The Impact of User, System, and Context factors on Gaming QoE: a Case Study Involving MMORPGs

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***Abstract*—In this paper we present a study evaluating the Quality of Experience (QoE) of players in the case of Massively Multiplayer Online Role-Playing Games. We consider the impact of different influence factors on players' QoE, namely system factors (delay, packet loss, jerkiness, and frame rate), user skill (in terms of game play experience), and context (in terms of action category and social context). In addition to obtaining subjective scores indicating overall QoE, we address the correlations between overall QoE and the following quality features subjectively perceived by players: immersion, interactivity, and fluidity. Results from laboratory tests involving 55 participants playing World of Warcraft (version 5.3.) have shown that player skill and social context affect user subjective evaluation scores. Furthermore, jerkiness and packet loss were found to significantly degrade QoE, while latency did not have a strong impact.**

I. Introduction

As the market of online games is becoming even more competitive, the question of "What makes games good?" becomes increasingly important. While the question might be simple, the answer is very complex and probably not universal. The psychological aspects of gameplay have been a challenge addressed by a number of researchers over the years in the field of user experience (UX) [1], [2].

In general, the subjective end user perception of the overall acceptability of an application or service has been referred to in literature as Quality of Experience (QoE) [3]. A more recent definition specifies a user's QoE as resulting from "the fulfillment of his or her expectations with respect to the utility and/or enjoyment of the application or service in light of the user's personality and current state" [4]. While often highly dependent on technical Quality of Service (QoS) and linked to performance parameters, QoE extends the notion of QoS by additionally considering the impact of user- and context-related factors on a user's subjective quality assessment. Hence, for example, two users with the same underlying QoS may ultimately experience very different QoE upon using the same service, due to additional factors such as context of use and user related parameters (e.g., prior experiences and knowledge, motivation, etc.).

In this paper, we focus on the assessment of QoE for Massively Multiplayer Online Role-Playing Games (MMORPGs). Our focus is on studying the impact of different influence factors (including user, system, and context factors) on user-perceived QoE. We draw from the generic classification of factors as proposed in [4], and further make reference to the taxonomy of gaming QoE aspects proposed in [5] in terms of deriving our empirical test methodology. Specifically, we consider the impact of four different system factors (delay, packet loss, jerkiness, and framerate), user skill (in terms of game play experience), and context (in terms of action category and social context). In addition to obtaining subjective scores indicating overall QoE, we address the correlations between overall QoE and the following quality features subjectively perceived by players: immersion, interactivity, and fluidity.

The paper is organized as follows. Section II gives a short overview of related work addressing gaming QoE. Section III presents our laboratory set-up and test procedure used to conduct experiments evaluating the QoE of MMORPGs using the game World of Warcraft (WoW) as a case study. Results regarding the influence of system, user, and context factors on QoE are summarized in Section IV. Finally, section V provides concluding remarks and outlook for future work.

II. Related work on gaming QoE

The majority of related work studying the user perception of game quality has focused on the impact of traditional QoS parameters (e.g., delays, jitter, loss, throughput) on subjective user perceived quality [6], [7], [8], [9]. Reported acceptable network impairment thresholds clearly differ for different game genres, with studies focusing on MMORPGs showing that acceptable latency values were under 120 ms, as higher delays resulted in Mean Opinion Scores (MOS) lower than 4 [10]. Another study extracted play sessions lengths for MMORPGs from network traffic traces and showed that session durations decline sharply for latency between 150 ms and 200 ms [11].

Certain studies have also focused on objective performance metrics, using synthetic players to assess gameplay [12], or introducing such measures as game outcome score [13] and online playability score [14]. Going beyond studying the impacts of network impairments, studies of frame rate impact on the performance of players and their perceived playability and quality in First Person Shooter games has been investigated [15], showing that decreased frame rate lowers playability and player performance, especially when frame rate goes under 15 frames per second (fps). Finally, only limited research has addressed the impact of additional user and context related factors, such as user skill [13], [16], psychological motivators for playing MMORPGs [17], or user physical effort and playing context (i.e., interaction with other players) [18].

Following the previously cited white paper [4], in recent work Möller et al. [5] have proposed a detailed taxonomy of gaming QoE aspects. Aimed at providing a generic evaluation framework, they identify the following three layers: QoS influence factors (related to the user, system, and context);

user and system interaction performance aspects; and finally QoE features related to the end user quality perception and judgement processes. The authors classify influence factors as being the following:

- *user factors*: experience, playing style, intrinsic motivation, static factors (e.g., age, gender), and dynamic factors (e.g., emotional status).
- *system factors*: game genre, structure, game mechanics and rules, technical set-up (including server, transmission system, interface software, and device characteristics).
- *context factors*: physical environment, social context (e.g., relation to other players involved), extrinsic motivation, and service factors (e.g., access restrictions, gaming cost).

The given influence factors impact system and user performance resulting from player interaction with the system, and are finally linked to the following quality features (dimensions): interaction quality (also linked to *playability*), playing quality (addressing game learnability and intuitivity), aesthetic aspects, and overall player experience. As previously proposed by Poels et al. [19], player experience may be considered in terms of sub-aspects flow, challenge, control, tension, immersion, positive and negative affect.

Motivated by the fact that QoE is a multidimensional concept, and that the majority of previous research addressing gaming QoE has addressed the impact of limited and isolated influence factors on players' QoE (mostly focusing on network QoS), we aim to simultaneously address the impact of multiple factors. Furthermore, we consider QoE in terms of multiple quality features. Stemming from the generic taxonomy proposed by Möller et al. [5], we propose a test methodology to study player QoE in the case of MMOPRGs, addressing a chosen number of influence factors and quality features as described further in the following section.

III. Methodology

The study was conducted in two phases: the first involved all participants taking part in a pre-survey questionnaire, and the second involved laboratory testing whereby participants took part in three-hour long gaming sessions. Participants were recruited from masters level students enrolled at the University of Zagreb, Faculty of Electrical Engineering and Computing. A total of 69 participants took part in the pre-survey, while 55 of them took part in the laboratory tests as game players.

A. Pre-survey

A pre-survey was performed several weeks before the laboratory testing using an online questionnaire. The primary aim was to gather data about the participants' previous gaming experience (games in general, multiplayer games, MMORPGs, and specifically WoW as a game which was to be tested). 33% reported having previous experience playing MMORPGs. Participants were asked to rate their skill level with regards to playing online games as being: novice, intermediate, or advanced. We opted for three levels, given that there were participants that had no previous experience in game play. This collected data was used in order to create player groups with different skill levels (further explained under test procedure). In addition to game experience, we collected data with regards to age, gender, right/left handedness, playing style, motivations for playing, average hours spent playing games per week, computer hardware used while playing, type of Internet connection, preferred business model (regarding costs of playing/purchasing a game), opinion regarding acceptable delay thresholds (for different types of games), motivation for playing, and user expectations with regards to various quality aspects. For example, results showed that users expected to be able to notice quality degradations for RTTs over an average of 143 ms. While we further limit our focus in this paper to reported player skill levels, further analysis of the additional obtained data will be addressed in future work.

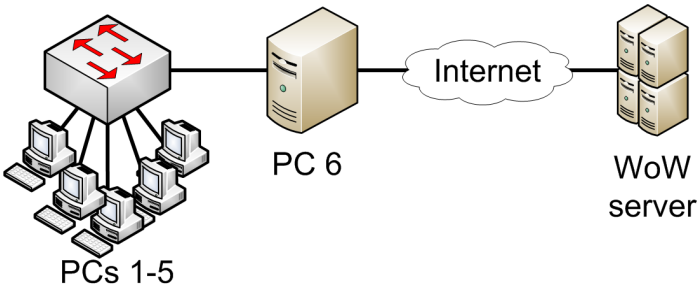

Fig. 1. Laboratory testbed

B. Laboratory set-up

The laboratory set-up that was used is shown in Figure 1. The game being played was WoW 5.3. The game was played on PCs 1-5, all running the WoW client on Windows 7 with the following configuration: DELL Optiplex 390, i3@3,3 GHz, 4GB RAM, ATI Radeon HD 6450. The graphical settings on each WoW client were set to *fair*, resulting in the frame rate being stable between 50 and 60 fps. PC 6 was used as a gateway to the Internet used to manipulate network transmission parameters (delay, packet loss). We acknowledge the fact that we could not control the transmission quality of the Internet connection to our laboratory, but note that our lab is connected via a 100 Mbps link, and that round trip time (RTT) between PC 6 and the WoW server was continuously measured between 30-40 ms. A summary of all QoE influence factors (IF) that have been considered in the study is given in Table I. Drawing from the taxonomy proposed by Möller et al. [5], factors are classified as being either system-, user-, or context-related. A total of 34 different combinations were tested, as described further under the test procedure. The following system factors were manipulated:

Frame rate: Frame rate was limited using the graphical settings on each WoW client (PCs 1-5). The values of the limits were 15 FPS and 25 FPS.

Jerkiness: Jerkiness, or popularly called "choppy graphics", can occur when the machine running the game cannot display the virtual world scene in real-time, resulting in temporary scene "freezes". This can occur in various situations, e.g., due to difficulty in rendering a scene comprising computing intensive graphics, other applications consuming hardware resources, inadequate hardware configuration, etc. We introduced this effect using a special script (run on PCs 1 – 5) which created a large number of processor jobs, effectively shortly freezing the game. Two versions of the script were created, one resulting in 1-second interrupts every 30 seconds, and the other resulting in 2-second interrupts every 15 seconds.

Delay: Delay was introduced on PC 6 using an Integrated Multiprotocol Network Emulator/Simulator tool (IMUNES) [20]. Two delay values were introduced (100 ms and 200 ms) resulting in an increase of Round Trip Time (RTT) by 200 ms and 400 ms. As noted, the nominal RTT to the WoW server from our laboratory was between 30 ms-40 ms.
Packet loss: Packet loss was controlled through a FreeBSD firewall. The probabilities for packet loss were 0.05 and 0.1.

The values of the manipulated system parameters were chosen based on empirical testing. Two players played the game, with each listed parameter being slowly degraded. The first value was chosen when the players reported they first noticed the degradation, while the second value was chosen at the value where players reported the degradation as severe. Only the values for latency were taken from previous studies of QoE for MMORPGs [10].

With regards to user factors, player gender, age, and experience (skill) was recorded. Player skill was taken into account when forming test groups. Further regarding context factors, we manipulated the *social context* by forming different types of player groups (group corresponds to five players simultaneously taking part in the lab testing). The group composition was either homogeneous (meaning all group members were of the same skill level), or mixed (meaning the five players involved were of mixed skill levels, including novice, intermediate, and expert). The group composition was an important factor as players were also requested to take part in collaborative group efforts. This is related to the tasks the players were requested to take part in, whereby we refer to these tasks as action categories. In previous work, five different action categories have been defined for MMORPGs [21]: Raiding, Questing, Trading, Player vs. player combat, and Dungeons. Considering the given action category that a player is involved in as a contextual factor, in this study we focus on two categories, namely *Dungeons* and *Questing*, differing in that Dungeons are an interactive group-based activity, while Questing involves a player taking on individual quests.

Following the identified influence factors, we summarize the parameters which we measured in Table II. Subjective ratings using a standardized 5-point MOS scale were collected to evaluate overall QoE, and the following additional quality features: perceived immersion, perceived responsiveness (in terms of the system reacting to user commands in real-time), and perceived fluidity (referring to the perception of the smoothness in the rendering of the virtual scene). Following a given test scenario, players were also requested to rate the level of challenge they experienced in the given scenario (5-point scale, from "very simple" to "very challenging"). Making once again reference to the taxonomy proposed in [5], we can consider this metric as being related to the user performance in terms of perceptual effort. Finally, two objective metrics we collected include: overall game play success achieved by a given player (corresponding to the level reached while questing, and the number of bosses (i.e., very strong enemy non player characters, with only a few of them in each dungeon) slain while passing through dungeons); and the number of "disruptive" events (i.e., player deaths, player getting lost).

Given the large number of variables and possible interactions to be taken into account, we focus primarily on the impact of system, user, and context influence factors on overall QoE, while correlations between QoE and the other quality features are only shortly reported.

TABLE I. INFLUENCE FACTORS AND CORRESPONDING VALUES

Factor	Values	IF category	Manip.
Delay	0ms, 200 ms, 400 ms (RTT)	System	X
Packet loss	0, 0.05, 0.1 (probability)	System	X
Jerkiness	0, 1s every 30s, 2s every 15s	System	X
Frame rate	60FPS, 25FPS, 15FPS	System	X
Game genre	MMORPG	System	
Game	World of Warcraft	System	
Transport protocol	TCP	System	
Age	From 21 - 26 years (average 23)	User	
Gender	Male (38), female (17)	User	
Player skill	Novice (14 players), intermediate (23 players), experienced (18 players)	User	
Social context	Homogeneous player group (2 novice, 3 intermediate, 2 experienced groups) and mixed (4 groups)	Context	X
Action category	Questing, Dungeons	Context	X
Physical environment	Laboratory	Context	
Extrinsic motivation	Obtaining credits for the course	Context	
Service factors	Full system availability, no costs	Context	

TABLE II. MEASURED PARAMETERS

Name	Metrics
Overall QoE	5 pt. MOS scale (1-bad, 5-excellent)
Perceived Immersion	5 pt. MOS scale (1-bad, 5-excellent)
Perceived Responsiveness	5 pt. MOS scale (1-bad, 5-excellent)
Perceived Fluidity	5 pt. MOS scale (1-bad, 5-excellent)
Perceived Challenge	5 pt. scale (1 - very simple, 5 - very challenging)
Score	Level reached (Questing), bosses slain (Dungeons)
Disruptive events	Death count, players getting lost

C. Test procedure

A total of 55 participants took part in the study as part of a masters course requirement, 38 male and 17 female, ages 21-26 with an average age of 23. The participants were organized into 11 player groups, each with 5 players. Based on reported player skill (collected via the pre-survey), the following groups were formed: 2 novice groups, 3 intermediate groups, 2 experienced groups, and 4 mixed groups (each consisting of 1 novice, 2 intermediate, and 2 experienced player). Each of the formed groups had at least one female player.

A total of 34 different test scenarios were evaluated (based on manipulated test factors: delay, frame rate, jerkiness, packet loss, and action category). Each of the parameters (except for action category) was tested for 3 values: 1) unimpaired, 2) degraded, and 3) severely degraded. Given that it proved too time-consuming for each player to evaluate all scenarios, 22 scenarios were chosen to be evaluated within each player group. The tests were organized so that every one of the 34 scenarios was evaluated by at least 10 players. Each group took part in the testing over a three-hour time period, with a 10-minute break allotted in the middle. Each test scenario lasted 5 minutes. The scenarios were set-up and coordinated by a test administrator, who requested players to pause after 5 minutes of game play, and provide subjective ratings of overall QoE, immersion, fluidity, responsiveness, and perceived challenge. Following these ratings, players continued to play the game (at the point in the game where they had left off), but under the conditions of a new scenario. The first 10 scenarios were tested while players were questing, after which the following 12 scenarios were tested while players were involved in

Dungeons. We note that for each group, an experienced WoW player "consultant" was available on site who only interfered with minimal advice in need, such as disconnects from the server, or if an inexperienced player did not know how to proceed. The following testing procedure was used:

1) Players were given instructions regarding the study, and the concepts of the game and controls.
2) Each of the players in the group created a new WoW character.
3) Players performed one quest in the game to familiarize themselves with the game and controls.
4) Players went through the first two reference scenarios (i.e., no degradations being administered, and maximum degradations of all system parameters).
5) The following eight scenarios iterated the values of one of the system influence factor, while all other dimensions were fixed at nominal values (no added degradation). The scenario sequence was randomized.
6) Following each 5-minute scenario, players were asked to provide subjective quality ratings.
7) Following a 10-min break, players switched to level 20 characters (which we previously created). These virtual game characters corresponded to the same class/race combinations that each player had been previously assigned.
8) All 5 players were added to a group and joined a Dungeons instance. The players took part in joint battles and tried to protect/help each other.
9) After eight scenarios which were based on testing each of the four system factors individually (as in step 5 for Questing), groups were instructed to evaluate an additional 4 scenarios in which multiple factors were simultaneously degraded. As the number of possible combinations for different values of degradations for four parameters is large (16), each group was assigned with a chosen number of scenarios which allowed us to test each combination of degradation parameters at least two times.

Latency	Loss ratio	Frame rate	Jerkiness	Action category
0	0	60	0	D
				Q
400	0,1	15	0,133	D
				Q
200	0	60	0	D
				Q
400	0	60	0	D
				Q
0	0,05	60	0	D
				Q
0	0,1	60	0	D
				Q
0	0	25	0	D
				Q
0	0	15	0	D
				Q
0	0	60	0,067	D
				Q
0	0	60	0,133	D
				Q

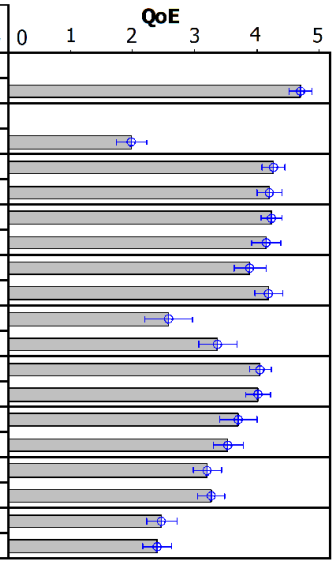

Fig. 2. The QoE scores of best case scenario, worst case scenario, and 16 scenarios with only one parameter degraded: avg. values and 95% CI.

IV. Results

A. System and context factors

The results of the QoE scores obtained across the first 18 scenarios (i.e., scenario 1 with no system parameters degraded, scenario 2 with all parameters degraded, and the remaining scenarios in which only one of the parameters was degraded while others were kept constant) are shown in Figure 2. All of the experiments have been done for both the Questing (Q) and Dungeons (D) action categories, except for the first two (reference) scenarios.

Results show that introducing what we have referred to as jerkiness (or freezing) is the factor which has the strongest impact on QoE, resulting in an average score of 2.4, which is slightly more then the average of 2.0 reported in scenario 1. The second most influential factor proved to be packet loss, followed by frame rate degradation, and in the end latency. While it has been reported in literature that some games, e.g., Quake 3 can tolerate up to 30% packet loss rates (with MOS scores over 4), for other games such as Halo loss rates of 2% already resulted in MOS scores dropping below 4 [16]. Our studies have shown that for WoW (Dungeons action category), packet loss of 10% resulted in average scores of 2.56, while for 5% packet loss average scores were 3.88. The impact of loss may be attributed to the TCP transport protocol being used. Another indicator of how packet loss affects the gameplay is based on the in-game latency indicator - hovering over a computer icon in the main menu of WoW results in a pop-up window showing the estimated latency by the WoW client. Introducing 1% packet loss resulted in reported latency estimations of hundreds of milliseconds (due to TCP retransmission mechanisms), although no delays were actually present on the transmission link.

What we found peculiar was the issue of latency, whereby we introduced latencies of 200 ms and 400 ms, which resulted in RTTs being up to 240 ms and 440 ms. Contrary to previous measurements and QoE models in which introducing this much latency resulted in significant lowering of the reported QoE, e.g., MOS of 2.6 for 400 ms latency reported in [10], the latency degradation proved to be barely noticeable to our test players.This phenomena might be attributed to the degradation of other parameters which resulted in more easily observable degradation (e.g., jerkiness), in-game mechanisms for hiding/combating latency, unfamiliarity of tested player group with the game under test (WoW). To shed further light on this issue we aim to further test this finding in future experiments.

When considering the impact of action category, we note that Questing is an action category in which players perform relatively simple tasks and usually do not require high player skill (especially true for the starting quests performed in our scenarios). On the other hand, Dungeons are a much more demanding action category which requires cooperation between players, enemies are much more dangerous, and players can easily be killed. Comparing Questing and Dungeons with respect to reported QoE values, we found that for delay, frame rate, and jerkiness there were no significant differences, while in the case of loss increases, player QoE was more severely impacted in the case of Dungeons. Inspecting immersion as a quality dimension revealed that there is a significant correlation between the reported perceived immersion and overall QoE

TABLE III. RESULTS OF SCENARIOS WITH MULTIPLE DEGRADATION

Jerkiness	Frame rate \ Delay	Loss rate 0,05 – 200ms	Loss rate 0,05 – 400ms	Loss rate 0,1 – 200ms	Loss rate 0,1 – 400ms
0,067	25	2.7	2.8	1.9	2.19
	15	2.73	3.1	1.93	1.6
0,133	25	1.9	2.53	1.5	1.7
	15	3.25	2	1.5	1.7

= 5

= 1

score. In 6 out of 8 scenarios, we found the same relationship between QoE and immersion for both Questing and Dungeons.

B. *User and context factors*

Further, we wanted to inspect how combinations of different simultaneous degradation parameters affect the QoE. We inspected this through an additional 16 scenarios which were only performed in the Dungeons action category. In each of these scenarios all parameters were degraded (i.e., frame rate, jerkiness, latency, and loss) to two different levels. Each of the scenarios was performed by two different player groups, and for some even three. The results are presented in Table III. In the table, darker fields correspond to lower QoE score. Results of these scenarios confirm the findings in the first set of scenarios that jerkiness and loss rate are the factors that affected QoE the most. The highest QoE degradation (i.e., the lowest scores) are noted when both of these parameters are severely degraded (level 2 degradation). It is interesting that the lowest reported values are not reported in cases involving increased latency.

A further goal of our study was to investigate the impact of players' previous game experience (skill) on perceived QoE. We distinguish between scores reported by novice, intermediate, and experienced users (focusing on the first 18 scenarios). As previously mentioned, user skill was determined based on results of the pre-survey we conducted. The average score reported by experienced players was 0.3 less than the average reported by novice players, as shown in Figure 3. While this difference is not very extreme, it still confirms previous findings that have shown experienced players to be more demanding [16]. In addition to the impact of player experience, we were interested in studying the impact of social context on how users rated the quality of their experience. By social context, we refer to the composition of the 5-member group that a player was involved in. From 11 groups, 2 groups were composed of only novice players, 2 groups from only experienced players, and 3 groups from only intermediate players. The remaining four groups were "mixed" groups. In Figure 4 we compare average QoE scores for players in "homogeneous" groups and compare them with the scores of players of the same skill level but in mixed groups. Interestingly, results have shown that both novice and intermediate players improve their QoE when playing in mixed groups, most likely due to improved group game performance resulting from the involvement of more experienced players. On the other hand, experienced players reported lower QoE when novice and intermediate players were involved, as they found such a group composition to degrade their overall QoE. The highest observed difference between mean values is for novice players (0.3).

To inspect the influence of in-game performance on QoE we measured "unexpected events" which were: deaths of characters, players getting lost in the virtual world, from the server, etc. These events were noted for each of the performed scenarios (all 34 scenarios). Most of the noted events (over 90%) were character deaths. Our hypothesis was that if a player's character would die, that would result in lower QoE. We inspected the mean QoE of all the players who reported unexpected events in a particular scenario versus the QoE of player with no unexpected events. We found that there was no significant correlation between in-game performance and QoE in our specific case. We aim to investigate this aspect in more detail in future studies.

Finally, we inspected the Pearson correlation coefficient between overall QoE and the additional rated QoE features: responsiveness (0.809, $p<0.005$,) fluidity (0.796, $p<0.005$), and immersion (0.809, <0.005). Results show significant correlations between overall QoE and all three observed perceptual features, confirming that these are indeed significant quality features for MMORPGs. Additionally, we found no correlation between QoE and the indicated perceived challenge

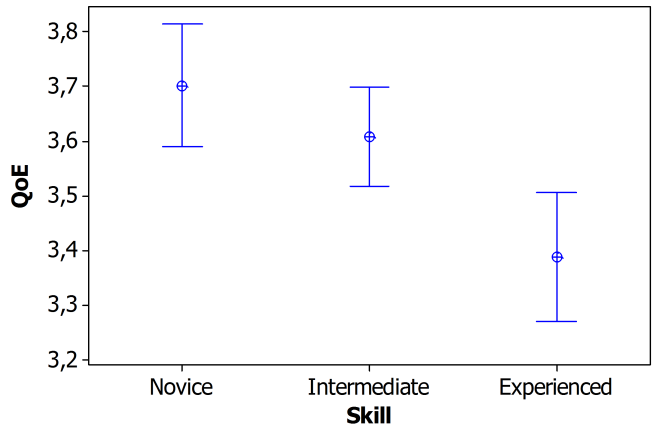

Fig. 3. The impact of player experience on QoE (avg. values and 90% CI).

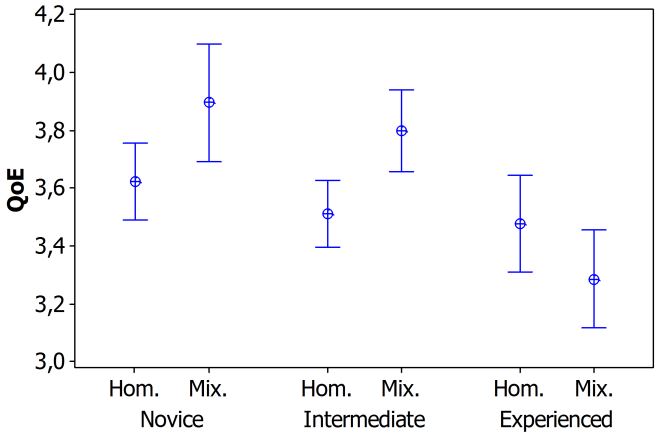

Fig. 4. The impact of group composition QoE (avg. values and 90% CI).

level, meaning that even though certain tasks were perceived to be much more challenging (mostly related to Dungeons), this did not necessarily impact QoE scores.

V. Conclusions and future work

We have presented the results of a study focused on MMORPGs that has addressed the impact of various system-, user-, and context-related factors on the QoE of game players. Out of four manipulated system factors (delay, packet loss, jerkiness, and frame rate), we found jerkiness to have the greatest impact on players' QoE scores, followed by packet loss and frame rate. Our delay manipulations resulting in RTTs of up to 240 ms and 440 ms surprisingly did not result in lower QoE scores. Furthermore, we found that the impact of packet loss on QoE was greater in the case of the action category *Dungeons* as opposed to *Questing*, indicating also that the impact of system factors differs depending on the concrete actions being performed by the players. With regards to the impact of player experience (in terms of skill), our results confirm that skilled players are more critical than non-skilled players, which can be concluded based on lower average QoE scores for skilled players. We also found that players' social context (given that this is a multiplayer game), had an impact on QoE, confirming that the skill of other players involved needs to be considered as in influencing factor.

With regards to further work, additional studies are needed to consider more fine-grained factor manipulations and their impact on QoE, paving the way for deriving a QoE model for MMORPGs. Also, other MMORPGs need to be studied in order to generalize results. Finally, while we have observed correlations between overall QoE and the identified quality features immersion, responsiveness, and fluidity, further studies based on multidimensional analysis and regression techniques may be used to identify additional QoE dimensions and their relevance in terms of overall QoE. Our long term goal may be seen as the development of a validated gaming QoE model which considers key system, user, and context factors,derived based on extensive experimental results.

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