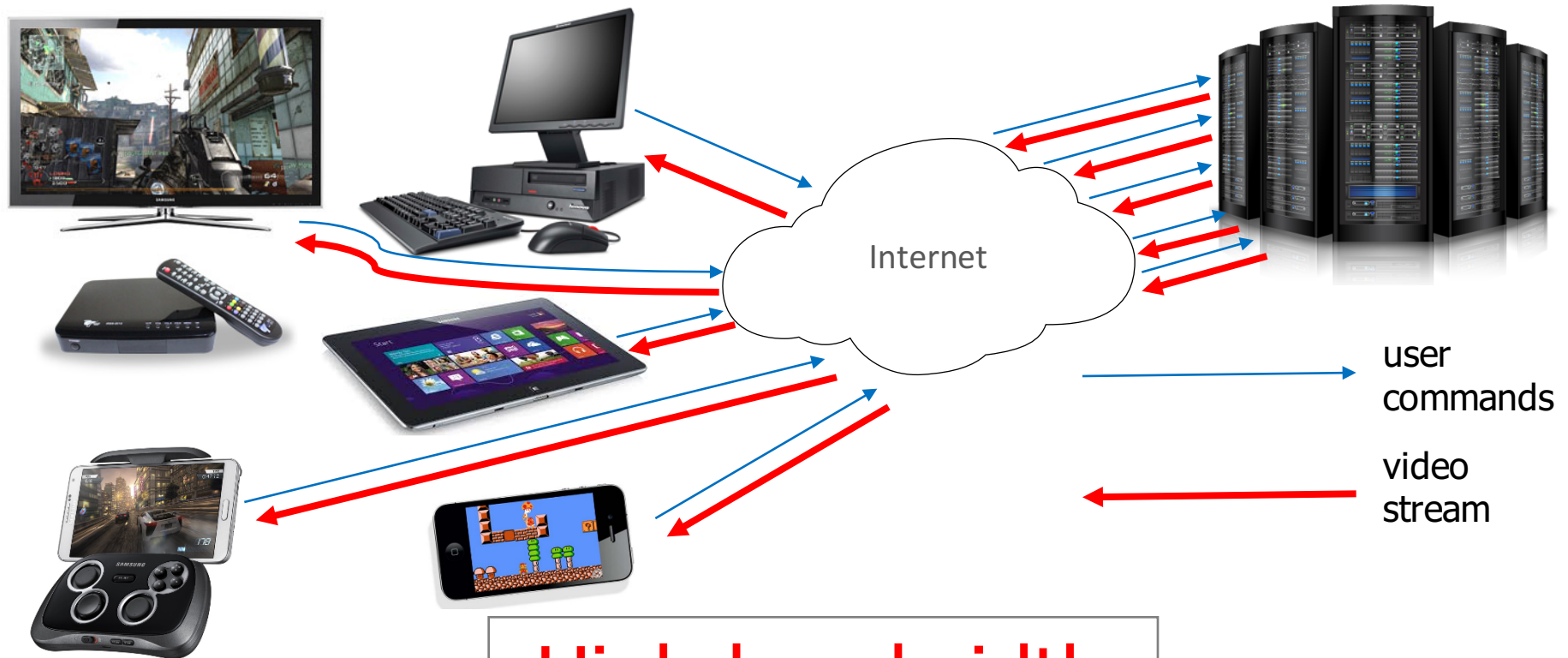# Cloud Gaming QoE Models for Deriving Video Encoding Adaptation Strategies

Ivan Slivar, Lea Skorin-Kapov, Mirko Sužnjević

Faculty of Electrical Engineering and Computing
University of Zagreb, Croatia

Introduction

Internet

user commands

video stream

Low hardware requirements

High bandwidth and strict delay requirements

Controlled platform

Problem – What, how and why?

- How to best adapt the video encoding parameters of the game video stream in light of decreased bandwidth availability, while maximizing the end user QoE

- QoE measurements in which we compare playing sessions on Valve's Steam In-Home streaming platform for various video streaming parameters

- Basis for effective QoE optimization strategies at the cloud gaming server
  - Build on previous work published by Hong *et al* (IEEE TCSVT, 2015)

Laboratory setup

- 24 test scenarios
  - Four levels of framerate – 25 fps, 35 fps, 45 fps and 60 fps
  - Three levels of video bitrate – 3 Mbps, 5 Mbps and 10 Mbps
  - Two games: Serious Sam 3 (first-person shooter game) and Hearthstone(card game)
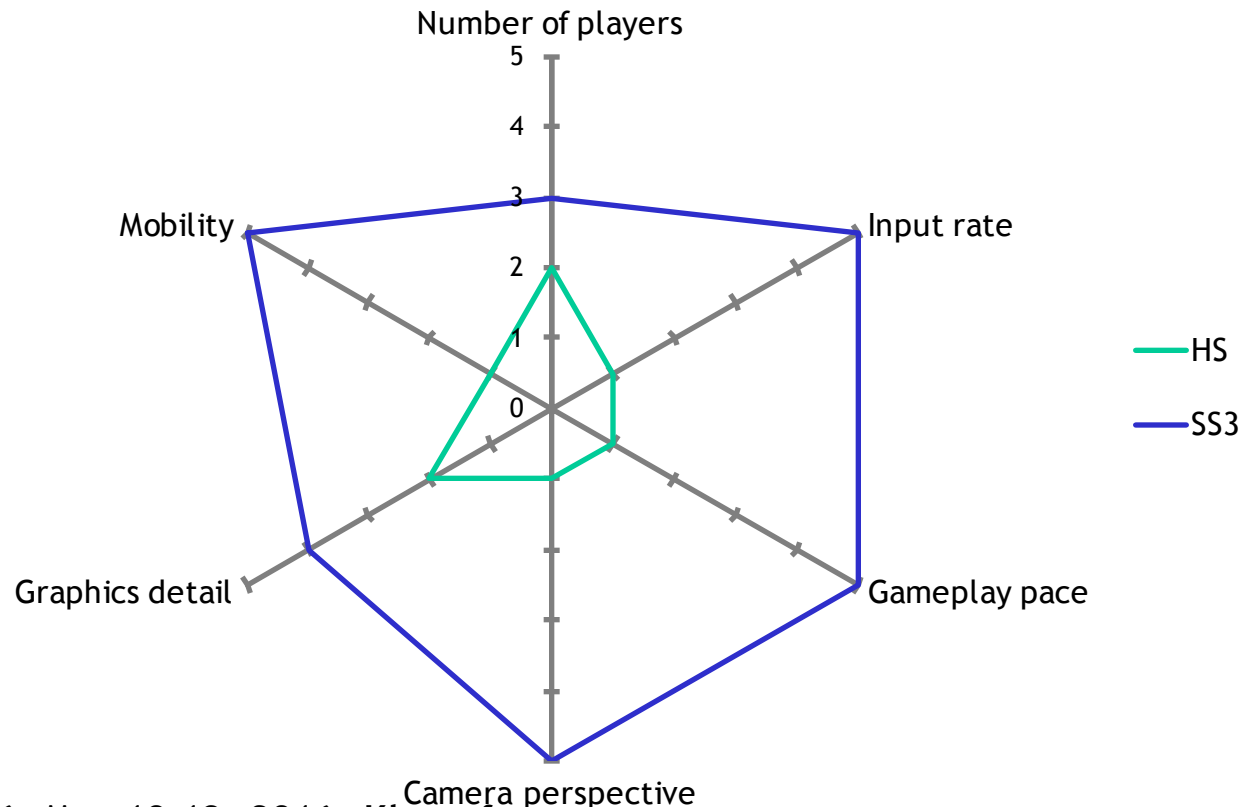
Participants

- 52 participants
  - 38 male and 14 female, aged between 21 and 26 (mdn. age 23)
  - 16 novice, 22 intermediate and 14 experienced players

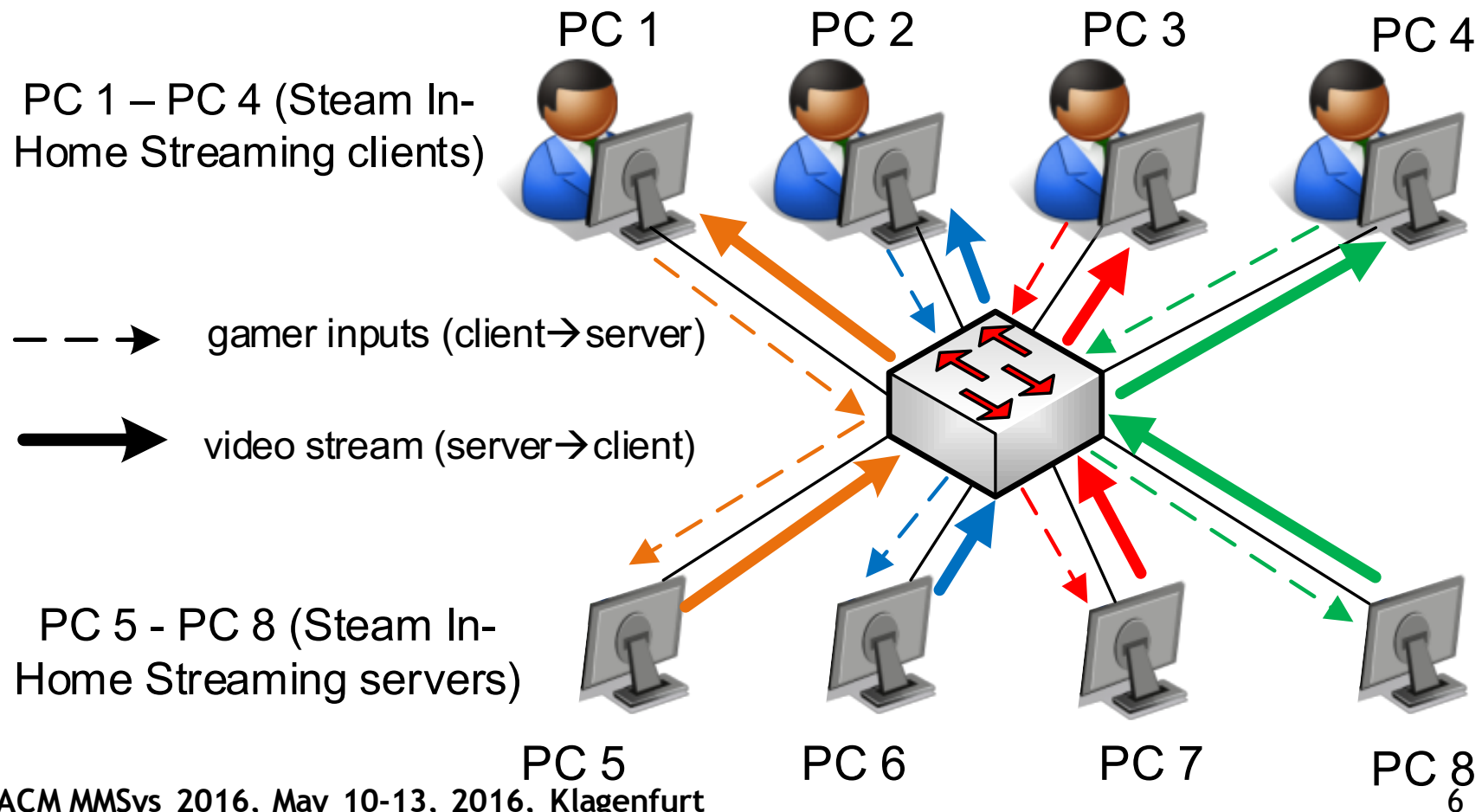- Group composition based on self reported experience
  - 13 groups with 4 players in each group
  - Heterogeneous (one novice and one experienced player) and homogeneous groups (4 players with the same gaming skill level)

- Answered questionnaire after each test scenario:
  - Players reported *perceived graphics quality*, *perceived fluidity* and *overall QoE* (5-pt ACR scale)
  - Players also reported *willingness to continue playing* in the given conditions

Testbed

- Gaming platform: Steam In-Home streaming platform
  - Played at the default graphics settings and resolution was set to 720p
  - Manipulation of video encoding parameters done on PC 1 – PC 4

PC 1 – PC 4 (Steam In-Home Streaming clients)

PC 1   PC 2   PC 3   PC 4

gamer inputs (client→server)

video stream (server→client)

PC 5 - PC 8 (Steam In-Home Streaming servers)
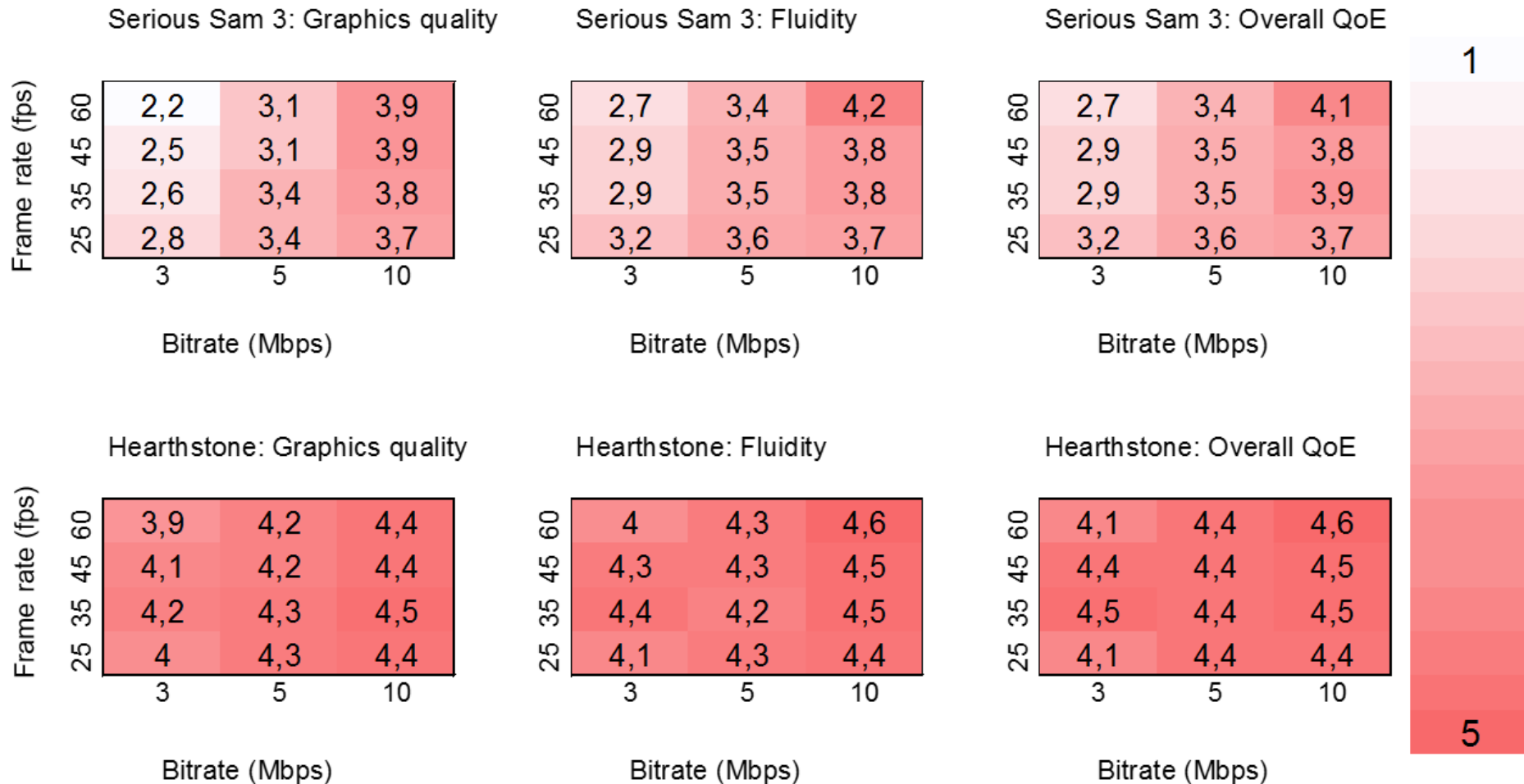
PC 5   PC 6   PC 7   PC 8

Results – subjective ratings of overall QoE

- HS has on average higher scores of overall QoE for all test conditions in comparison with SS3
- Neither lowering video frame rate nor video bitrate had a significant impact on perceived QoE during HS gaming sessions
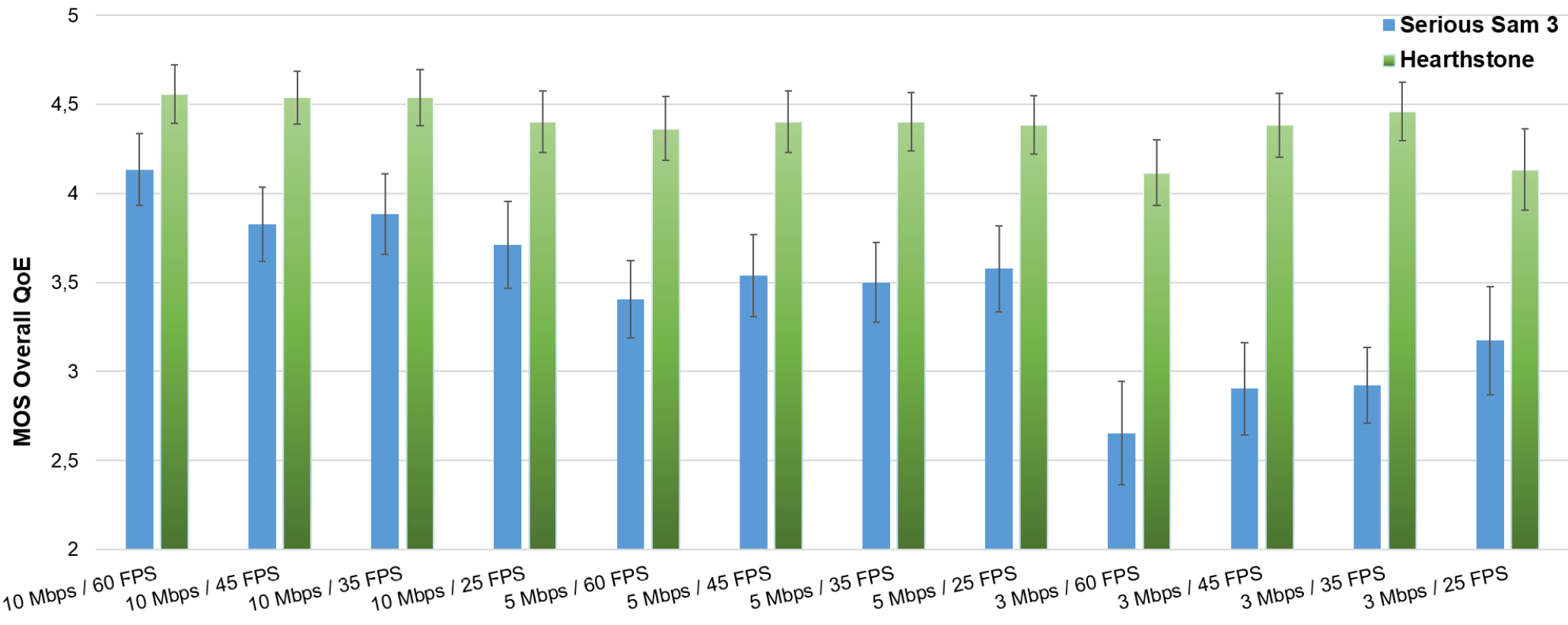
# Results – mean subjective ratings of QoE features

📚 High correlation between the measured metrics

Serious Sam 3: Graphics quality

Frame rate (fps)	3	5	10
60	2,2	3,1	3,9
45	2,5	3,1	3,9
35	2,6	3,4	3,8
25	2,8	3,4	3,7

Bitrate (Mbps)

Serious Sam 3: Fluidity

Frame rate (fps)	3	5	10
60	2,7	3,4	4,2
45	2,9	3,5	3,8
35	2,9	3,5	3,8
25	3,2	3,6	3,7

Bitrate (Mbps)

Serious Sam 3: Overall QoE

Frame rate (fps)	3	5	10
60	2,7	3,4	4,1
45	2,9	3,5	3,8
35	2,9	3,5	3,9
25	3,2	3,6	3,7

Bitrate (Mbps)

Hearthstone: Graphics quality

Frame rate (fps)	3	5	10
60	3,9	4,2	4,4
45	4,1	4,2	4,4
35	4,2	4,3	4,5
25	4	4,3	4,4

Bitrate (Mbps)

Hearthstone: Fluidity

Frame rate (fps)	3	5	10
60	4	4,3	4,6
45	4,3	4,3	4,5
35	4,4	4,2	4,5
25	4,1	4,3	4,4

Bitrate (Mbps)

Hearthstone: Overall QoE

| Frame rate (fps)	3	5	10
60	4,1	4,4	4,6
45	4,4	4,4	4,5
35	4,5	4,4	4,5
25	4,1	4,4	4,4

Bitrate (Mbps)

Scale: 1 – 5

Results – willingness to continue playing

📖 A large discrepancy in the number of test scenarios where the participants were not willing to continue playing under current test conditions between tested games (e.g. 3 Mbps / 60 fps)
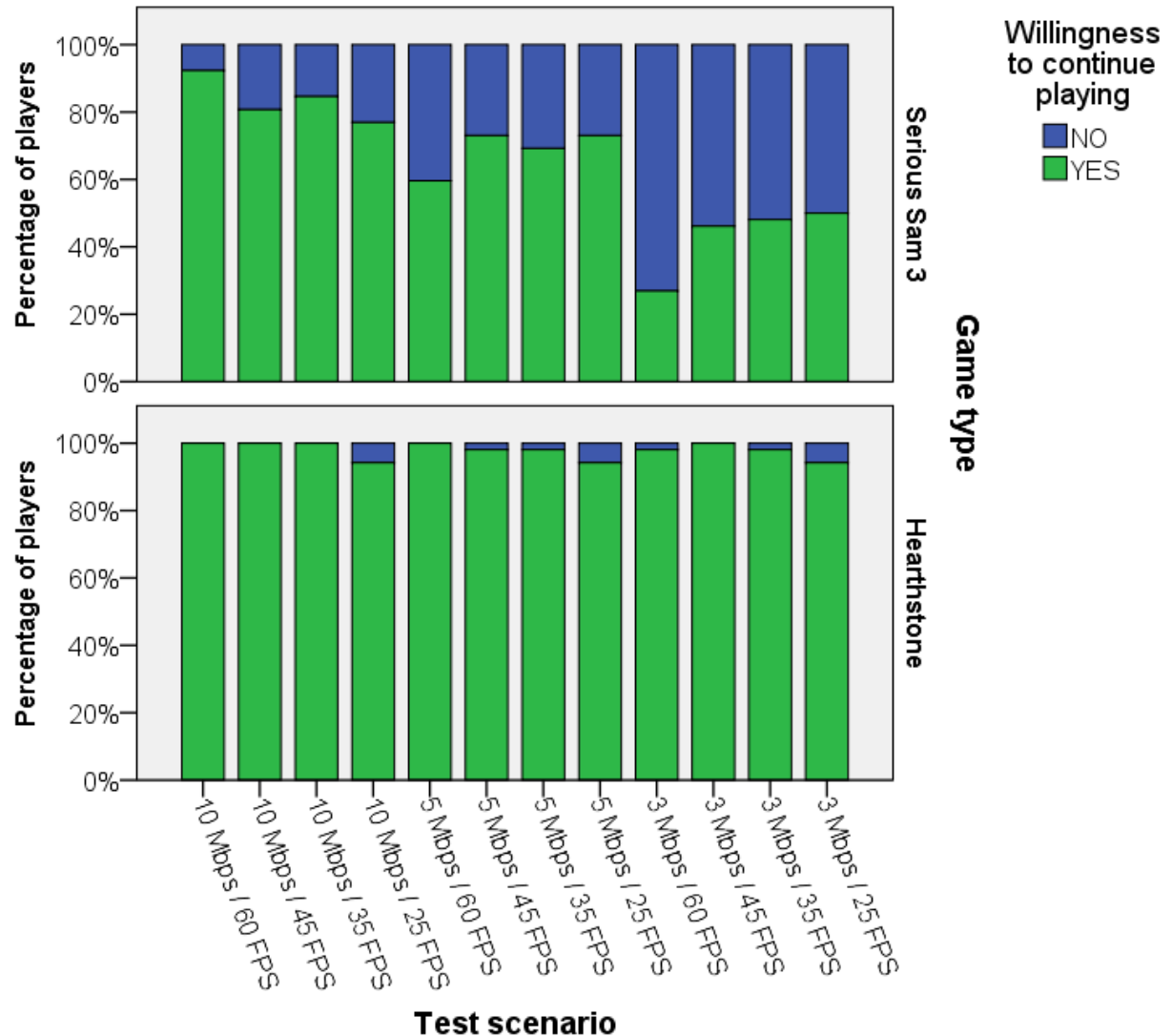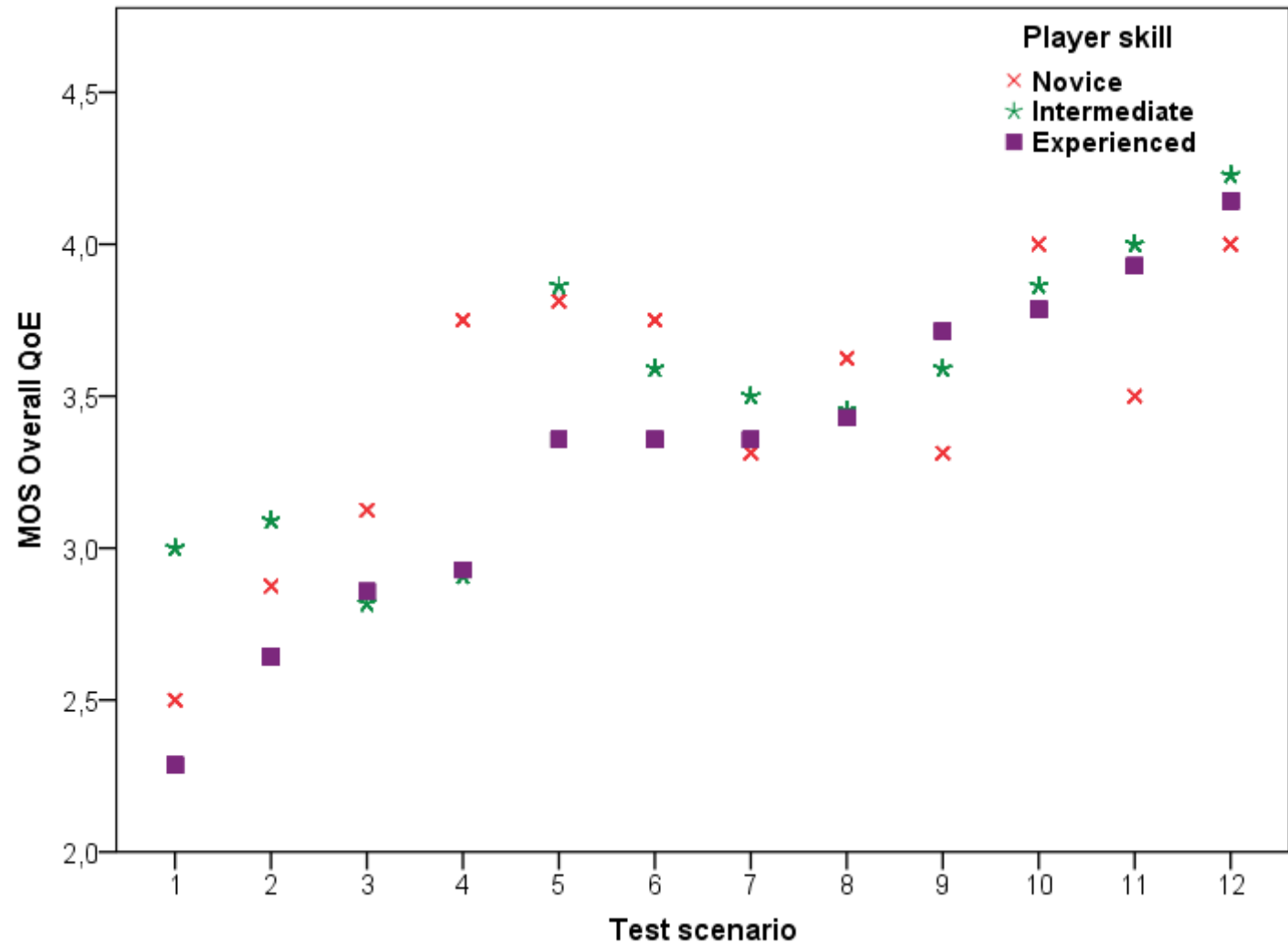
Results – impact of player experience on QoE (1/3)

📚 For aggregated scores, no clear statistical distinction can be made between differently experienced players
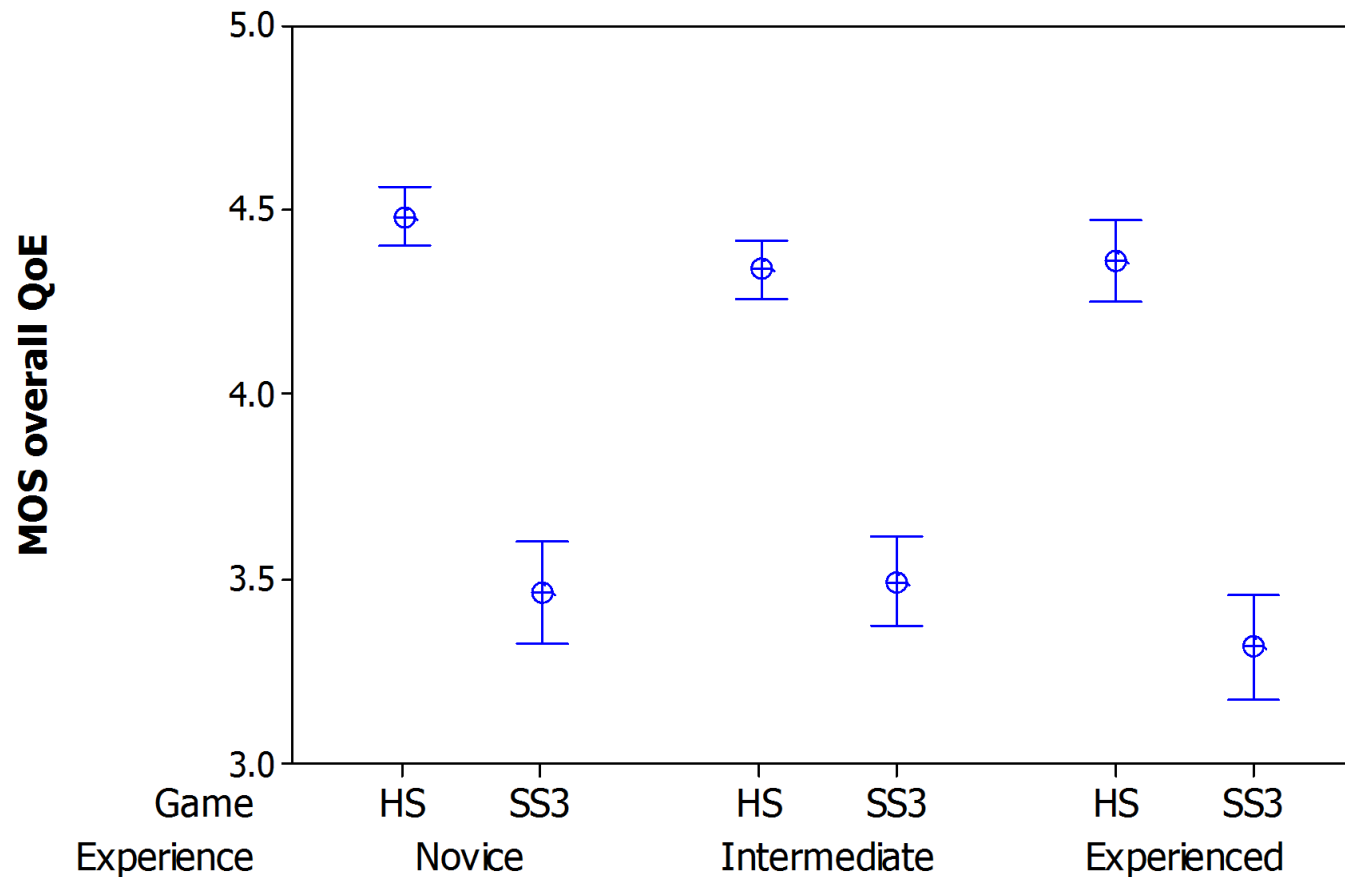
Results – impact of player experience on QoE (2/3)

When analysed on a per test scenario basis, experienced players tend to give lower scores for lower quality scenarios, and higher scores for higher quality scenarios, as opposed to novice players

Results – impact of player experience on QoE (3/3)

- Comparison of the overall QoE scores of experienced players considered in this study with the results from our previous study

- The same test condition (25 fps, 10 Mbps) was rated quite differently, emphasizing the challenge of standardizing test methodologies for gaming QoE
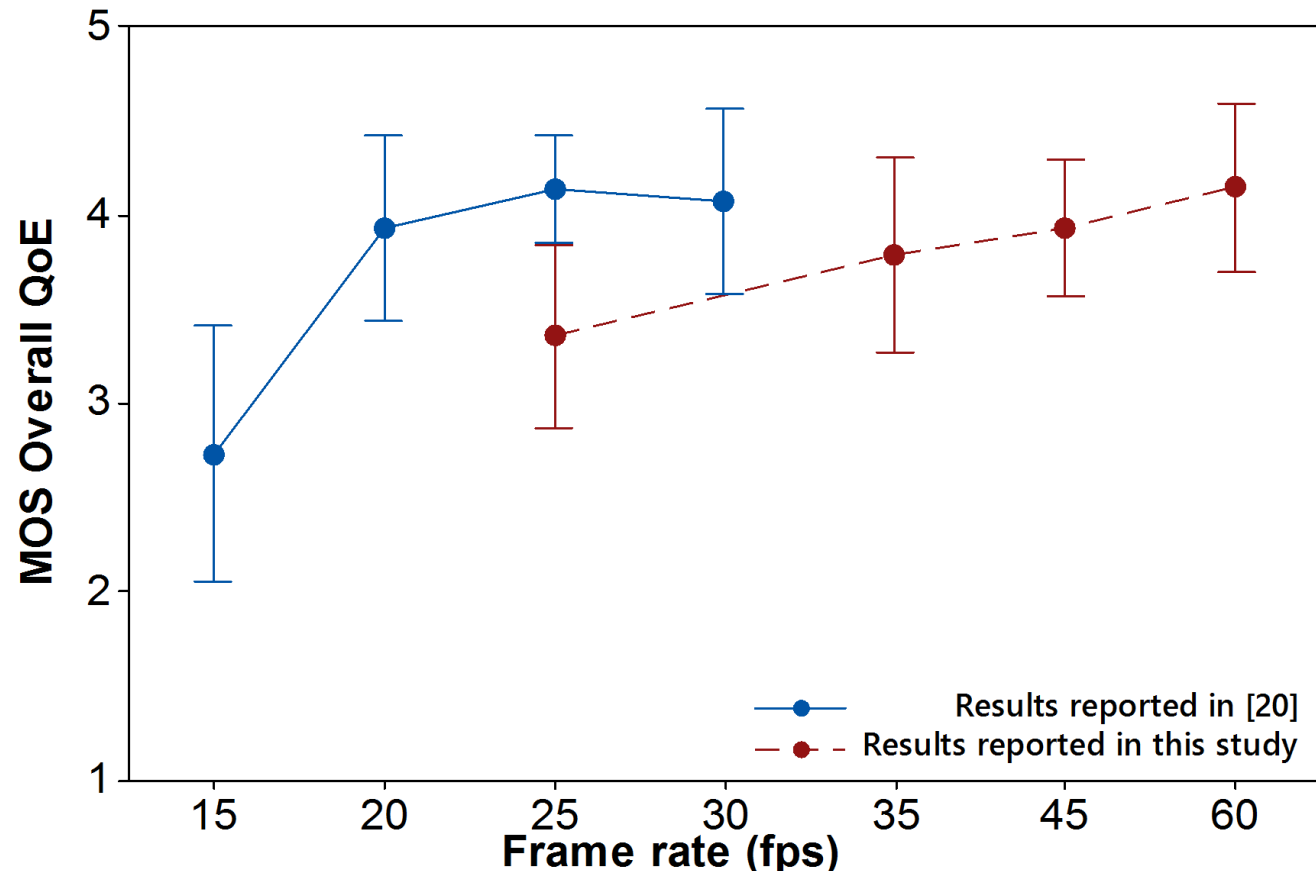
I. Slivar, M. Suznjevic, and L. Skorin-Kapov. The impact of video encoding parameters and game type on QoE for cloud gaming: A case study using the Steam platform. In Proceedings of the 7th International Workshop on Quality of Multimedia Experience (QoMEX), pages 1–6, May 2015.
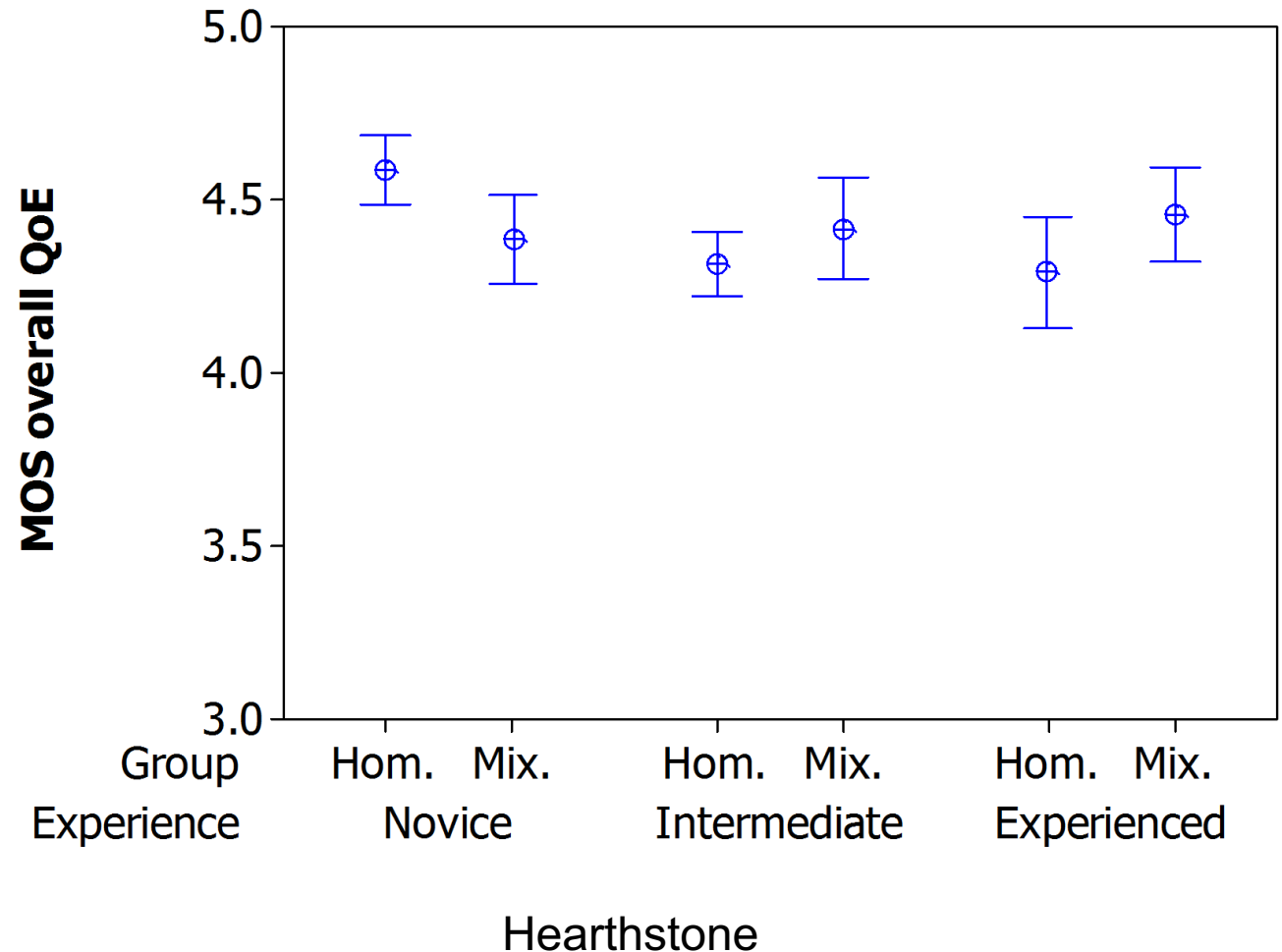
Results – impact of degradations on QoE

① – No distortion ② – User disturbed ③ – User gives up
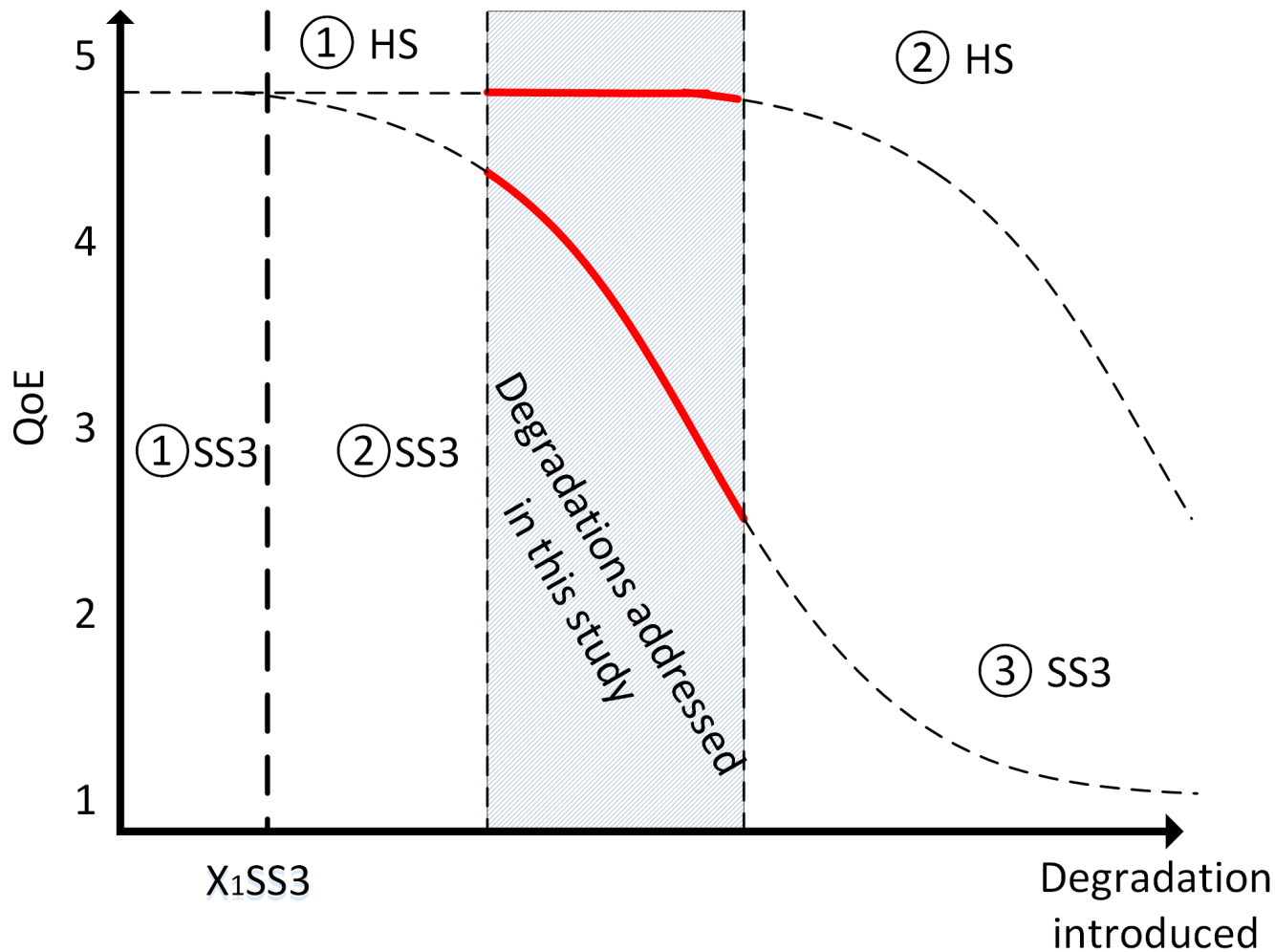
Results – impact of group composition on QoE

- No clear statistical distinction can be made between hom. and mixed groups for SS3
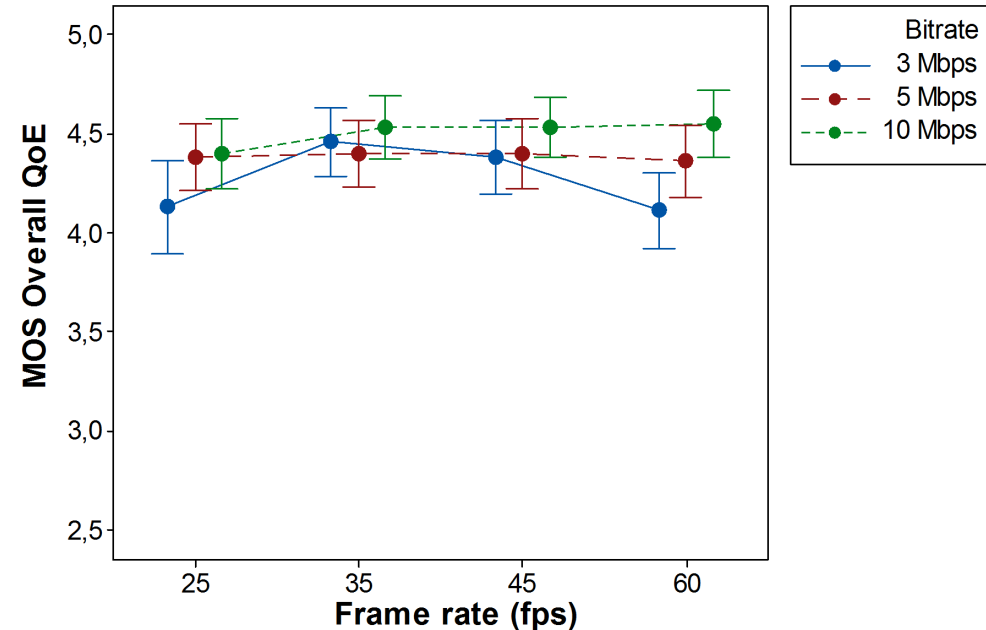- Novice players report lower QoE scores in mixed groups for HS

Hearthstone

Results – impact of video parameters on QoE

📚 Different encoding configuration strategies can be employed for different types of games
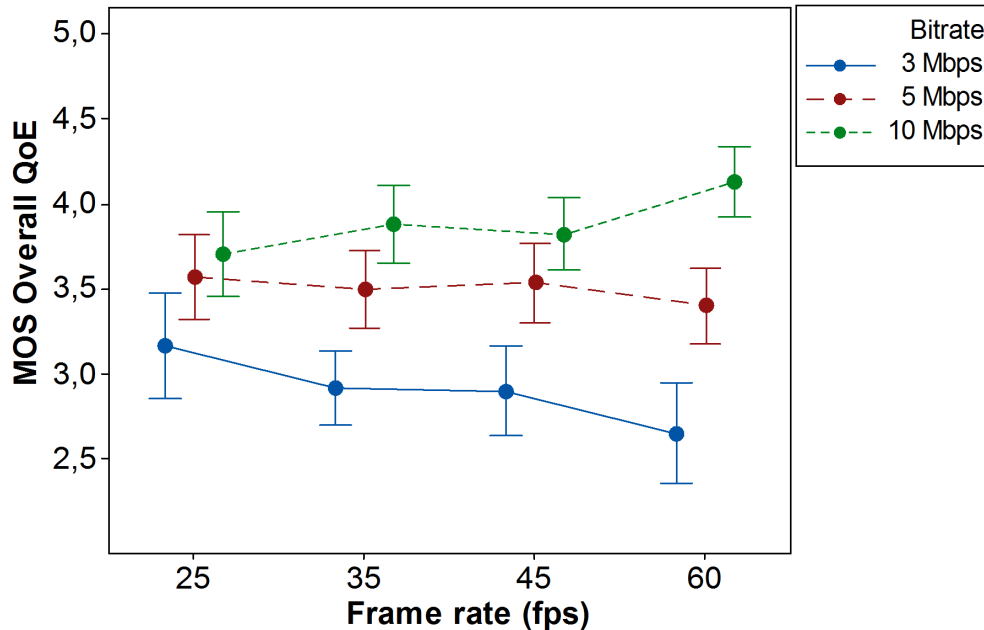
Serious Sam 3

Hearthstone

Results – QoE estimation models (1/2)

- Modelled the MOS scores as a quadratic function of manipulated video encoding parameters (as previously proposed by Hong *et al.*)
- The derived QoE model for SS3 has a better fit considering collected data then the QoE model for HS

	Serious Sam 3				Hearthstone			
	All	Novice	Intermediate	Experienced	All	Novice	Intermediate	Experienced
framerate, $\alpha_{g,1}$	-0.028	0.199	0.466	0.541	0.034	0.072	0.107	-0.025
bitrate (Mbps), $\alpha_{g,2}$	0.404	-0.022	-0.028	-0.046	0.060	-0.003	-0.010	0.002
I($framerate^2$), $\alpha_{g,3}$	6.391E-04	-0.096	-0.009	0.019	0.060	0.014	0.039	0.049
I($bitrate^2$), $\alpha_{g,4}$	-0.031	0.001	7.701E-05	-0.001	-0.004	-2.168E-04	-0.001	-0.001
framerate:bitrate, $\alpha_{g,5}$	0.003	0.005	0.001	0.005	0.001	1.572E-04	0.002	0.001
Constant, $\alpha_{g,6}$	2.611	4.902	1.897	1.116	3,473	4.065	3.155	3.296
R^2	0.986	0.915	0.969	0.977	0.782	0.496	0.773	0.763

H. Hong, C. Hsu, T. Tsai, C. Huang, K. Chen, and C. Hsu. Enabling adaptive cloud gaming in an open-source cloud gaming platform. *IEEE Transactions on Circuits and Systems for Video Technology*, PP(99):1–14, 2015.

Results – QoE estimation models (2/2)

📖 Wide discrepancies between estimated and reported values of QoE for different skilled players when using the QoE model designed without considering player experience
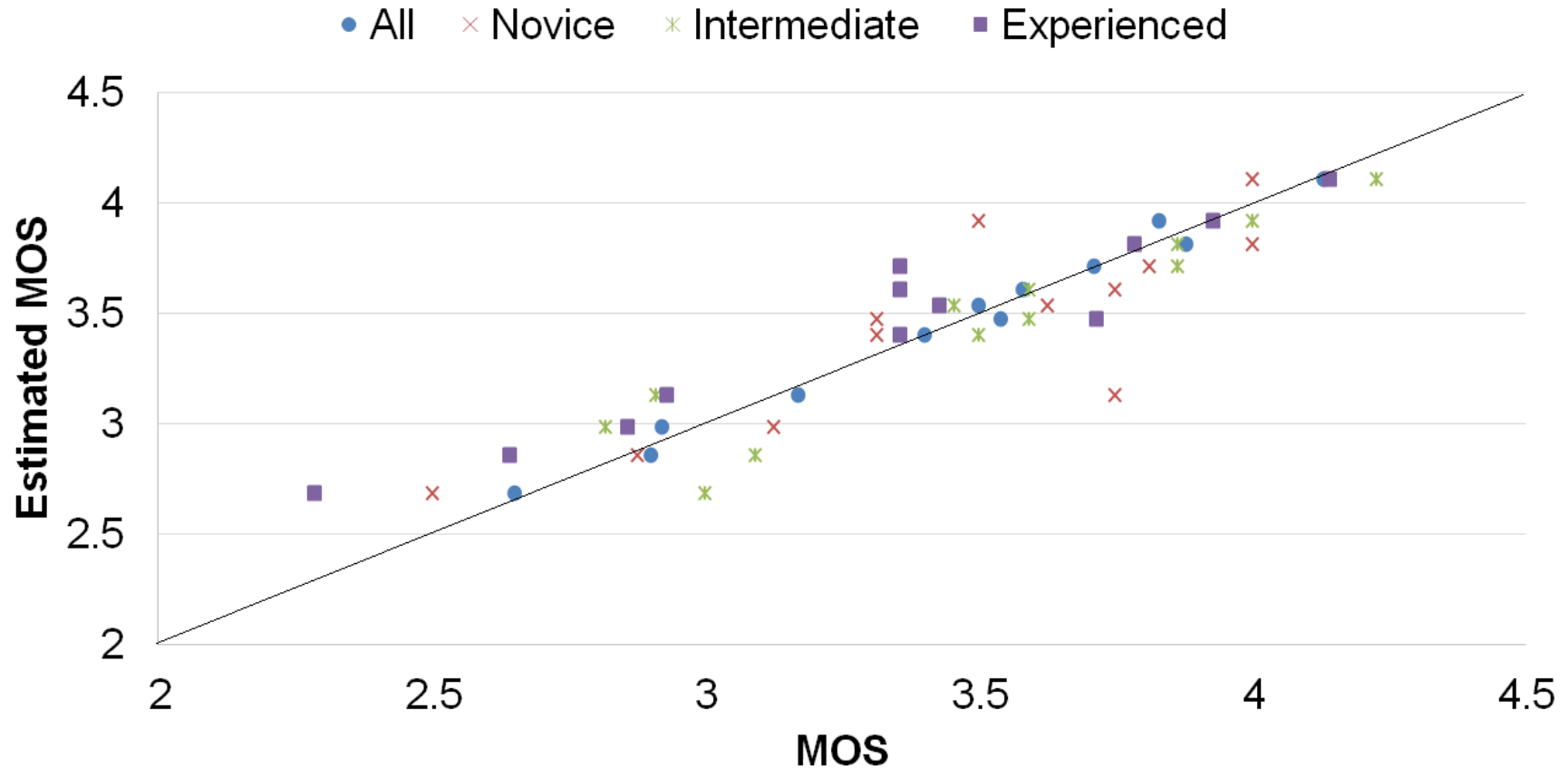
Results – measured objective video metrics

University of Zagreb

- Utilized to empirically quantify the differences between video streams of separate games
- Could provide a basis for future automatic game categorization which can be used for selecting optimal adaptation strategies for cloud gaming
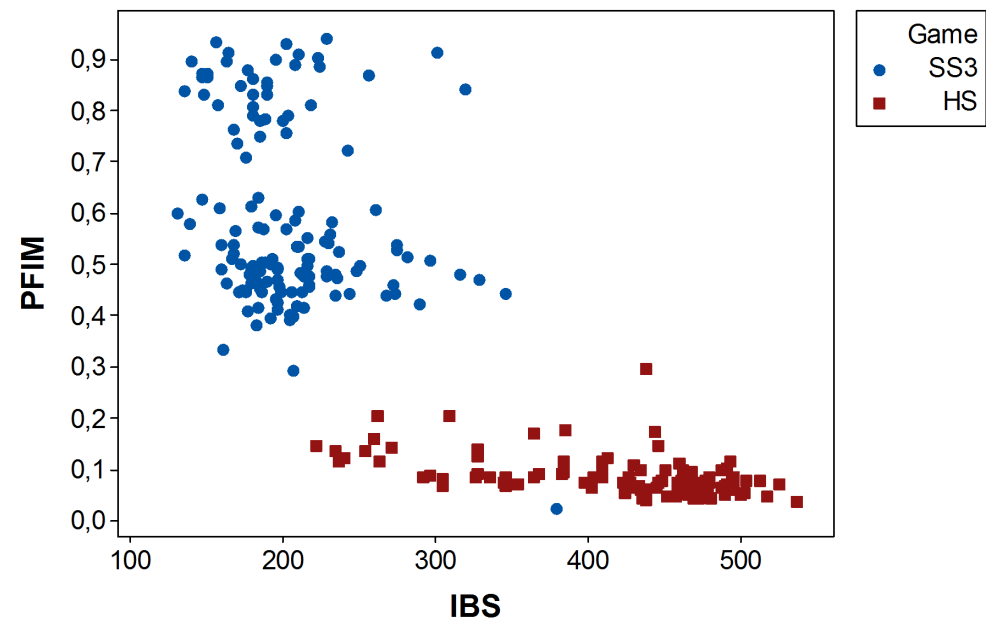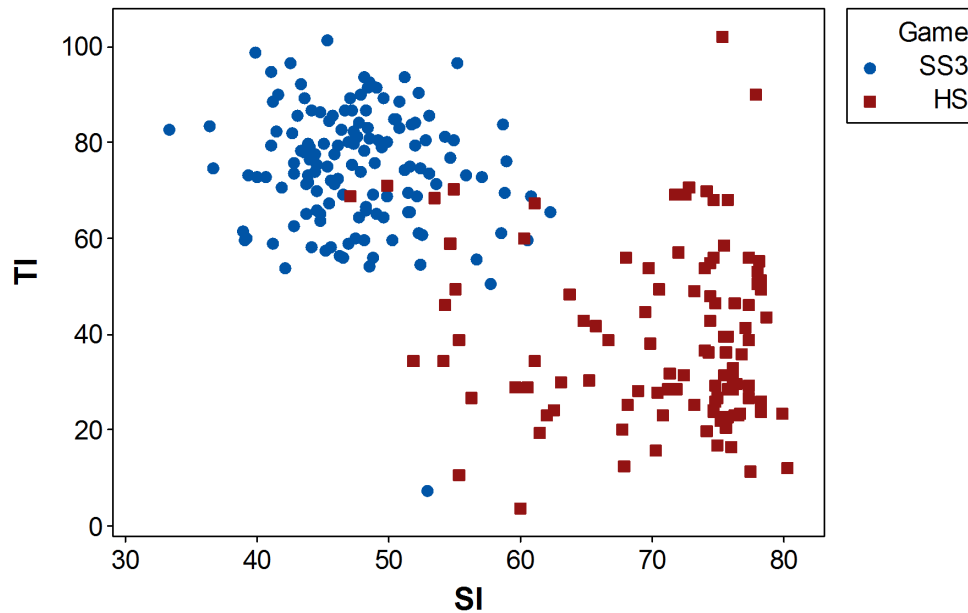
Conclusions

- The game type needs to be taken into account when evaluating the QoE of cloud games

- There is no linear relationship between frame rate and QoE – in some cases it is better to deliver lower frame rate and increase graphics quality

- There is significant impact of players' previous gaming experience on QoE, while for social context more research is needed in order to be able to numerically quantify its impact

Future work

- Deriving QoE-driven video encoding adaptation strategies for different available network conditions

- A game categorization for cloud gaming based on a subset of objective game characteristics and additional relevant context data used for determining optimal adaptation strategies for classes of games

- Extend the reported QoE models