Fear, Discomfort, and Perception of Time in Virtual Reality

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Abstract—**This paper presents the results of preliminary tests of the QoE4VR (Quality of Experience for Virtual Reality Applications) project, funded by the University of Zagreb. The project is aimed at achieving the better understanding of the relationship between different objective and subjective parameters that may affect user Quality of Experience when using different VR applications. We conducted the initial experiment with 10 test subjects who played racing game Project Cars in VR environment. The paper discusses the impact of subjective parameters, such as fear and discomfort of our test subjects, on the achieved level of QoE in the game. The results show how even high levels of discomfort were not negatively reflected on a user experience. Additionally, the paper reports on user misperception of time after being immersed into VR.**

Keywords-Virtual reality, Quality of Experience, Subjective parameters, Objective parameters, Games

I. Introduction

Over the past 10 years, the scientific community has invested considerable efforts in disclosing the dependencies between the objective and the subjective parameters that can have an impact on user perception of telecommunication service quality. The new concept emerged – QoE (Quality of Experience) – highlighting the importance of a user and its' opinion as well as the importance of the environment where the QoE evaluation takes place. With this new QoE concept, the research community took a step forward, leaving behind more typical approaches to service quality evaluation when the focus was on the network parameters (i.e., monitoring if a service performance targets are met).

Broadening the scope of the service quality evaluation and putting the focus on the user means that different subjective parameters must be included in the evaluation process. Hence, different authors in their analysis investigate the impact of a wide pallet of parameters, for instance, level of user entertainment, stress and fatigue, past experience of service usage, the social context in which a service is used and others. The authors in [1] grouped these parameters into three main categories, i.e. impact factors (IF): human IF, system IF, and context IF.

In the 2017 University of Zagreb granted funds for the implementation of the Quality of Experience for Virtual Reality Applications (QoE4VR) project [2]. One of the main objectives of the project is to discover the relationship between a user perception of quality of Virtual Reality (VR) applications in different network conditions. Since the virtual and augmented reality hardware and software only recently started to truly penetrate the markets [3], the problem of QoE evaluation for these types of services comes to the fore. At the pinnacle of this new field of research, is the investigation of user QoE for VR applications which run online (such as video streaming, online multiplayer gaming and different forms of real-time social interactions in VR environments).

For this purpose, we are building on our past research presented in [4-5] and continue investing an effort to find out the correlation between the level of user QoE for VR applications and values of measurable system IF, such as latency, packet loss, and video frame rate. These correlations can then be modeled and used for remote QoE evaluation or prediction, similarly as it is done in [6]. Additionally, the set of system IF which may produce an impact on user experience can be extended by other parameters such as field of view (FOV) or vertical synchronization (V-sync) as argued in [7].

After acquiring the necessary equipment, at this stage of the project, we are beginning to analyze the user QoE without introducing network or visual impairments. The objective of this stage is to reach a better understanding of the impact of human and context IF on the user perception and QoE. This paper presents the first results of this stage.

The paper is organized as follows. In Section 2 we present our test environment and test methodology. Section 3 brings and discusses the results of our first tests. Concluding remarks are given in Section 4.

II. The Experiments

A. Test Environment

The computer used for testing was equipped with Intel Core i7 6800K processor, 16 GB of DDR4 RAM and EVGA GeForce GTX 1080 Ti FTW3 gaming graphics card. For the VR headset, we acquired HTC Vive. Although it was more expensive, compared with other products like Oculus Rift, the HTC Vive came with two VR controllers right from the box and it has a SteamVR support. Note that HTC Vive supports two possible VR settings, namely, Room Scale playing area or Standing playing area. In this experiment, we used the former.

The test was done using the racing game Project Cars which has full VR support and its Pagani Edition version is *free to play* on Steam. In the game, the player enters the virtual cockpit of a car and races in a single player mode with or without computer opponents on a track. As mentioned in the Introduction, at this stage of the project we are not yet focused on multiplayer gaming, i.e. the impact of system IF such as latency or packet loss on user QoE. The computer used for the test can maintain the stable frame rate (>60 fps in HD resolution) in all game scenes (the graphics settings of the game were set to maximum quality).

Note that the racing game is chosen because it requires continuous concentration from a player and all our test subjects drive a car in real life, so they were able to compare, to some extent, that real and VR driving experience.

Figure 1. Test environment

Since we wanted to increase the level of immersion of our test subjects into the VR racing environment, the subjects raced on a VR track using Logitech G29 racing wheel that provides force feedback effects (Fig. 1). As stated in [8], haptic feedback can enhance realism and QoE in the VR environment.

B. Test Subjects

The tests were done with 10 test subjects between 25 and 50 years of age. Namely, we had two female and eight male participants. On a scale from 1 to 5, where 1 means *No experience* and 5 means *Extensive experience*, five test subjects rated their previous racing experience in computer games with 1, two test subjects rated it with 3 and another two rated it with 4, while one test subject rated it with 5. On average, the previous racing experience (in or out of VR) of the test group equaled to 2.4, while the average racing experience in the game used in the test equaled to 1.4. The subjects' past experience is also depicted in Fig. 2.

All test subjects received a short description of the test procedure. The subjects were introduced with the hardware and its functionality (VR headset and racing wheel controls) and they were all given enough time to adapt to the VR environment. Note that before the actual racing in the game, the subjects spent some time in the VR living room area where they could familiarize themselves with the VR mechanics (for instance, how to move in VR reality or how to interact with VR objects in the scene).

After this introduction, test subjects entered the virtual cockpit and drove around the track without the computer opponents. All test subjects drove the same car, on the same track, in the same conditions (weather and time of day). We did not want to force the subjects to complete a predefined number of laps on the track, thus, each test subject drove the car as much as he or she wanted. This was since some people can experience nausea, i.e. cybersickness, in a VR environment [9], so our test subjects were able to end the testing session when they pleased.

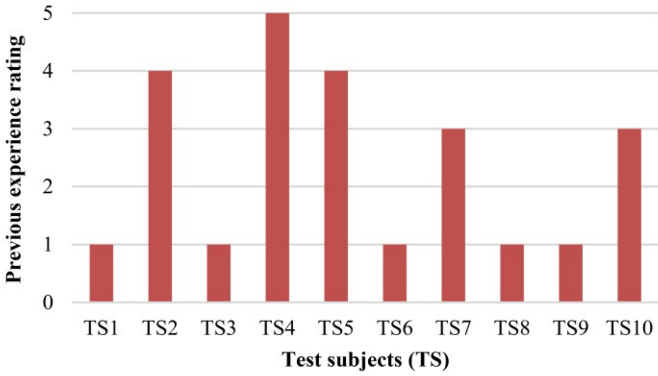

Figure 2. The previous gaming experience (VR and other)

III. THE RESULTS OF THE INITIAL EXPERIMENTS

During each test session, the game recorded the best lap time of that session. In Tab. 1 the best lap times of the sessions are presented for each test subject. For some test subjects (TS1, TS3, TS7, and TS9) the game did not record the time. The game stops recording the lap time if a player cuts the track corners or if a player went off the track.

TABLE I. TEST SUBJECTS' RACING RESULTS

Test subject	**In-game performance**	
	No. of laps driven around the track	***Best lap time (mm:ss)***
TS1	1	No record
TS2	4	2:30.107
TS3	1	No record
TS4	15	1:50.933
TS5	7	1:54.996
TS6	5	2:37.500
TS7	1	No record
TS8	4	2:34.180
TS9	1	No record
TS10	5	2:32.458

eISSN: 2453-6571, cdISSN: 1339-5076
10.18638/rcitd.2018.6.1.120
ISBN: 978-80-554-1495-9

One can immediately see that those four test subjects (TS1, TS3, TS7, and TS9) drove only one lap around the track. This was due to feeling discomfort or fear while driving. Note that TS1 did not felt discomfort (e.g., nausea, disorientation etc.) like other three test subjects from this sub-group. TS1 felt fear after losing the control over the car when the crash was unavoidable and discontinued the session because of that.

On a scale from 1 to 5, where 1 means *No discomfort at all* and 5 means *Extremely discomfort experience*, the subjects rated their level of discomfort. The results are presented in Fig. 3. As mentioned earlier, TS3, TS7, and TS9 experienced higher levels of discomfort which forced them to end the session after only one lap. We believe that this is because these three test subjects wear glasses and they had to take them off in order to put VR headset on; that impacted their discomfort level. Interestingly, TS1 did not report any discomfort, even though this subject felt the fear of crashing the car.

Note that in these initial experiments we did not investigate the subjects' level of cybersickness using, for instance, the questionnaires developed by Kennedy et al. in [10]. However, that is one of the tasks of the QoE4VR project since we are interested to disclose in detail the impact of user discomfort, including cybersickness, on the level of QoE.

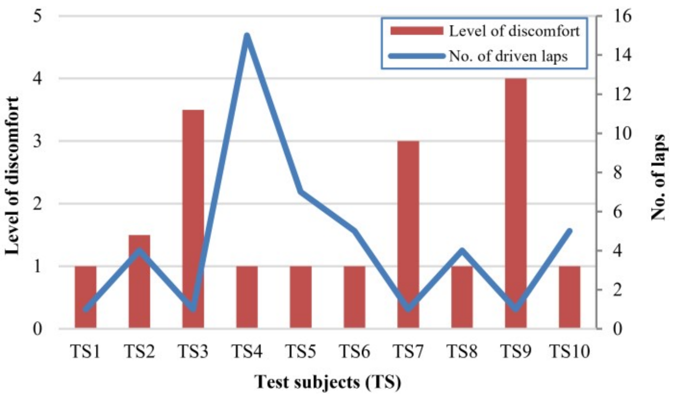

Figure 3. The subjects' level of discomfort in relation to the number of driven laps around the track

When comparing the results presented in Fig. 2, Fig. 3 and Tab. 1, we can see that the best lap times were achieved by the subjects who are experienced players in computer gaming (TS4 and TS5), which is an expected result.

Average user Quality of Experience equaled to 4.15 (on a scale from 1 to 5, where 1 means *Worst experience* and 5 means *Excellent experience*). Notwithstanding, even the subjects who reported the higher levels of discomfort rated their VR racing experience with a high rating (Fig. 4).

At this stage of the project, when only a few tests were made with a relatively small group of test subjects, we can only speculate why the higher levels of discomfort were not reflected entirely on a user QoE level. One explanation can be the "wow effect" which VR technology can still invoke in many inexperienced test subjects. Nine out of 10 test subjects had only a little or no experience in VR gaming, while neither of them had the opportunity to race in VR environment using a haptic device such as a racing wheel. Thus, the overall user experience was probably under a large influence of the new VR technology which completely imprisoned the test subjects' senses inside the virtual racing track.

Consequently, in our future tests, we would need to use more experienced testers, to avoid the aforementioned "wow effect" and to be able to differentiate between QoE ratings in relation to dynamic VR conditions (e.g. changes in the frame rates or resolution). It can be expected that more experienced test subjects would be able to devote more attention to the VR application performance and rate their QoE with more accuracy and objectivity.

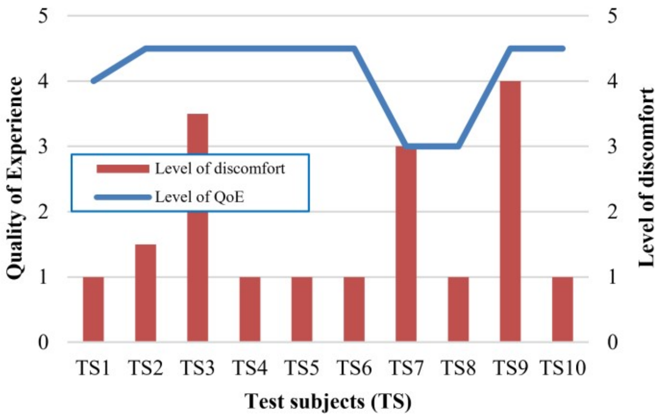

Figure 4. The subjects' Quality of Experience in relation to their Level of discomfort

We want to report on another interesting finding considering the test subjects' perception of time (Tab. 2). Half of our test subjects felt that their VR racing session lasted shorter compared to the actual time (negative values in the *Difference* and *Relative error* column in Tab. 2). The most distinctive difference is recorded for TS4 who thought that the session lasted 10 minutes shorter than it was (the relative error equals -33.33%). Note that this test subject was the most experienced one and probably had the most fun during the test. He set the best lap time and achieved a high level of QoE with no discomfort.

TABLE II. TEST SUBJECTS' PERCEPTION OF TIME

Test subject	Session duration [min]	Subjective feeling about the session duration [min]	Difference	Relative error [%]
TS1	2	4.5	2.5	125
TS2	15	10	-5	-33.33
TS3	4	6.5	2.5	62.5
TS4	30	20	-10	-33.33
TS5	20	15	-5	-25
TS6	20	20	0	0
TS7	2	2	0	0
TS8	15	15	0	0
TS9	3	1.5	-2.5	-50
TS10	10	6	-4	-40

eISSN: 2453-6571, cdISSN: 1339-5076
10.18638/rcitd.2018.6.1.120

ISBN: 978-80-554-1495-9

When we observe the previous gaming experience of other test subjects (Fig. 1), it is interesting to note that all test subjects with the experience ≥3, i.e. TS2, TS4, TS5, and TS10 (except TS7), reported shorter session duration. If we assume that these test subjects enjoyed this new format of gaming (VR environment paired with the haptic device), then it is reasonable to argue that there is a correlation between a user perception of time, his or her level of enjoyment and previous experience. However, we will pursue the testing of this hypothesis in our future research.

Interestingly, the results presented in Tab. 2 differ from those reported in [11] where the authors showed how the subjects' perception of time in the VR environment was 6.5% increased compared to the actual time. Yet, the authors' experiment included only walking in a VR environment without the interactions or competitiveness which were a part of our experiment. Another important distinctiveness between these two experiments is the test duration. The tests in [11] lasted between 2 and 5 seconds which is considerably shorter compared to our experiment. Moreover, the test subjects in [11] were asked *Did you move longer or shorter than # seconds?* with the # replaced by the corresponding reference time spend in the VR environment. Hence, due to shorter tests and an implication of its actual duration in the stated question, it was easier for the test subjects to accurately quantify the time, leading to smaller relative errors.

Note that it is also shown in [11] how the relative error decreases with the increase of the test duration, but the absolute error increases. This explains the misperception of time of our test subjects.

Finally, we can report that all test subjects stated that haptic device used for testing, i.e. the force feedback wheel, enhanced their level of immersion into the VR, making the whole experience feel more realistic, thus, confirming the findings of Ryge et al. presented in [8].

IV. Conclusion

In this paper, the results of the first initial experiments of the QoE4VR project were presented. At this stage of the project, when only a few tests were conducted with a relatively small group of test subjects, we are not yet able to draw comprehensive conclusions regarding the impact of different human, system, and context IF on user QoE for VR applications. However, the experience gained with conducting these initial tests and interpreting the obtained results will help us in deciding where to steer our future research endeavors in this project and beyond.

The paper showed how the test subjects reported high levels of their QoE, despite the discomfort which they might have experienced. We are particularly interested in disclosing further what is the nature of the relationship between human emotions, such as fear, and user QoE; since one of our test subjects had to end testing session due to fear induced by the game, yet the subject rated the whole experience with the high rating.

Another cognition that was reached is the need to experiment with test subjects who already have at least some previous experience in using VR technology for different purposes (gaming, video streaming etc.). This is because, for instance, only an experienced VR gamer could devote more attention to how a game performs and how that reflects on the level of QoE; compared to the inexperienced test subject who is more likely to be fascinated with VR environment and somewhat oblivious to the provided service quality.

Our previous research experience teaches us that the content used for the testing greatly affects the results. This finding is confirmed also in these tests. Hence, we would like to continue experimenting with VR applications, such as multiplayer games, 360° video streaming, and others, which are more likely to be used by standard users in everyday situations.

Even though the HTC Vive headset can accommodate user' glasses, in our experience we witnessed that test subjects with glasses often felt nausea and discomfort while being immersed into VR. Their testing sessions ended prematurely, hence in future we would have to employ test subjects with unimpaired vision.

The additional path for the future research, which was opened with these initial experiments, is finding a better understanding of the relationship between a user perception of time while immersed into the VR environment and the level of user past experience and enjoyment. As indicated in the paper, more experienced test subjects, who enjoyed our testing sessions, had difficulty in perceiving the time accurately.

Finally, we proved that our test environment, including hardware and software components, can be used for such testing.

Acknowledgment

The results presented in this paper originate from the Quality of Experience for Virtual Reality Applications (QoE4VR) project activities. The project is funded by the University of Zagreb under *Short-term financial support for researchers* program in 2017.

The authors wish to thank their colleagues who participated in the experiments.

Declaration of Interest

The authors have no conflicts of interest to declare nor they promote any hardware components or software applications mentioned in this paper.

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