

A QoE and Simulator Sickness Evaluation of a Smart-Exercise-Bike Virtual Reality System via User Feedback and Physiological Signals

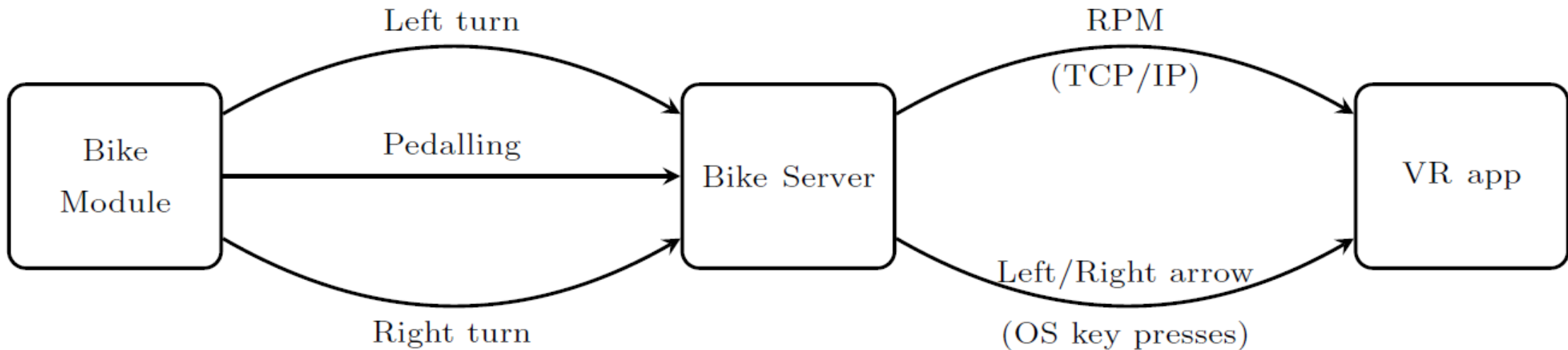
S. Katsigiannis, R. Willis, N. Ramzan

Google, Mountain View, CA

Motivation

- Exergaming is highly beneficial due to motivating people to engage into physical exercise
- Cycling exergames have received a lot of attention:
 - Low cost
 - Availability of equipment
 - Familiarity with activity
- Use of virtual reality in cycling exergames:
 - More immersive experience
 - Increased motivation to exercise
- Study on visual quality perception and simulator sickness required

Developed system overview



Bike Hardware & Software

Bike module

- Designed as plug and play kit
- Micro-controller based custom circuit
- Magnetic switch for pedalling detection
- Buttons on handlebar for steering
- USB connection for power supply and signal transmission

Bike server

- Receives signals from bike module
- Steering button presses converted to OS key presses
 - Continuous pressing supported
- Rotation signal handling:
 - As OS key press, or
 - Transmission of rotation speed in RPM via TCP/IP socket
- Key mapping supported

The VR environment



Experiment overview

- Users asked to use the VR system for various visual quality settings
 - Texture resolution
 - Frame rate
- Physiological signals captured while using the system
 - Electrocardiography (ECG)
 - Galvanic Skin Response (GSR)
- Self-assessment of visual quality and simulator sickness symptoms
 - MOS ratings
 - Simulator Sickness Questionnaire (SSQ)
- Study of the effects of
 - Quality settings on perceptual quality
 - Quality settings on simulator sickness scores
 - Physiological responses on perceptual quality
 - Physiological responses on simulator sickness scores

Head-mounted display

Oculus Rift

- OLED panels
- 1080 x 1200 pixels per eye panel
- 90 Hz refresh rate
- 2160 x 2400 total resolution
- 110° field of view
- Headphones



Self-assessment scales

MOS scale

Value	Quality
1	Bad
2	Poor
3	Fair
4	Good
5	Excellent

Simulator sickness questionnaire

Symptoms:

1) general discomfort, 2) fatigue, 3) headache, 4) eye strain, 5) difficulty focusing, 6) increased salivation, 7) sweating, 8) nausea, 9) difficulty concentrating, 10) fullness of head, 11) blurred vision, 12) dizziness (eyes open), 13) dizziness (eyes closed), 14) vertigo, 15) stomach awareness, 16) burping

4-point scale:

0: None, 1: Slight, 2: Moderate, 3: Severe

Experimental protocol

- Written instructions for the experiment
- Clarifications from supervising researcher
- Consent form and prior experience questionnaire
- Attachment of ECG and GSR electrodes and positioning and adjustment of HMD
- 3 random test scenarios performed for familiarisation
 - 30 sec at the highest quality setting
 - 60 sec at the test quality setting
 - Quality assessment & Simulator sickness questionnaire
- All test scenarios performed twice in random order
 - 30 sec at the highest quality setting
 - 60 sec at the test quality setting
 - Quality assessment & Simulator sickness questionnaire

Quality settings

#	Texture quality setting	Frame rate setting	Texture resolution (Width x Height)	Frame rate (fps)
HH	High	High	1024 x 1024	60
MH	Medium	High	512 x 512	60
LH	Low	High	256 x 256	60
RH	Random low quality textures	High	Random textures at 256 x 256	60
HM	High	Medium	1024 x 1024	30
HL	High	Low	1024 x 1024	15

VR questionnaire

Rate Current Quality

★ ★ ★ ★ ☆
Bad Poor Fair Good Excellent

▶ General Discomfort ◀

★ ★ ★ ☆
None Slight Moderate Severe

Fatigue

★ ☆ ☆ ☆
None Slight Moderate Severe

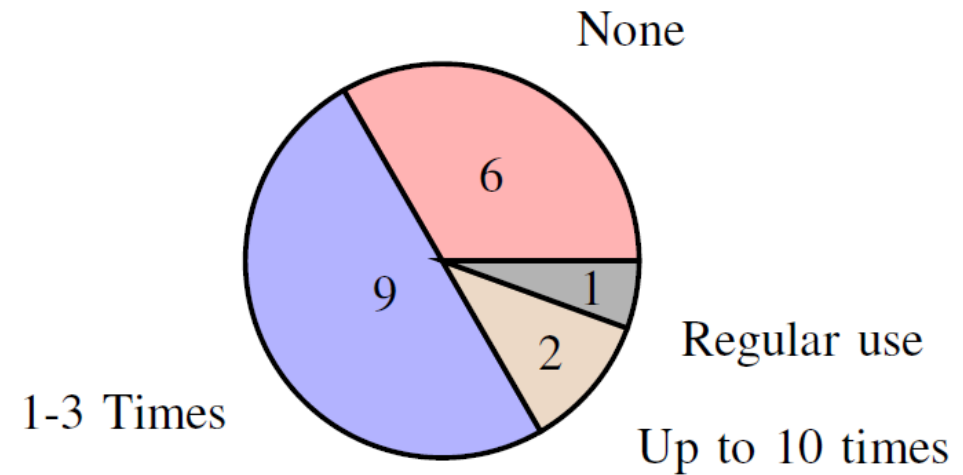
Headache

★ ☆ ☆ ☆
None Slight Moderate Severe

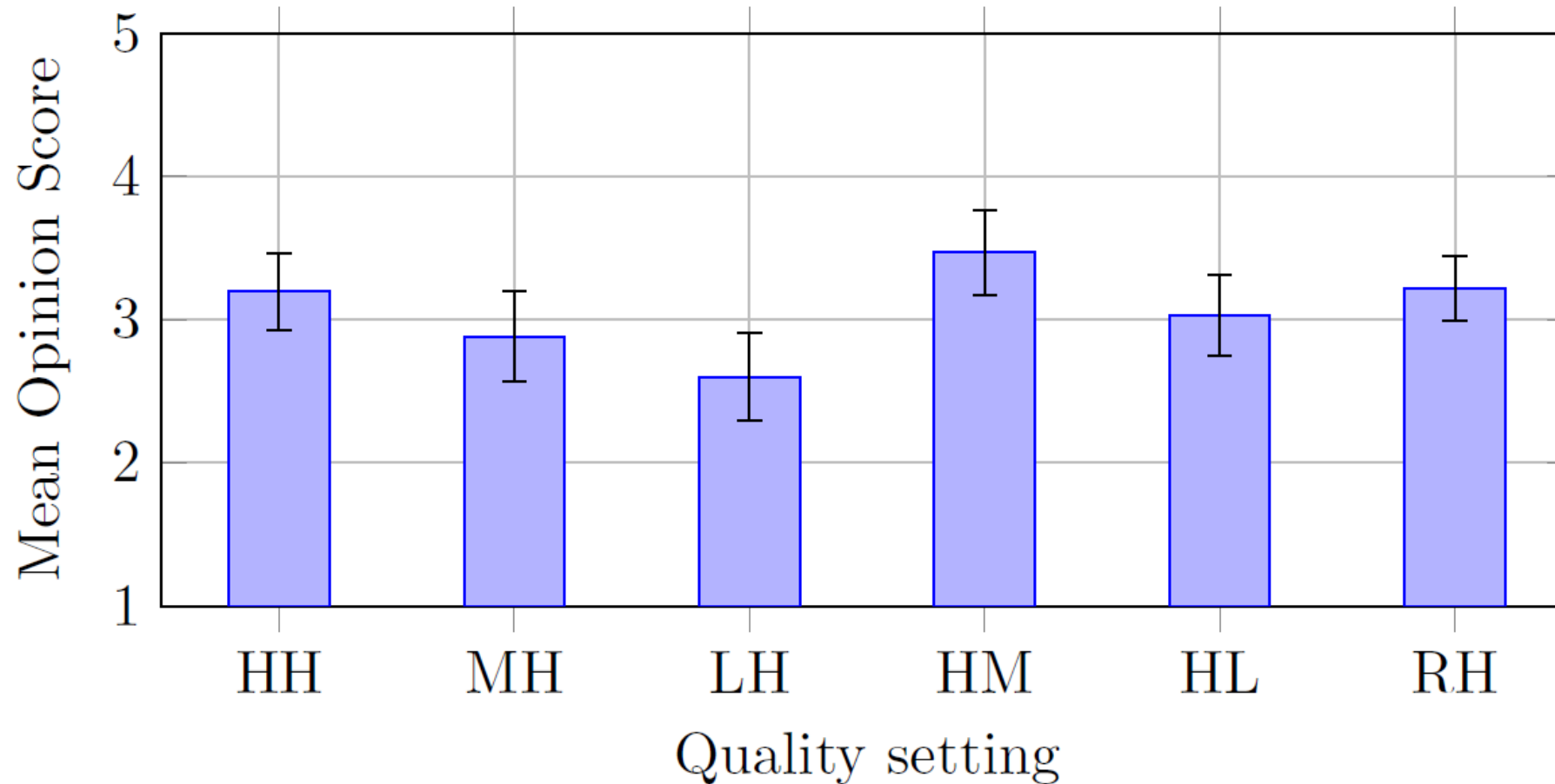
Participants

Number of participants	18 (16 male, 2 female)
Age	$\mu = 26$ $\sigma = 5.65$
Occupation	Undergraduate students Postgraduate students PhD students
Eyesight	Normal / Corrected

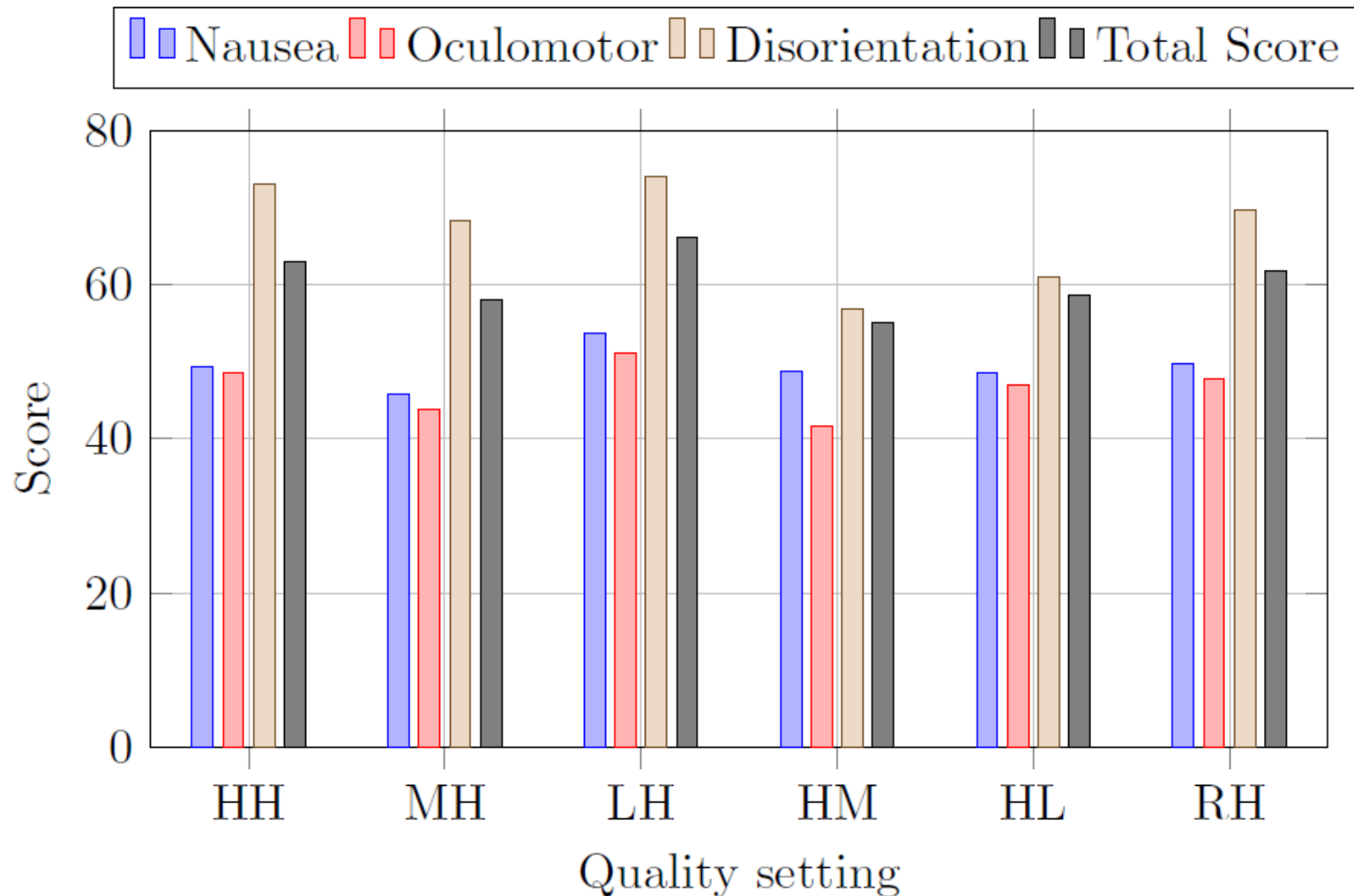
Prior VR experience



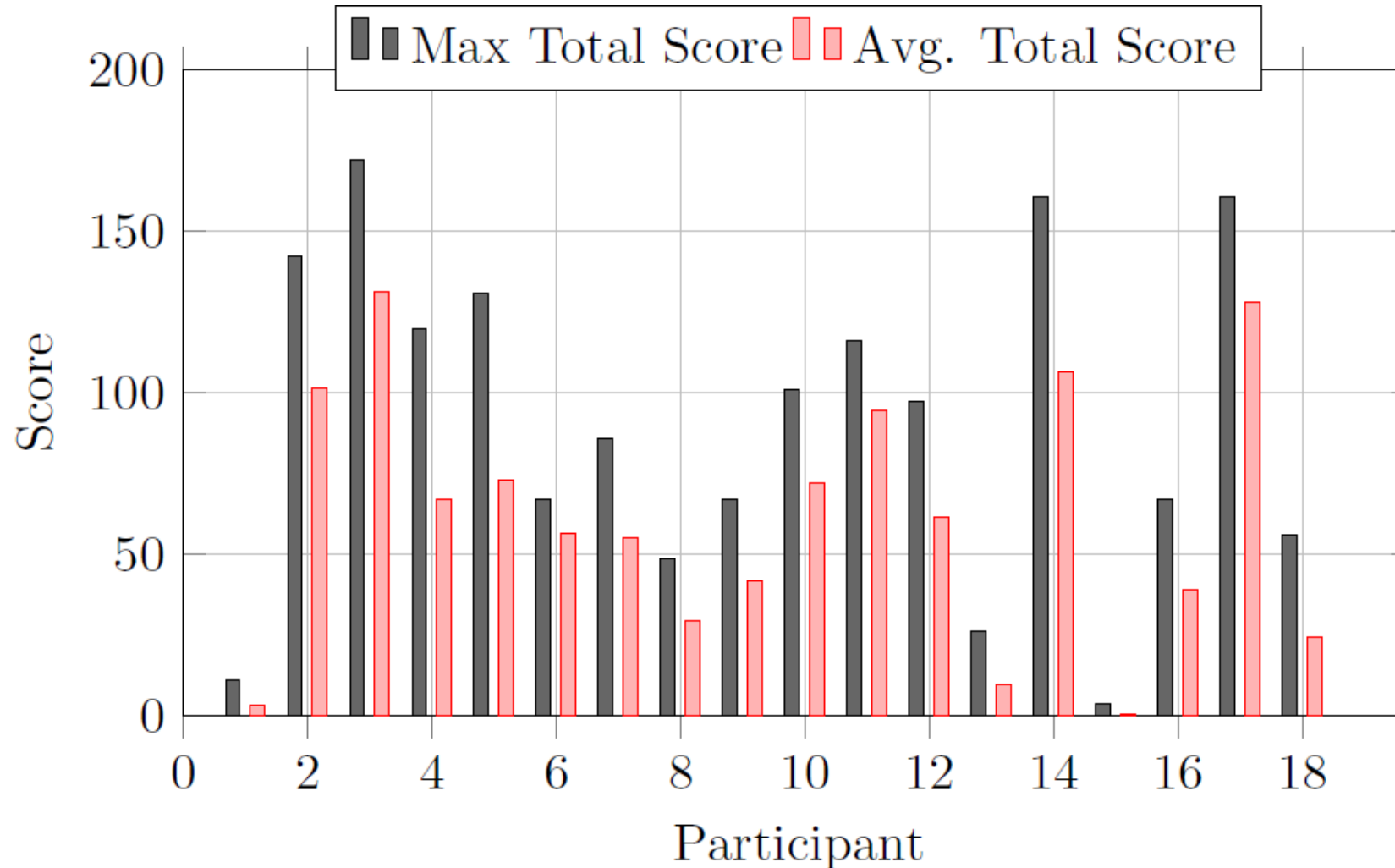
Quality assessment



Simulator sickness scores



Max/Avg simulator sickness total scores



Factors affecting quality perception and simulator sickness

Quality perception

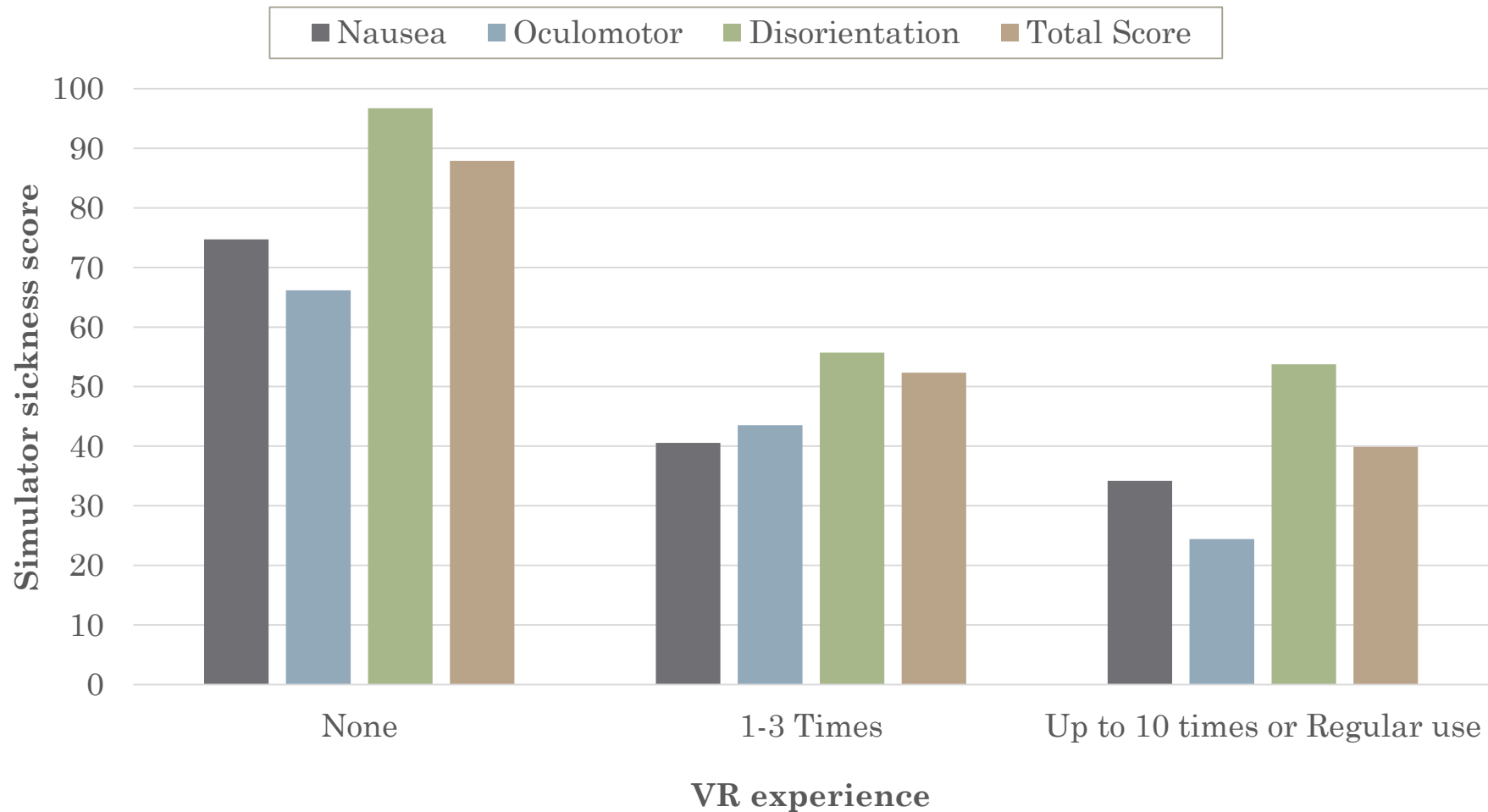
Factor	ANOVA p	Significance
Texture resolution	0.0012	YES
Frame rate	0.0127	YES
Quality setting	0.0010	YES

Simulator sickness scores

Factor	ANOVA p	Significance
Texture resolution	0.8463	NO
Frame rate	0.6759	NO
Quality setting	0.9287	NO
VR experience	1.6×10^{-11}	YES
<i>Gender*</i>	<i>0.0169</i>	<i>YES</i>

*Results for gender are biased due to sample size

Simulator sickness scores vs VR experience



Effect of physiological signals on perceptual quality and simulator sickness scores

Quality perception

Factor	ANOVA <i>p</i>	Significance
GSR peaks	0.2756	NO
Mean HR	0.9387	NO
Min HR	0.9649	NO
Max HR	0.8314	NO
Median HR	0.9273	NO
St.Dev. HR	0.8124	NO

Simulator sickness scores

Factor / PCC	<i>TS</i>	N	O	D
GSR peaks	-0.01	0.01	0.02	-0.05
Mean HR	-0.12	-0.17	-0.04	-0.15
Min HR	-0.09	-0.13	-0.00	-0.13
Max HR	-0.09	-0.13	-0.03	-0.12
Median HR	-0.13	-0.17	-0.04	-0.16
St.Dev. HR	0.06	0.07	0.01	0.09

PCC: Pearson's Correlation Coefficient

Conclusions

- Texture resolution, frame rate, and their combination:
 - Had a statistically significant impact on the perceived visual quality
 - Did not have a statistically significant impact on simulator sickness scores
 - Did not have a statistically significant impact on physiological responses
- Moving speed and focus on not crashing the virtual bike prevented users from noticing quality degradation:
 - Between 60 and 30 fps
 - When random low resolution textures were used
- Weak correlation between physiological responses and simulator sickness scores
 - Strenuous activity (pedalling) led to increased sweating and cardiac activity, interfering with the physiological responses related to simulator sickness
- Prior experience with VR had a statistically significant impact on simulator sickness scores
 - Slow familiarisation period with the system recommended

Thank you