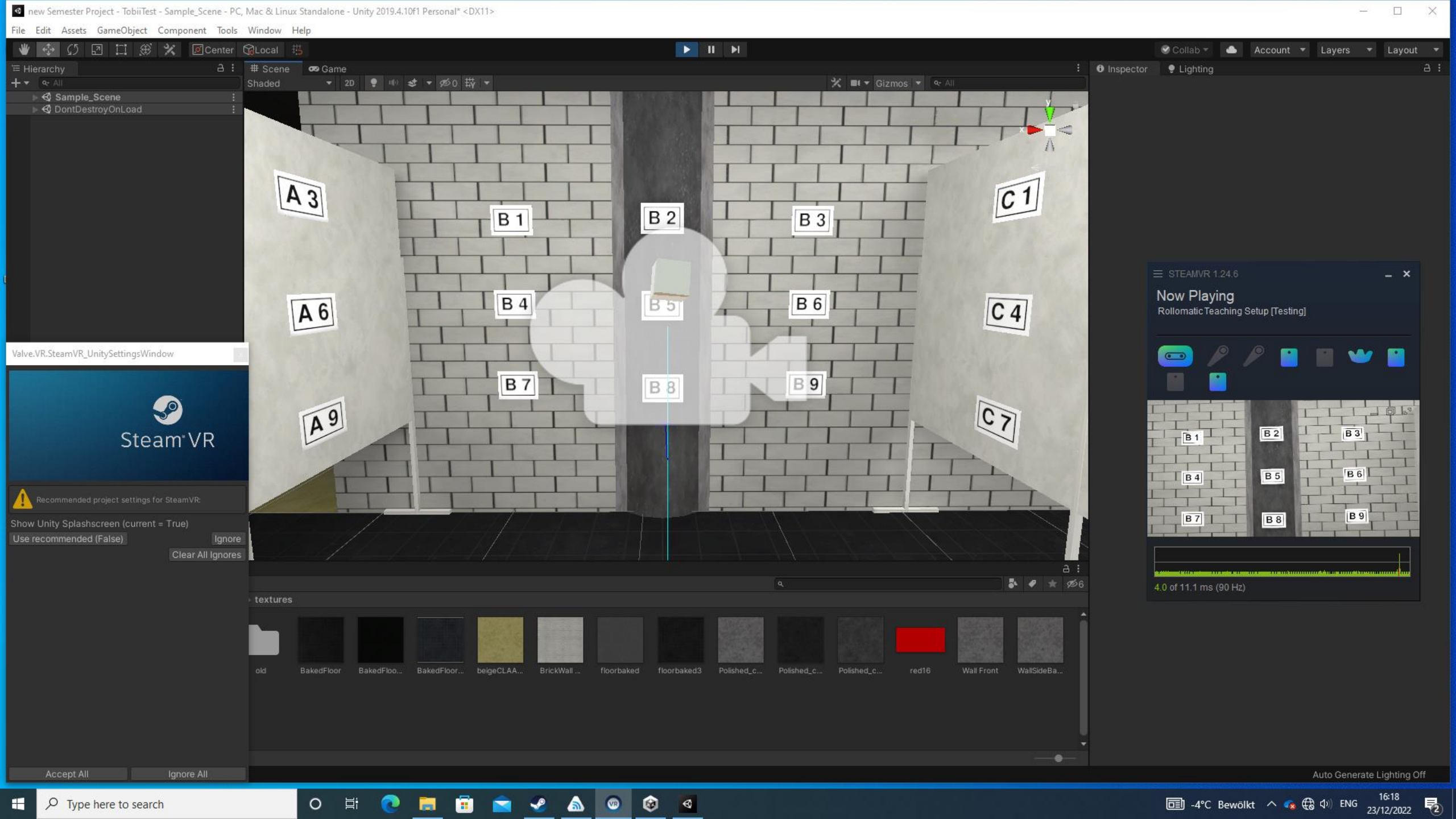
- ☐ B5 -> B6 -> B9 -> B8 -> B5 -> B4 -> B1 -> B2 -> B5
- ☐ B5 -> B3 -> B1 -> B9 -> B3 -> B7 -> B1 -> B5 -> B7 -> B9 -> B5
- ☐ B5 -> A5 -> C5 -> B5 -> C2 -> B8 -> A2 -> A8 -> B2 -> C8 -> B5
- ☐ B5 -> B4 -> A4 -> C6 -> B6 -> B5

2 VR:

- ☐ B5 -> B4 -> B1 -> B2 -> B5 -> B6 -> B9 -> B8 -> B5
- ☐ B5 -> B7 -> B9 -> B5 -> B3 -> B1 -> B9 -> B3 -> B7 -> B1 -> B5
- ☐ B5 -> C5 -> A5 -> B5 -> C2 -> B8 -> A2 -> A8 -> B2 -> C8 -> B5
- ☐ B5 -> B6 -> C6 -> A4 -> B4 -> B5

3 LR

- ☐ B5 -> B6 -> B9 -> B8 -> B5 -> B4 -> B1 -> B2 -> B5
- ☐ B5 -> B9 -> B7 -> B5 -> B3 -> B1 -> B9 -> B3 -> B7 -> B1 -> B5
- ☐ B5 -> C2 -> B8 -> A2 -> A8 -> B2 -> C8 -> B5 -> A5 -> C5 -> B5
- ☐ B5 -> B4 -> A4 -> C6 -> B6 -> B5


new Semester Project - TobiiTest - Sample_Scene - PC, Mac & Linux Standalone - Unity 2019.4.10f1 Personal* <DX11>
File Edit Assets GameObject Component Tools Window Help
Center Local
Collab Account Layers Layout
Hierarchy
Sample_Scene
DontDestroyOnLoad
Scene Game
Shaded 2D Gizmos
Inspector Lighting
A 3 B 1 B 2 B 3 C 1
A 6 B 4 B 5 B 6 C 4
A 9 B 7 B 8 B 9 C 7
Valve.VR.SteamVR_UnitySettingsWindow
Steam VR
Recommended project settings for SteamVR:
Show Unity Splashscreen (current = True)
Use recommended (False)
Ignore
Clear All Ignores
Accept All
Ignore All
STEAMVR 1.24.6
Now Playing
Rollomatic Teaching Setup [Testing]
4.0 of 11.1 ms (90 Hz)
textures
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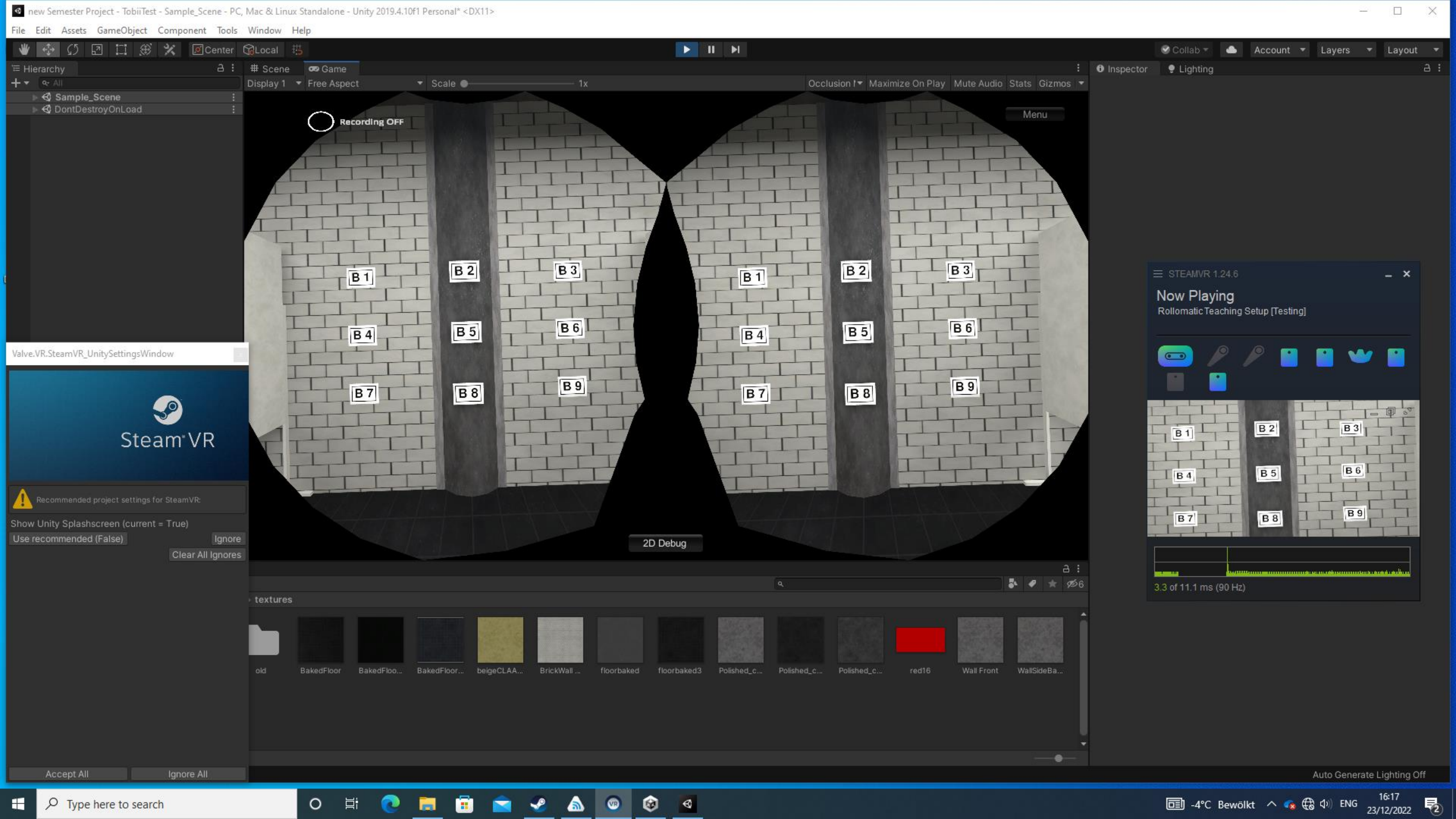
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Free Aspect
Scale
1x
Occlusion I
Maximize On Play
Mute Audio
Stats
Gizmos
Recording OFF
Menu
B 1
B 2
B 3
B 4
B 5
B 6
B 7
B 8
B 9
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