Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Electronic Systems

Daniel Breive Havre

VR i Sport

Master's thesis in Electronics Systems Design and Innovation
Supervisor: Andrew Perkis
January 2020

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Summary

Repetitive indoor endurance exercises such as running on a treadmill or rowing on an ergometer used to be tedious. The use of technology in sports and other physical aspects is rapidly emerging to improve performance, motivation, and experience. This has led to the development of immersive experience products (such as Nintendo Wii and PS4 VR/AR). Where one of the more popular experiences is Virtual Reality.

This project looks at how technique related feedback presented inside a virtual reality during an ergometer rowing session affects the Quality of Experience regarding the user's motivation, performance, and immersion. The testing setup consists of a rowing ergometer and a head-mounted display connected to a virtual world. Here the user is be fed information in real-time throughout the session.

The system was tested by 30 participants, 20 males, and 10 females, with an average age of 24.3. After experiencing the scenarios, the participants filled out a subjective evaluation of the system. The results indicate that the participants had a positive increase in motivation, performance, and immersion. The total experienced workload had increased significantly compared to the previous system. Additionally, the results show that the overall Quality of Experience was higher for the new system.

Keywords: Gamification, Virtual Reality, Quality of Experience, User Experience, Performance, Motivation

Sammendrag

Repeterende utholdenhetsøvelser gjort innendørs, som å løpe på en tredemølle eller ro på et ro-ergometer pleide å være ensformig og kjedelig. Bruk av ny teknologi i idrett og andre fysiske aktiviteter er i kraftig vekst, hvor det er fokus på forbedring av motivasjon, prestasjon og opplevelse. Dette har medført utvikling av produkter som fremmer ”immersive” opplevelser (som Nintendo Wii, PS4, ”virtual reality” og ”augmented reality”), hvor virtuell virkelighet (VR) er den mest populære opplevelsen.

Dette prosjektet vil se på hvordan brukeropplevelsen (Quality of Experience) blir påvirket av at brukere får tilbakemeldinger på teknikk under en økt. Prosjektet vil også se på hvordan dette påvirker brukerens motivasjon, prestasjon og ”immersion”. Testutstyret består av et ro-ergometer og en hodemontert skjerm som som gir brukeren innsyn i en virtuell verden. Her vil brukeren få informasjon i sanntid gjennom hele økten.

Systemet er testet av totalt 30 personer hvorav 20 av dem er menn og 10 er kvinner, og gjennomsnittsalderen er 24.3 år. Etter hver økt fylte testdeltakerene ut en subjektiv evaluering av systemet. Resultatene indikerer at deltakerene hadde en positive økning i forhold til motivasjon, prestasjon og ”immersion”. De viser også at den den totale arbeidsbyrden opplevd, var større for den virituelle opplevelsen der tilbakemelding ble vist. Resultatene viser også at den totale poengsummen (Quality of Experience) til opplevelsen har økt.

Preface

I am submitting my master thesis to fulfill the requirements for a Master of Science (MSc) degree at the Norwegian University of Science and Technology (NTNU). The work regarding this thesis has been done over 20 weeks, from September 2019 to January 2020. There are several people who have helped me during these months.

I would like to thank PhD Student Asim Hameed for supervising me continuously these months. He has given me valuable feedback and engaged in many discussions regarding the project.
Professor Andrew Perkis has been my main supervisor, and have done an excellent job.
I would like to thank my 30 test participants, who took time off their busy schedule test my project.
Finally i would like to thank NTNU for giving me this Master thesis opportunity.

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1 | Introduction

The use of technology in sports and other physical aspects is rapidly emerging to improve performance and gain experience. There are products in the market which have made a name for themself in the gaming and exercise community. Products such a Nintendo Wii and PlayStation 4 (PS4) have over the last decade developed advanced equipment for a more immersive, alternate gaming and exercise platform. Combinations of games and exercise are increasing in popularity, e.g., golf simulator, tennis, running, and cycling, to mention some [2]. Introducing the concept of *exergames* [3], a combination of game and exercise. Students at NTNU have developed a cycling ergometer exergame, where you are controlling a tank from POV in a multiplayer virtual world where you control the tank by cycling. There are several projects out there, and we see that immersive games are increasing rapidly. Reasons for this is the feeling of immersed- and enjoyable experiences that these exergames bring to the table [4].

Figure 1.1: Participant after experiencing VR

Providing users with more immersed experiences tend to increase the Quality of Experience (QoE) [5]. The description of immersion is how our other senses and emotions are affected by the experience. To get a better grasp of the User Experience (UX) the term Quality of Experience is introduced. According to *Quality of Experience: Advanced Concepts, Applications and Methods*, one fundamental understanding of Quality is the degree to which a set of inherent characteristics fulfills requirement [5].

The QoE is a measure of the quality regarding the user's subjective experience. Additionally, it is dependent on what reference point the participant uses to judge said experience. Hence, it is inherently difficult to objectively measure QoE since there is no formal set of rules for measuring one specific experience. In the paper *Qualinet White Paper on Definitions of Quality of Experience*, a definition of QoE is given, in which this paper uses as basis [6]:

Quality of Experience (QoE) is the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and / or enjoyment of the application or service in the light of the users´s personality and current state.

Along with the increased popularity for immersive experiences, there is more need for precise sensors and sensor feedback to optimize the experience. The use of sensor data can be a tool to increase the *immersiveness* of the experience. Retrieving sensor data provides an opportunity to register physiological information. With such data, we can create a precise and enhancing experience and give the user feedback information, which could prove preferable in an exercise situation. In exergames, personal performance is one of the main factors contributing to the increase and maintenance of motivation when exercising. Thus it is logical to expect this applies to exergames. In many aspects of sports and exercise, performance enhancement requires an understanding of the technique and progress. Therefore the use of real-time information about technique and progress is desired.
One platform with the potential to exploit said desires is Virtual Reality, henceforth abbreviated VR. VR is per definition a universal term for audiovisual and haptic-based computer simulation of real or imaginary environments. With the use of VR, we can both display and interact with a computer-generated environment, which allows the users to interact with real-time audiovisual events in 3D [7]. The computer-generated experience is designed to either train, entertain, or explain the task at hand [8]. This is a human-computer-interaction (HCI) platform, which can induce a more immersive experience when combined with indoor exercise.

Where there is a desire to increase the motor skills of humans through the use of VR as alternative training [9], there is also room for more study. VR areas such as film, games, medicine, and sports are seeing a rapid increase in popularity. With an increasingly more advanced world and computer technology, simulated experiences such as VR are becoming more dynamic and hybrid. Combining advanced virtual realities with physiological sensor feedback creates many opportunities to create effective multimodal experiences [10].

In this particular project, an experiment is conducted. In the experiment, the participants experience a VR scenario, followed by a subjective questionnaire. The questionnaire results work as a basis for the *measurement* of QoE. The measurement method assesses the level of service and identifies the quality of the experience. Where the main goal is to see if an upgrade of an already existing project increases the user's motivation and performance. Proposing the initial hypotheses:

Introducing gamification and game elements inside an VR experience, such as feedback on technique and progress will increase both the motivation and performance of the user during an exercise workout

This research is based on how implemented gamification and game elements inside a virtual world affect the performance and motivation of a user during an exercise session. The setup consists of a rowing ergometer, a head-mounted-display (henceforth HMD), and a snowy mountain themed virtual world, in which the user partakes in a virtual rowing session.

Two systems are to be tested by the participants. The first one is the default system, where the users are getting no information — followed by a second experience, where the users receive real-time feedback regarding the technique displayed inside the virtual reality. The first experience works as a reference. After each session, the participants answer a subjective questionnaire, which is compiled by already validated, physiologically questions. These questions are mainly focusing on presence, workload, motivation, UX, and performance.

When operating in VR, the visual senses are crucial for the experience. Therefore, the presentation and UI (graphic design) of the technical data is essential to achieve the best possible QoE. At the same time, one needs to restrict the data flow and visual effect concerning the goal of the experience. Thus aspects such as graphic design and placement of data are discussed.

2 | Background

2.1 Existing projects

The use of technology in sports and other physical aspects is rapidly emerging to improve and prepare users for a specific experience or task. Since indoor exercise became a possibility, technology has seen steady growth and development. Treadmills and other ergometers started with mechanical resistance but have advanced to high technology machines where there are several applications for each user. Today these machines can come with screens that display performance data in real-time. Some treadmills can have you running in exotic environments, such as in jungles, woods, mountains. There are opportunities to watch television and movies while exercising. Several of these implementations increase motivation and performance [4]. A popular and still developing tool regarding technology and exercise advancement is the use of VR.

Some areas especially use VR more than others. Where there is a desire to increase motor skills of humans through the use of VR as an alternate training/preparing method [9]. In the health sector, there are oodles of HCI and VR projects with health benefits, both for young and old [11] [1]. By using VR, we have the opportunity to create realistic environments and provide users the opportunity to interact in a way that otherwise is impossible. Creating new and exciting opportunities for many patients and people with reduced capacity. If it is training for a medical procedure or wanting to have better balance, in general, there is a significant chance that there exists an exergame for just this [12] [13].

Figure 2.1: In-game screenshot of exergame (left) and a user playing the game (right). Picture obtained from [1]

The application areas of exergames are endless, and will most likely continue to expand during the next years, proportionally with the expanse of HCI technology. The introduction of VR has created several different opportunities, and in aspects such as sport and exercise, there is much one can achieve.

2.2 Virtual Reality in sports

Using alternative methods for traditional sports have been more and more relevant as both the technology and technicality of the given sport has developed [14]. Exercises such as running, rowing, cycling have developed alternative indoor platforms such as treadmills, rowing ergometer, and cycling ergometers. As mentioned with these alternatives comes many simulation opportunities, as in this case: the use of VR and sensor feedback [10]. As mentioned above, this is especially prevalent in individual endurance sports. Where the progress is based alone on the performance of the user.

With feedback from physiological sensors, the participant can receive valuable information about technique and progress during an exercise session. This information can, in turn, help the exerciser to perform better. Training in VR to increase performance and technique has already proven to be a success in some previously published projects [15] [16].

This concept has the opportunity to motivate the exerciser to push limits to achieve better results. By introducing an alternative virtual world with a steady stream of feedback values, one would assume the motivation for the workout would increase as well. The individual motivation is also dependant on *locus* (the spatial factor), control, and stability [17], which are factors that need to be satisfied by the users, especially when operating in an alternative world such as a virtual generated world.

2.3 Previous research

Previous study, which is particularly relevant to the practical part of this project, is amongst others; *Using Virtual Reality and Head-Mounted Displays to Increase Performance in Rowing Workouts* [16]. Where the results state that exercising while using VR, improved the performance and an enhanced experience. This research focused on how a virtual environment affected the performance and experience over a regular rowing session on a rowing machine.
There was two different test conditions during this research, one where the participants normally rowed on a rowing machine receiving distance data (traditional workout) continuously. The second condition took place in a virtual environment, with distance feedback every 50 meters. While the participants participated in the experiment, some objective measures were taken such as measuring the pulse.

The work in [16] said that athletes perform slightly better with regard to technical aspects in the VR-condition compared to the traditional workout. The performance data, such as completion time, show a significant difference. However this was disregarded since the participants concentrated on technique rather than on time. The subjective experience results in the paper [16] show that *Concentration on the task* has a higher score for the traditional workout. Postulating that during this session, the participants had fewer distraction elements, and could focus more on the technical elements.

Arndt et al. [16] says that the participants scored higher on *loose sense of time*, which may be in line with the fact that the participants enjoyed the VR experience more than the traditional experience. The results also show an increase in arousal score, but athletes felt less in control of the rowing experience for the VR session than the traditional session. They also scored higher for the autotelic experience (purpose).

Another project investigated *Factors of Immersion in Interactive Digital Storytelling* by Sebastian Arndt, Martin Ervik, and Andrew Perkis [18]. In this study, participants played through a digital story using HMD and its controllers. Afterward, they answered a subjective questionnaire. Where the goal was the investigate the subjective factors that are contributing to the immersion experience.

The results indicate that the content itself may not necessarily need to be highly arousing to feel most immersed. This is indicating that the user has the impression of being in control of the experience during a virtual experience, therefore enjoying it more.

2.4 Combining Virtual Reality with gamification elements

As games and game technology increasingly transcend the traditional boundaries of their medium, introducing concepts such as gamification and game elements.
Gamification is an informal umbrella term for the use of video games elements in non-gaming systems to improve the UX (user experience), and user engagement[19]. Potential new additions to an already existing application, which may cause an experience to be more gamified and thus increase the user experience. UX is in several regards heavily correlated with QoE [20]. Based on what application or experience, the implementation should be characteristic in each scenario.

To create more enjoyable interfaces, researchers have introduced gamification and game elements in HCI scenarios. In this paper, the HCI scenario is a virtually created world where the user is rowing in a snowy mountain themed water environment. Previous research showed that in general, the users enjoyed the VR experience more than rowing on an ergometer. Though the application has the potential to evolve more. By applying gamification, and thus game elements, the goal is to create a more immersive experience. Which in turn have the potential to increase the UX and QoE.

In this particular project, we have several metrics originating from the AugleticsEight rowing ergometer [21], see table 2.1.

Metric	*Description*
Stroke Length	**Stretch further! Roll forward until your shins are in vertical position**
Recovery	**Try to roll forward slowly and steadily. This put less strain on your joints**
Rhythm	**Pull handle quickly towards your chest then roll slowly forward. A good rhythm is 20 strokes per minute**
Consistency	**Try to make every like the last one, using the same amount of strength and the same technique**
Movement	**Extend you arms first, then move your upper body forward and only then begin to bend you knees and roll forward**

Table 2.1: Metrics from the ergometer from Augletics.

2.5 Hypothesis

These data have the potential to become game elements inside the virtual environment to increase the gamification factor of the experience. Where the goal is to increase the motivation and performance a user is experiencing during a VR exergame session. If assuming that providing users with relevant feedback regarding their technical performance motivates them to perform better. By introducing previously mentioned elements assumes that the level of immersion increases as well. Therefore a new postulation on which this research uses as a basis: that implementing gamification and game elements into this application will be a positive addition concerning the User Experience and Quality of experience. Formally changing the definition of the initial hypothesis, which the research of this paper uses as a basis. The second and final hypothesis:

Introducing gamification and game elements inside a VR experience, such as feedback on technique and progress will increase the QoE, with regard to motivation, performance and immersion of the user during an exercise workout.

3 | Theory

3.1 Basis

The idea of using game design elements in non-game contexts to motivate and increase user activity and retention has rapidly gained popularity in the design phase.
Ideally, one would want to introduce some game elements that are satisfying several or all components of *Flow*, developed by Csikszentmihalyi [22]. Where the goal is to achieve a higher level of attractiveness for the particular exergame.

3.2 Flow

The idea of the attractiveness of a game is supported by the *"flow"* construct developed by Csikszentmihalyi [22] (Table 3.1). The flow concept is equivalent to *being in the zone*. The mental state of operation where a participant is performing an activity is fully immersed in a feeling of energized focus. Where flow is a point list to achieve total engagement in an activity (table 3.1). The concept of flow is well established in several domains concerning exergames.

1	Balance between perceived skills and perceived challenge (difficulty)
2	The merging of action and awareness.
3	Clear goals (expectations and rules are discernible and goals are attainable and align appropriately with one's skill set and abilities)
4	Unambiguous feedback (successes and failures in the course of the activity are apparent, so that behaviour can be adjusted as needed
5	Concentrating and focusing, a high degree of concentration on a limited field of attention (a person engaged in the activity will have the opportunity to focus and to delve deeply into it).
6	A sense of personal control over the situation or activity.
7	A loss of the feeling of self-consciousness (no feelings of self-doubt or self-concern).
8	Transformation of time (one's subjective experience of time is altered).
9	Autotelic experience (the activity is intrinsically rewarding - it is undertaken for its own sake).

Table 3.1: The nine components of the experience of "flow"

Whereas the description of the golden rule of flow: skills need to be matched with challenges to maintain the interest of the participant.

When operating inside a virtual world, a larger display or including more multimodal elements of the environment increases the sense of immersion [23], and potentially influence on the performance. During a real-time cycling task that displays progress, detailed feedback has proven an increased motivation [23].

3.3 Quality of Experience Context

Quality of Experience is the measure of the overall level of satisfaction for a given customer. QoE expresses user satisfaction, both objectively and subjectively. Measuring of QoE is somewhat user-dependant since the evaluation is subjective, and some users are easier to please than others. The best way to evaluate the QoE is by providing a poll or questionnaire to a large number of participants.

Presenting QoE from the perspective of a person who's experiencing a given scenario involves a technical application, service, or system. Signals, as well as contexts, have the potential to influence the perception and quality that the user is perceiving.

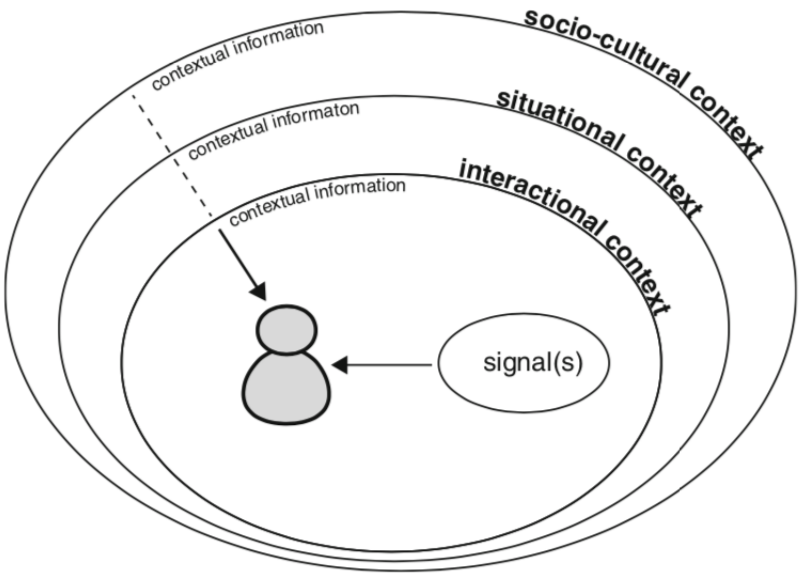

Figure 3.1: Different contexts a person may be embedded in. Each context is associated with a specific ecosystem

The perspective, shown in figure 3.1, whereas in the table under, the explanation.

Signals	the visual (3D virtual) and haptic feedback
interactional context	The virtual world and environment
Situational context	the reason why something is occurring. Participants, testing the system.
The socio-cultural context	the socio-cultural background of test participant and task master forms the socio-cultural context.

Table 3.2: QoE contex paramters

3.4 Measuring QoE

This exergame, where the main goal is to increase the quality of experience positively. By subjectively increase the motivation and performance of a user during an exercise session. Thus subjective indicators such as motivation and performance are of great interest to the developer. Another important indicator which is of relevance to the participants QoE is the sense of presence.

3.4.1 Presence

Presence is defined as *the subjective experience of being in one place or environment, even when one is physically situated in another*. Where the presence is a normal awareness phenomenon that requires directed attention and is based on the interaction between sensory stimulation, environmental factors the encourage involvement and enable immersion [24].

3.4.2 Motivation

From 2.1 five values provide the user technique feedback. These values are dynamic and updated for every stroke, providing the user with continuous and consistent feedback on his/her technical performance. In addition to informing the user about the technique feedback, it also motivates the user by the constant changes. Ideally, you would want to have the highest possible score, and displaying this visually on the rowing ergometer monitor allows the user to strive for excellence. Thus motivating the user to row better technically.

When rowing in a virtual world, it would be desired to provide this feedback to the users, in addition to the motivation that the virtual environment is providing. Since VR is heavily dependant on the visual senses, it would be preferable to display ergometer values in such a way that it coexists well with the virtual world.

3.5 Performance

Performance is another indicator that's correlated with motivation. Does the user subjectively increase performance during a virtual exergame such as the one in this project? Does the virtual experience motivate the user to perform better regarding progress and effort?

Displaying the ergometric values and motivating the user to achieve an ideal technique based on continuous feedback will, in the long run, boost the overall performance of a given rower. In addition to the ergometric values, its desirable to include some progress feedback, such as distance and time.

3.6 UI - User Interface / graphical interface

The way of presenting the data is an important issue. To optimize user performance in multimodal systems such as VR, a good design of data representation is critical. Presenting the ergometric data visually is desired. It is desirable to increase the level of gamification and reduce complexity. The goal would be to display the data in such a way that the users can see the presented data in an understandable and relatable way.

A "good vs. bad" interface may unconsciously affect the QoE. Thus the graphical representation of the ergometric values should be easily understandable and dependable e.g., visually pleasing and continuously updated. Presenting the data graphically instead of numerically makes the user more receptive to the feedback.

Displaying the five values as bars, ranging from 0 to 100, where 100 is the most ideal value (figure 3.2).

Figure 3.2: Sketch of graphical representation of ergometric values.

Displaying the values as bars ranging from 0 to 100 based on the input from the ergometer is more desirable than presenting the values numerically since it can be hard for a user to relate. Additionally, it allows the system to include data such as the previous stroke values without making the feedback overly complicated. Presenting previous stroke data as well as the current stroke values, makes the feedback more relatable. Figure 3.2 shows a potential view of the display during a hypothetical session. The values are ranging between 0 and 100, the darker lines are representing the previous stroke value. The box to the right is the current value represented numerically by %, and on top there is a timer.

3.6.1 Placement

In a 3D virtual world, there are many alternatives as to how and where data can be displayed. Just as commercials place logos and brand marks in the lower right corner, application theory has its ideas. One possibility is to make the technique feedback as a third link between the virtual world and the real world. The first test is to display the feedback in the camera view. Meaning that the feedback bars (fig. 3.2) are always in the upper right corner of the view when in VR.

Another approach is to display the data as a ”dashboard” on the boat. This way, the user has the opportunity to look at the feedback when it pleases him/her. Placing the ergometric feedback on the boat as a game element means that the overall gamification aspect increases.

4 | Materials

4.1 Questionnaire

The questionnaire used in this project is a result of compiling several other questionnaires. The reasoning is that it is important to use validated questionnaires that are known when asking for physiological feedback. The questionnaire is consisting of questions from the *NASA Task Load Index*, *User Experience Questionnaire* (UEQ) and *Presence questionnaire, Witmer&Singer* [25][26][24]. For each question in the compiled questionnaire the answers are registered on a 7-point Likert scale. Where 1 equals the negative response, and 7 equals a positive response. The compiled questionnaire used in this project, see appendix, named: *Questionnaire used - Compiled by WitmerSinger, UEQ and NASA-TLX*.

4.1.1 User experience questionnaire

The UEQ is a well-established questionnaire and has been investigated and validated in several studies [26]. The questionnaire contains 6 scales with a total of 26 rating questions (table 4.1.1). The items scales from -3 to +3, where -3 represents the most negative, 0 is neutral, and +3 represents the most positive answer.

- 1) **Attractiveness**: General impression towards the product. Do user like or dislike the product?
- 2) **Efficiency**: Is it possible to use the product fast and efficient?
- 3) **Perspicuity**: Is it easy to understand how to use the product?
- 4) **Dependability**: Does the user feel in control of the interaction? Is the interaction with the product secure and predicable?
- 5) **Stimulation**: Is it interesting and exciting to use the product? Does the user feel motivated to further use the product?
- 6) **Novelty** Is the design of the product innovative and creative? Does the product grab users attention?

The dependency of the UEQ scale is presented in the figure below (figure 4.1).

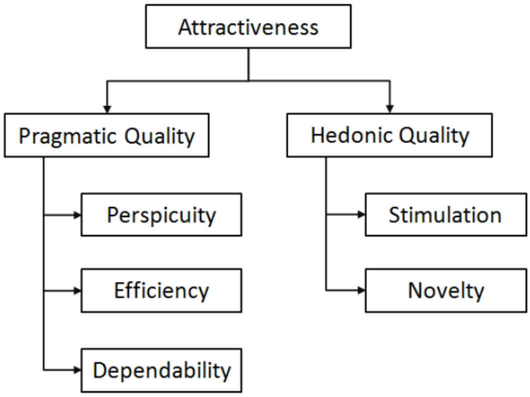

Figure 4.1: Scale structure of the UEQ questionnaire

The UEQ application has been proven to be useful when comparing the user experience of two products. Relevant to this project is the comparison of an established product version with a newer redesigned version to see if the new version has a better user experience. The overall scenarios in which to use this questionnaire is [26]:

- Evaluation of new beta versions by selected beta testers
- Assessment of released software by randomly selected users
- At the end of a classic usability test to evaluate a new prototype

(see Appendix for the original questionnaire (figure 8.1))

4.1.2 NASA Task Load Index

The NASA Task Load Index (NASA-TLX) is a multidimensional scale designed to retrieve the workload estimates from participants immediately afterward, a task. The workload is a term that represents the cost of accomplishing mission requirements for the human operator [25]. The NASA-TLX is built upon six subscales, which are somewhat independent clusters of variables: Mental, Physical and Temporal Demands, Frustration, Effort, and Performance (see appendix 8.2).

- **Mental Demand** How much mental and perceptual activity was required? (e.g thinking, deciding, calculating, remembering, looking, searching etc). Was the task east or demanding. Simple or complex or forgiving?

- **Physical Demand** How much physical activity was required? (e.g. pushing, pulling, turning, controlling, activating)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

- **Temporal Demand** How much time pressure did you fell due to the rate or pace at which the tasks, or task elements occur ed? Was the pace slow and leisurely or rapid and frantic?

- **Effort** How successful do you think you were in accomplishing the goals of the task set by the experimenter? How satisfied were you with your performance in accomplishing these goals?

- **Performance** How hard did you have to work (mentally or physically) to accomplish your level of performance?

- **Frustration Level** How insecure, discouraged, irritated stressed and annoyed versus secure gratified , content, relaxed, complacent did you feel during the task?

The combination of these factors are representing the workload experienced by the operator or user (See appendix for the NASA-TLX questionnaire original form 8.2).

4.1.3 Witmer&Singer - Presence Questionnaire

The Witmer and Singer questionnaire is a questionnaire for eliciting presence in virtual environments [27]. Witmer and Singer define presence as *Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another*. Presence also refers to experiencing the computer-generated environment rather than the actual physical locale. See Appendix for the selected questions from the original Questionnaire A.

4.2 Equipment

4.2.1 Rowing ergometer

The rowing ergometer is an Augletics Eight2 [Fig. 4.2] machine from Augletics [21]. A commercial factor is that the rower can feel the acceleration in every stroke.

Figure 4.2: Ergometric Machine - AugleticsEight

The machine consists of several physiological sensors used to determine factors such as technique, power, and progress. This data showed on the ergometer display as a digital coach. The digital coach parameters are shown in figure 4.3.

Figure 4.3: Digital Coach values from the AugleticsEight monitor during a test row

There are two different sets of data to be derived from the ergometer sensors. The data from the Digital Coach, giving technique feedback on your rowing. These values include rhythm, movement, stroke length, recovery, and consistency (table 4.3). The second data set is spatial information, e.g., data used for position, force, and speed. By using this, we can control/move the virtual boat per the user's actual movements.

4.2.2 HTC Vive

To the display of the virtual world, a HTC Vive Head-Mounted Display set is used (figure 4.4). This is a visual component used for VR and lets the user see the virtual world.

Figure 4.4: HTC Vive HMD

This tool can capture the user's view in a 360 degree in all directions, ideally for experiencing a 3D virtual world.

4.2.3 C-Sharp

The programming language is C-sharp (simplified C#).

C# is a simple, modern, general-purpose, and object-oriented (class-oriented) programming language. It is intended mainly for use in developing software components suitable for deployment in distributed environments. C# is one of two programming languages compatible with Unity (JAVA is the other). When creating and upgrading new objects or existing game-objects, the written language was C# .

4.2.4 Unity

The 3D graphical platform where the virtual worlds designed is created in Unity. The Unity program is where the creation of the world and all the game objects is happening. The design of the technique feedback parameters modeled here. The same goes for the environment (figure 4.5).

Figure 4.5: POV from the virtual boat, with several game-objects

Staring up the world consisted of a single rowing boat in the middle of water surrounding snowy mountain tops. There was an indicator every 50m called checkpoint that appeared as a colored line for each checkpoint so that the participants would have some control over distance.

5 | Method

Data from the Augletics rowing machine can be downloaded from a server to the computer (figure 5.1). From here, it is possible to convert and display the data in the virtual world.

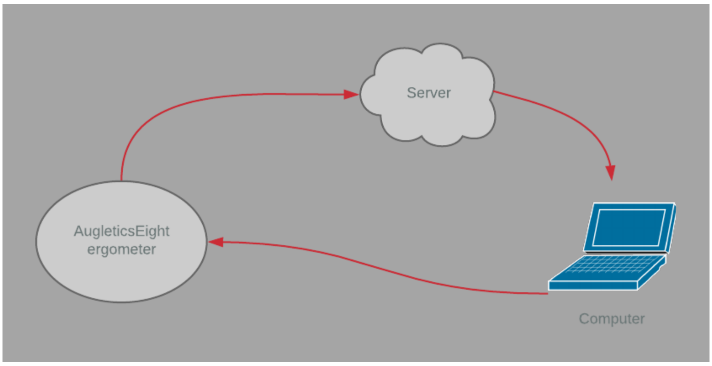

Figure 5.1: Data route map

The default system consists of the virtual environment (figure 5.2), and the ability to move, by performing strokes on the rowing ergometer. As you row, there are distance measures, which show as checkpoints every 50 meters.

Figure 5.2: View from default experience

5.1 Actual Setup

5.1.1 Feedback board

The graphical design of the feedback board is based on the sketch shown in figure 3.2. The actual implementation and graphical design can be seen in figure 5.3. Where each of the five values is ranging as bars from 0 to 100. Additionally, white markers were implemented, which represent the previous stroke value. The box to the right display the current bar values in percentages.

Figure 5.3: Front view of dashboard from start, all values equals zero

Each of the five stroke values on the rowing machine is updates for each stroke. The ergometric data is downloading and updating the same data by each frame rate, ensuring continuity. Above the technique tablet, there is a timer, letting the user know how much time has passed since start.

5.1.2 Prototype 1

The first prototype was to place the feedback of the ergometer data in-camera-view, meaning the feedback interface would always be in the upper right corner in camera view wherever you looked. The reasoning behind this was that this would act as a link between the virtual- and the real elements.

After some consideration and personal testing, a conclusion was made, this way of displaying the feedback was not ideal. Having the feedback always in view, was experienced as distracting and annoying. Thus another approach was chosen.

5.1.3 Prototype 2

The goal for the second prototype was to add the feedback data as a game element, an integrated part of the VR experience, displaying the feedback data on the front of the boat. The reasoning behind this placement was to create a more gamified and authentic experience. In comparison to drive a car, where there is information about fuel, speed, on the dashboard, you have information on technique and time on the boat (figure 5.4).

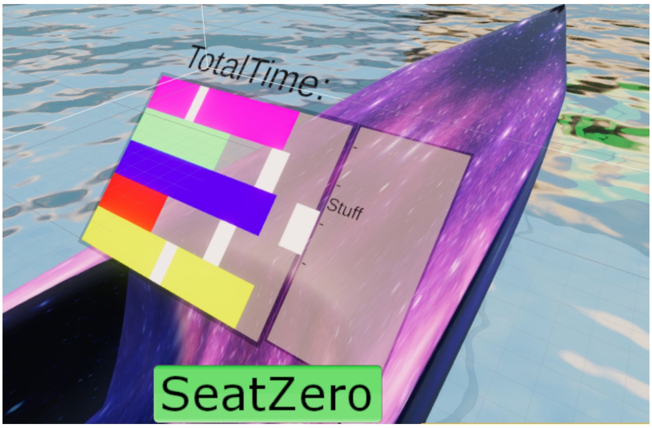

Figure 5.4: Ergometric value bars

5.1.4 Complications

During one of the tests, two of the five ergometric values disappeared from the ergometer monitor (movement and recovery). Resulting in the data was not being sent or registered in the server, meaning no feedback on movement and recovery, see figure 5.5. After resetting, re-calibrating and debugging both the software and hardware, the issue still wasn't solved. A call to the manufacturer was made.

Figure 5.5: Digital coach when bugged

The problem was that the magnetic sensor under the seat of the ergometer was out of position, probably due to candidates dropping too hard down on the seat or general rough use. The issue was quickly fixed by resetting the magnet position manually and resetting the seat position data on the ergometer monitor. After a restart of the whole system again, everything worked as it should.

5.2 Testing

Participants were testing two different rowing scenarios. The first scenario henceforth referred to as the *default scenario*, is the scenario with no feedback. The second scenario is with feedback. The reasoning behind having two scenarios tested is to use the default scenario as a reference.

After the participants had experienced a scenario, they would be asked to fill out a questionnaire. See appendix A - D for detailed information on this (e.g., questionnaires, research protocol, experiment conditions, and the consent form).

5.2.1 Measuring QoE

When measuring QoE, the Mean Opinion Score (MOS) is often the preferred method. This method is calculated as an arithmetic mean of each rating from the participants in subjective quality evaluation. Meaning that the results presented in the next chapter are the mean of each question delivered by the 30 participants.

6 | Results

6.1 testing summary

In total there was 30 participants, 10 female and 20 male. The average age of the participant was 24.33 years. Most of the participants said they had a *little* experience with rowing on a rowing machine (figure 6.1). Meaning that they mainly used it as a warm up exercise, or that they, on a rare occasion, rowed as exercise.

The participants tested two scenarios. First, they performed a reference session without any feedback, followed by a session where they rowed with feedback. These two sessions will be referenced as such, respectively, without feedback (Without FB) and with feedback (With FB). Each question answer is based on the 7 points Likert scale.

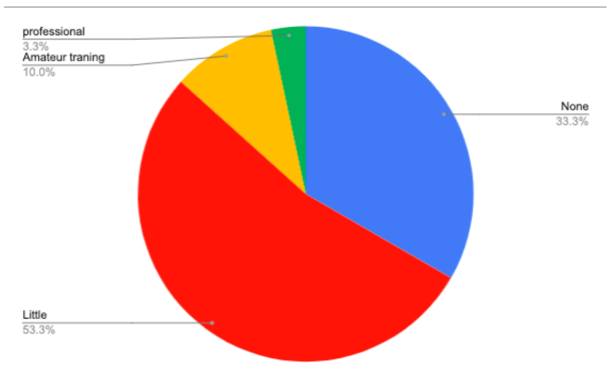

Figure 6.1: Participants previous experience with rowing on a ergometer

6.2 Metric results

See Appendix A - ***Questionnaire used - Compiled by WitmerSinger, UEQ and NASA-TLX***, for questions reference

6.2.1 Workload - NASA-TLX

The NASA Task Load Index result is presented in figure 6.2, which is questions 1 to 6. These results provide feedback on the subjective workload estimate that each user felt during the exercise.

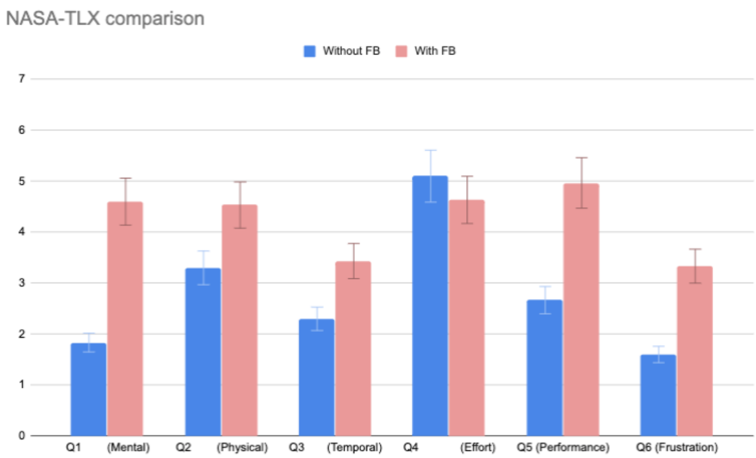

Figure 6.2: NASA-TLX MOS. Scenario 1 vs Scenario 2

From figure 6.2 we see that the perceived workload scores are higher for the experience with technique feedback. One scale that is off compared to the rest of the scales is *Effort: How hard did you have to work to accomplish your level of performance*. The mental demand and performance demand scored significantly higher for the system with feedback regarding technique. All the other NASA-TLX scales favor the system with feedback.

To calculate the weighted workload scores, we assume that each score is equally weighted in this scenario. The calculation of the overall workload is a result of the summation of the mean values, see figure 6.3. These results show a significant difference between the two scenarios, where the one with technique- and progress feedback have the highest workload score.

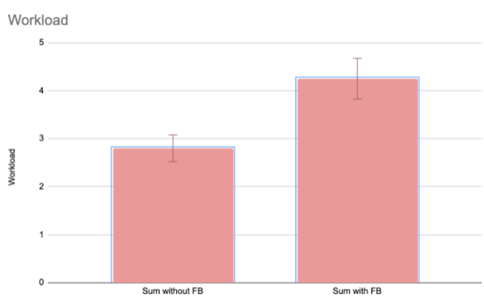

Figure 6.3: Total avg. workload

6.2.2 UEQ results

The results of question 7 to 12 is presented in figure 6.4.

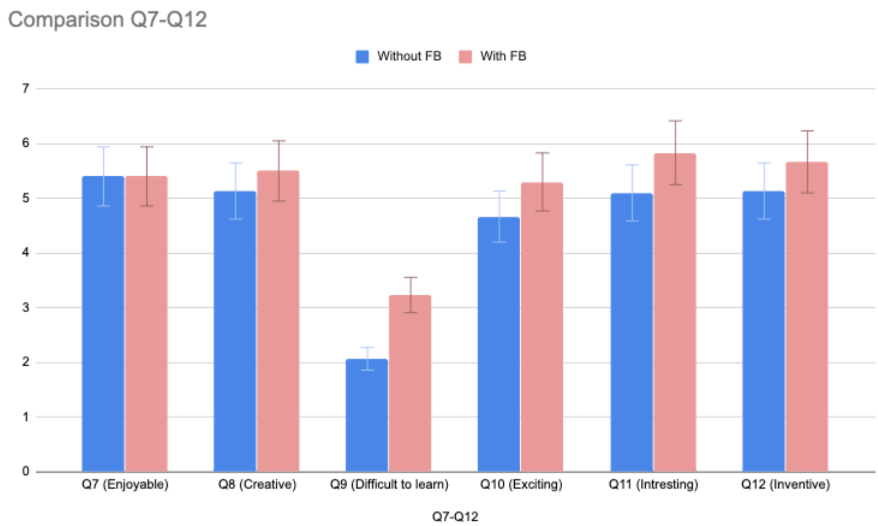

Figure 6.4: Mean score questions 7 to 12

The results from Q7 to Q12 shows that the participants find the experience just as enjoyable regardless of feedback or not. Participants scores low on *Q9 - What was the learning experience like for you (Easy to learn → Difficult to learn)*, indicating that both experiences are not overly complex and understandable. The experience with technique feedback scored higher on this scale, meaning the experience was harder regarding the learn-ability, but this is as expected when most amateur users are struggling with advanced technique feedback.

Results from questions 13 to 18 is presented in figure 6.5.

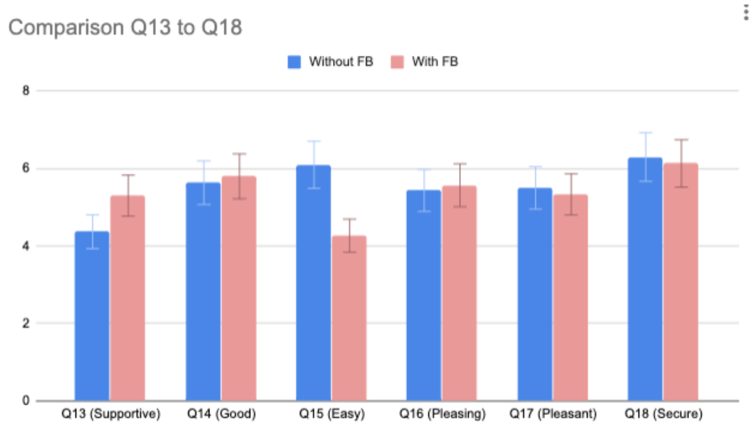

Figure 6.5: Mean score questions 13 to 18

The results of *Q13 - How did you find the experience in terms of support? Objective* → *Supportive* shows that the participants feel that getting feedback is resulting in a more supportive experience. On *Q15 - How was the experience in terms of difficulty? Complicated* → *Easy* the results indicate that the system with advanced feedback was experienced as more complicated. The difference between general enjoyment such as, *bad/good, unpleasant/pleasant and not pleasing/pleasing* scores high on both experiences.

Results from question 19 to 24 is presented in figure 6.6.

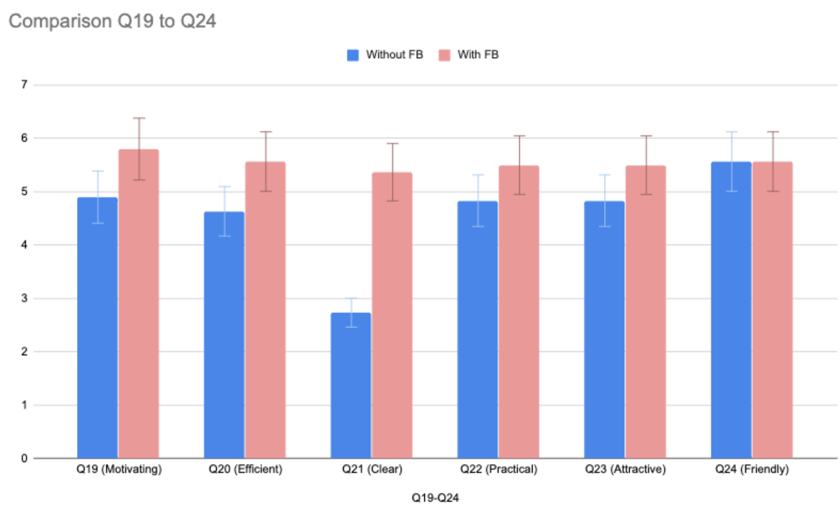

Figure 6.6: Mean score questions 19 to 24

Participants found that rowing with technique feedback was more motivating and efficient (figure 6.6). On *Q21 - Did you find the experience to be clear? Confusing → Clear*, the scales show a significant spike between the two experiences, whereas the new system scores high in contrast to the default system. Indicating that the participants had a higher sense of purpose when rowing with feedback.

Results from Question 25 to 30 is presented in figure 6.7.

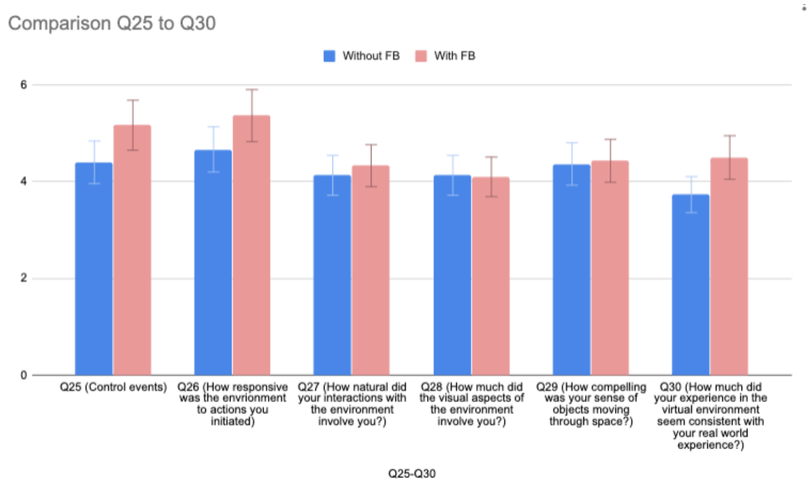

Figure 6.7: Mean score Questions 25 - 30

Figure 6.7 shows that participants feel more in control of events with the new system, in addition to how responsive the environment was to the user's action. There is some difference in question 30, regarding *How much did your experience in the virtual environment seem consistent with your real world experience? Not consistent* $\rightarrow$ *Very consistent*. The small scale spike in question 26 and 30 indicate an increase of immersiveness.

6.2.3 Witmer&Singer Presence questions

Results from question 31 to 37 is presented in figure 6.8.

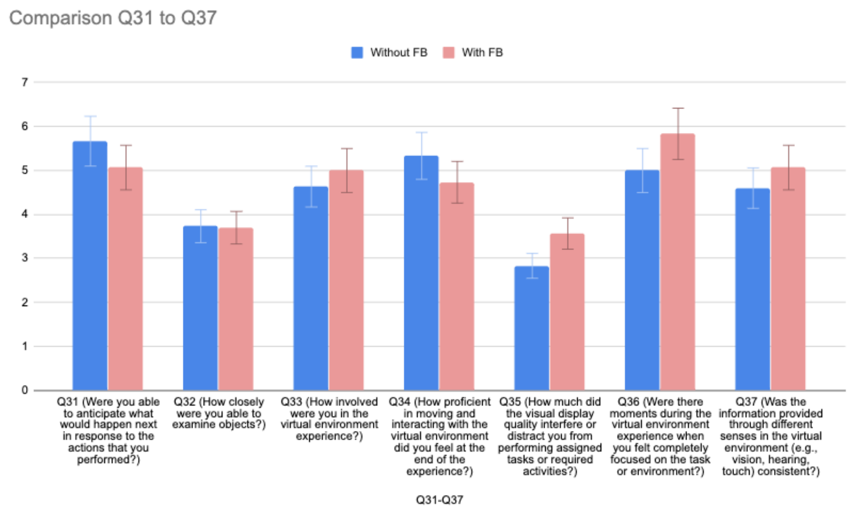

Figure 6.8: Mean score Questions 31 - 37

The results presented in figure 6.8 shows the default scenario scored higher on *Q31 - Were you able to anticipate what would happen next in response to the actions that you performed? Not at all → Very closely*. The participants scored higher on *Q36 - Were there moments during the virtual environment experience when you felt completely focused on the task or environment? Not at all → Most of the time* for the feedback experience.

6.3 Additional comments

After the second experience, the participant could choose if they wanted to give some general notes regarding improvements, the experience, or anything else they had in mind.

1	Synchronization of the oars are off, which was disturbing
2	The feedback was a distraction from the scenery in the background
3	The different technique bars jumped a lot / hard understand when i was doing something correct
4	Difficult to make out how the different categories that could be improved.
5	The oars was a little disturbing. It was an advantage to have rowed before, which helped me knowing what to do in order to improve myself. A fun experience, felt that i would row better to achieve a 100 percent

Table 6.1: Comments from participants after performing the last session

7 | Discussion

When handling psychological results, there is always some level of uncertainty since the results are based on a participant's subjective experience. The assessment of QoE in systems such as this is promising but uncertain to some extent. Having more participants would help normalize the data more accurately, but due to the time limitations of the master thesis, a number of 30 participants was found adequate. When measuring QoE, which is the subjective experience of a participant, external factors such as mood, gender, previous experience, level of system review are factors that may influence the outcome of results. The precaution measurement (appendix E) was taken in order to achieve the same social, cultural, and spatial context base point for all participants.

It was expected that the new system with the feedback board would give better experience. It was expected that the participants would score higher on subjects such as performance, motivation, and immersed presence. For questions Q10, Q13, and Q19, which represent excitement, support, and motivation, respectively, there is a small spike in favor of the new experience. All three questions gave a mean difference value equal $p_{Q10} = 0.63$, $p_{Q13} = 0.93$, $p_{Q19} = 0.9$. Participants found the new version to be more interesting, inventive, and attractive, in comparison to the old version.

Regarding performance, the participants scored significantly higher in the new experience. For question Q5 and Q21 regarding performance and experience clarity there is a large spike with a mean difference value of $p_{Q5} = 2.3$ and $p_{Q21} = 2.63$. In addition the participants reported that the physical- and temporal demand was higher for the new experience with a mean difference value of $p_{Q2} = 1.25$ and $p_{Q3} = 1.13$ respectively. Indicating that the new experience induced an increase of performance-enhancing motivation for the users. In addition, the feedback provided to the user a clearer experience goal, indicating that the display board motivated the user to perform better regarding technique during the session.

From the presence part of the evaluation, there are mixed results. The new system scored higher on questions Q33, Q35, Q36, and Q37. Question 33 regarding how involved in the VR experience, the user was scored higher in favor of the new experience with a mean difference of $P_{Q33} = 0.37$. In addition Q36 favors the new experience with a mean difference of $P_{Q36} = 0.83$. Indicating that the participants felt more immersed in the new experience. Question 34 which favors the old experience with a mean difference of $P_{Q34} = 0.57$ regarding the interaction with elements in the virtual experience and question 31 regarding *Were you able to anticipate what would happen next in response to the actions that you performed* scored in favor of the old (default) system with a mean difference of $p_{Q31} = 0.6$. Indicating that the sense of control was less apparent in the new system in contrast to the old system. Additionally, this will have a negative impact on the immersion aspect of the experience.

Overall, the participants, scored equally on subjects such as enjoyment, *"good vs. bad*, security, and level of pleasing and pleasant indicating that the majority found the experience as positive.

The results show a significant difference in workload between the two experiences (figure 6.3). The total mean difference in total workload between the two experiences is $p_{workload} = 1.45$. Indicating that the new experience is demanding significantly more of the user in terms of the different workload parameters. Question 1 regarding mental demand have a mean difference value of $p_{Q1} = 2.77$. The physical demand with a mean difference in favor of the new experience with $p_{Q2} = 1.25$. This is supported by Q9 and Q15, where the participants reported that the new system was more difficult to learn and that the default system was easier. The temporal demand, regarding time pressure, rate of pace, or task elements, scored higher in favor of the new experience with a mean difference value of $p_{Q3} = 1.13$. The performance demand scored higher for the new version. When asked about Q6 *How insecure, discouraged, irritated stressed and annoyed versus secure gratified, content, relaxed, complacent did you feel during the task?* the mean difference is $p_{Q6} = 1.76$ in favor of the new system. An indication that the technique board was a subject of frustration. Whether or not this is in terms of a negative frustration of the overall VR experience or frustration from not achieving the perfect technique score is uncertain. The results of Q4 is in favor of the default system, with a mean difference value of $p_{Q4} = 0.47$. Supporting the other results that the new version required more of the participants in terms of workload demand to increase their performance.

The results indicate that the proposed hypothesis is true. The participants report that the implementations increased performance, motivation, and immersion. The feedback was mainly positive or equal in favor of the new implementations, thus indicating a positive result regarding the QoE.

Future work

In the future, there are several improvements which would be preferred. The synchronization of the oars, which several participants commented on, saying it was distracting. Improve the UI and graphic representation of digital coach values. The graphical representation of the different bars has a significant room for improvement regarding display and layout. Add more game elements, such as Co-op and player vs. player alternatives. Additional feedback information regarding progress would be favorable. Previously mentioned implementations would affect the overall QoE positively.

For further research, do objective measurements, e.g., see if participants actually row faster with progress and technique feedback. See how a "good vs. bad" UI unconsciously affects the overall QoE.

8 | Conclusion

We have performed a subjective evaluation of a virtual reality experience to investigate how exercise-feedback affects the overall QoE. The following hypothesis was formulated: Introducing gamification and game elements inside a VR experience, such as feedback on technique and progress, will increase the QoE, with regard to motivation, performance, and immersion of the user during an exercise workout. This has been done by extracting different technique data from a rowing ergometer, implemented, and displayed in a virtual world.

The experience is based on a rowing session, where participants are rowing on a virtual boat and are being fed technique- and some progress feedback continuously. In total 30 participants tested the system. Each participant tested two versions, one without feedback and one with feedback.

The results show that the participants enjoyed both scenarios equally, but that the performance, motivation, and immersion scored higher for the version with feedback. The results show that the participants were more motivated to both perform better in regards to technique and the overall experience. The results show that the participants subjectively performed or wanted to perform better in the feedback version. Results regarding presence and immersion report that the user was more immersed in the version with feedback. Additionally, the total workload demanded of the user scored higher for the version with feedback, indicating that this version demanded more of the user in terms of mentality, performance, temporal, effort, and physical. These results were expected and according to the hypothesis.

Based on the results, it is concluded that the proposed hypothesis is true, namely that providing the user with feedback in the form of a game element such as a display board, increased performance, motivation, and immersion. Increasing the overall quality of experience positively.

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Appendices

A Questionnaires

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	○	enjoyable	1
not understandable	○	○	○	○	○	○	○	understandable	2
creative	○	○	○	○	○	○	○	dull	3
easy to learn	○	○	○	○	○	○	○	difficult to learn	4
valuable	○	○	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	○	exciting	6
not interesting	○	○	○	○	○	○	○	interesting	7
unpredictable	○	○	○	○	○	○	○	predictable	8
fast	○	○	○	○	○	○	○	slow	9
inventive	○	○	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	○	○	supportive	11
good	○	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	○	easy	13
unlikable	○	○	○	○	○	○	○	pleasing	14
usual	○	○	○	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	○	○	pleasant	16
secure	○	○	○	○	○	○	○	not secure	17
motivating	○	○	○	○	○	○	○	demotivating	18
meets expectations	○	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	○	efficient	20
clear	○	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	○	practical	22
organized	○	○	○	○	○	○	○	cluttered	23
attractive	○	○	○	○	○	○	○	unattractive	24
friendly	○	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	○	○	innovative	26

Figure 8.1: User Experience Questionnaire

RATING SCALE DEFINITIONS		
Title	Endpoints	Descriptions
MENTAL DEMAND	*Low/High*	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	*Low/High*	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	*Low/High*	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
EFFORT	*Low/High*	How hard did you have to work (mentally and physically) to accomplish your level of performance?
PERFORMANCE	*Good/Poor*	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
FRUSTRATION LEVEL	*Low/High*	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Figure 8.2: NASA TLX - Rating Scale and Definition

Questions from the WitmerSinger Questionnaire:

- 1. How much were you able to control events?
- 2. How responsive was the environment to actions that you initiated?
- 3. How natural did your interactions with the environment involve you?
- 4. How much did the visual aspects of the environment involve you?
- 7. How compelling was your sense of objects moving through space?
- 8.How much did your experience in the virtual environment seem consistent with your real world experience?
- 9. Were you able to anticipate what would happen next in response to the actions that you performed?
- 15. How closely were you able to examine objects?
- 18. How involved were you in the virtual environment experience?
- 21. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?
- 22. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?
- 30. Were there moments during the virtual environment experience when you felt completely focused on the task or environment?
- 32. Was the information provided through different senses in the virtual environment (e.g., vision, hearing, touch) consistent?

Questionnaire used - Compiled by WitmerSinger, UEQ and NASA-TLX

Each answer is ranged between 0 to 7 on a Likert scale

1) How much mental and perceptual activity was required? (e.g thinking, deciding, calculating, remembering, looking, searching etc). Was the task east or demanding. Simple or complex or forgiving?

Low mental demand → High mental demand

2) How much physical activity was required? (e.g. pushing, pulling, turning, controlling, activating)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low physical demand → High physical demand

3) How much time pressure did you fell due to the rate or pace at which the tasks, or task elements occur ed? Was the pace slow and leisurely or rapid and frantic?

Low temporal demand → High temporal demand

4) How successful do you think you were in accomplishing the goals of the task set by the experimenter? How satisfied were you with your performance in accomplishing these goals?

Poor performance → High performance

5) How hard did you have to work (mentally or physically) to accomplish your level of performance?

Low effort → High effort

6) How insecure, discouraged, irritated stressed and annoyed versus secure gratified , content, relaxed, complacent did you feel during the task?

Low frustration → High frustration

7) How did you find the experience to be?

Annoying → Enjoyable

8) How did you find the experience to be in terms of creativity?

Dull → Creative

9) What was the learning experience like for you?

Easy to learn → Difficult to learn

10) How did you find the experience in terms of excitement?

Boring → Exciting

11) Did you find experience interesting?

Not interesting → Interesting

12) Did you find the experience inventive?

Conventional → Inventive

13) How did you find the experience in terms of support?

Objective → Supportive

14) How was your overall experience?

Bad → Good

15) How was the experience in terms of difficulty?

Complicated → Easy

16) How did you find the experience to be?

Unlikeable → Pleasing

17) How did you, during the experience, feel?

Unpleasant → Pleasant

18) How did you feel during the experience in terms of security?

Not secure → Secure

19) How did you find the experience in terms of motivation?

20) How do you feel the experience was with respect to efficiency?

Inefficient → Efficient

21) Did you find the experience to be clear?

Confusing → Clear

22) How did you feel the experience was in terms of practicality?

Impractical → Practical

23) Did you find the experience attractive?

Unattractive → Attractive

24) How did you find the experience to be?

Unfriendly → Friendly

25) How much did you feel you were able to control events?

Not at all → Completely

26) How responsive was the environment to actions that you initiated?

Not Responsive → Completely responsive

27) How natural did your interactions with the environment involve you?

Extremely Artificial → Completely natural

28) How much did the visual aspects of the environment involve you?

Not at all → Completely

29) How compelling was your sense of objects moving through space?

Not at all → Very compelling

30) How much did your experience in the virtual environment seem consistent with your real world experience?

Not consistent → Very consistent

31) Were you able to anticipate what would happen next in response to the actions that you performed?

Not at all → Completely

32) How closely were you able to examine objects?

Not at all → Very closely

33) How involved were you in the virtual environment experience?

Not involved → Completely engrossed

34) How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

Not proficient → Very Proficient

35) How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

Not at all → Prevented task performance

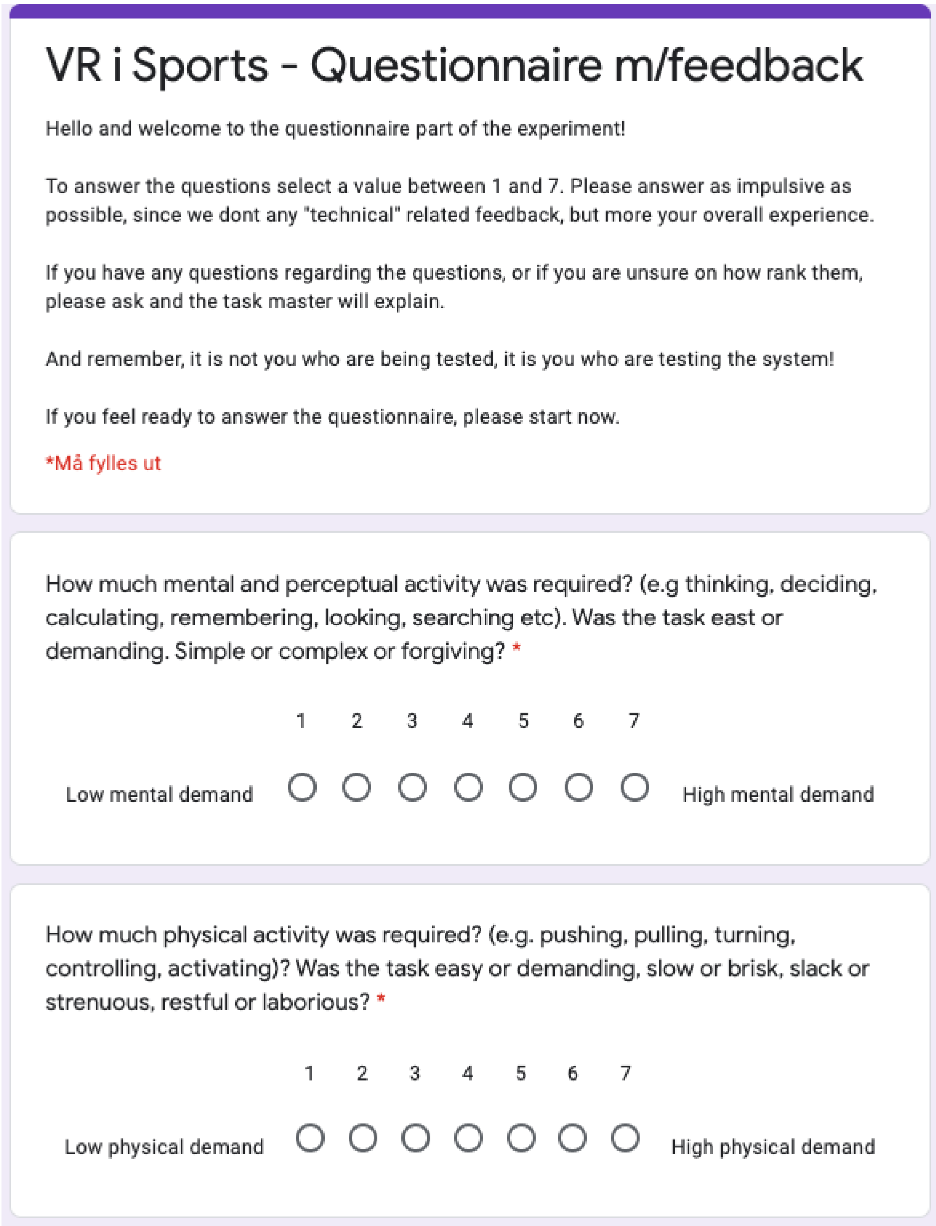
36) Were there moments during the virtual environment experience when you felt completely focused on the task or environment?

Not at all → Most of the time

37) Was the information provided through different senses in the virtual environment (e.g., vision, hearing, touch) consistent?

Not consistent → Very Consistent

B Screenshot of Questionnaire layout



VR i Sports - Questionnaire m/feedback

Hello and welcome to the questionnaire part of the experiment!

To answer the questions select a value between 1 and 7. Please answer as impulsive as possible, since we dont any "technical" related feedback, but more your overall experience.

If you have any questions regarding the questions, or if you are unsure on how rank them, please ask and the task master will explain.

And remember, it is not you who are being tested, it is you who are testing the system!

If you feel ready to answer the questionnaire, please start now.

*Må fylles ut

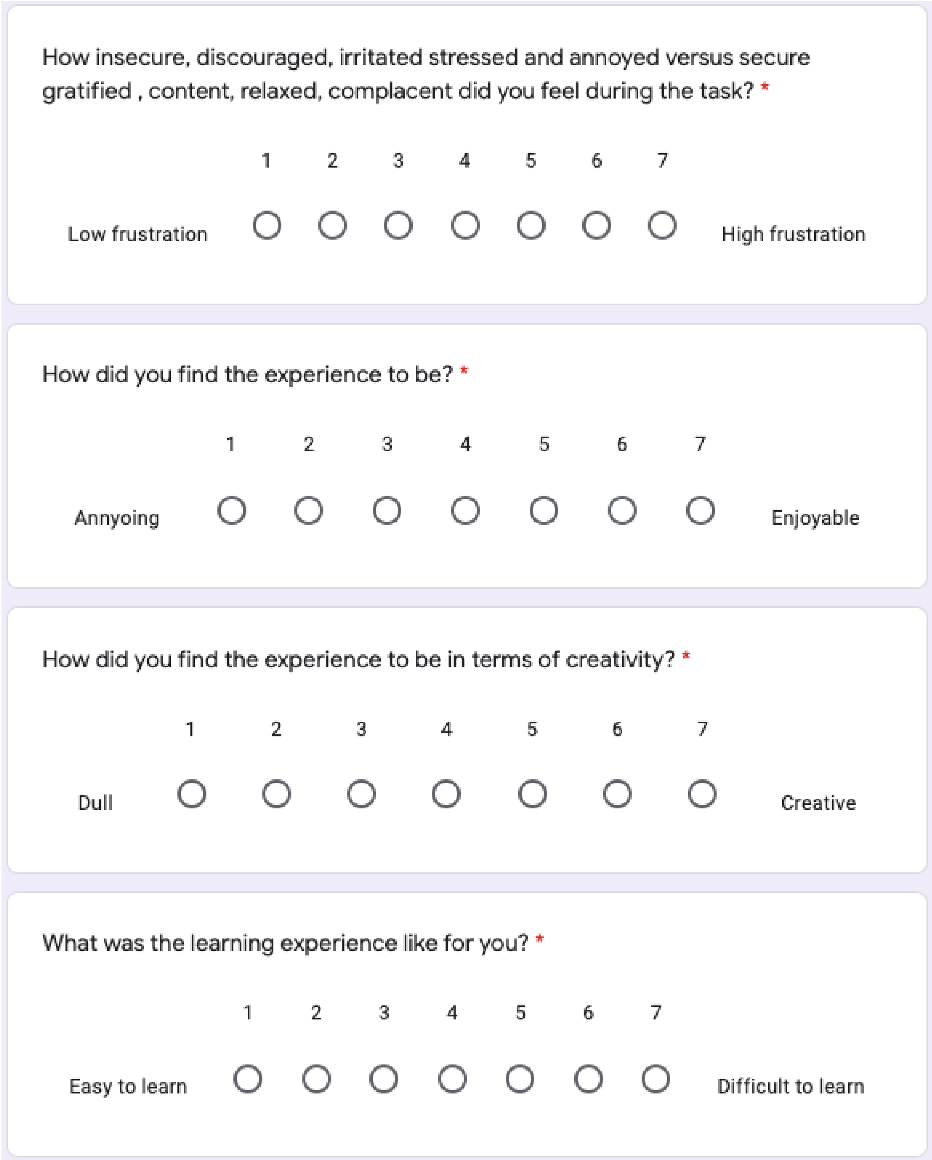
How much mental and perceptual activity was required? (e.g thinking, deciding, calculating, remembering, looking, searching etc). Was the task east or demanding. Simple or complex or forgiving? *

	1	2	3	4	5	6	7	
Low mental demand	○	○	○	○	○	○	○	High mental demand

How much physical activity was required? (e.g. pushing, pulling, turning, controlling, activating)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious? *

	1	2	3	4	5	6	7	
Low physical demand	○	○	○	○	○	○	○	High physical demand

Figure 8.3: Layout of the actual questionnaire, at start


How insecure, discouraged, irritated stressed and annoyed versus secure gratified , content, relaxed, complacent did you feel during the task? *

	1	2	3	4	5	6	7	
Low frustration	○	○	○	○	○	○	○	High frustration

How did you find the experience to be? *

	1	2	3	4	5	6	7	
Annyoing	○	○	○	○	○	○	○	Enjoyable

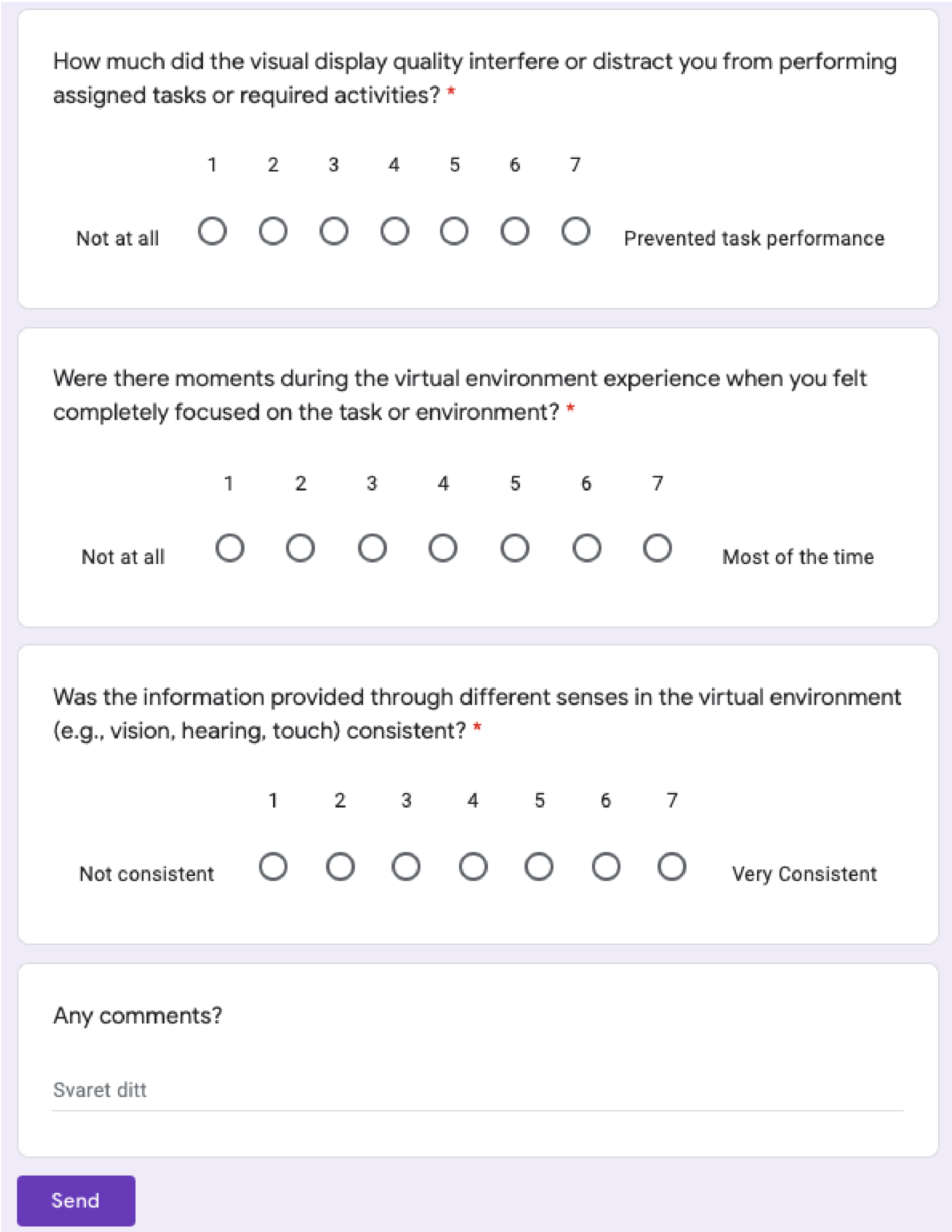
How did you find the experience to be in terms of creativity? *

	1	2	3	4	5	6	7	
Dull	○	○	○	○	○	○	○	Creative

What was the learning experience like for you? *

	1	2	3	4	5	6	7	
Easy to learn	○	○	○	○	○	○	○	Difficult to learn

Figure 8.4: Layout of the actual questionnaire, at the middle



How much did the visual display quality interfere or distract you from performing assigned tasks or required activities? *

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Prevented task performance

Were there moments during the virtual environment experience when you felt completely focused on the task or environment? *

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Most of the time

Was the information provided through different senses in the virtual environment (e.g., vision, hearing, touch) consistent? *

	1	2	3	4	5	6	7	
Not consistent	○	○	○	○	○	○	○	Very Consistent

Any comments?

Svaret ditt

Send

Figure 8.5: Layout of the actual questionnaire, at the end

C Research Protocol

Repetitive indoor endurance exercises such as running on a treadmill or rowing on an ergometer used to be tedious. But since the introduction of immersive media technology we have a greater opportunity to bring a greater incentive to these exergames, which raises the questions regarding how this will affect the users experience.

In this study i will present my exergame with a rowing ergometer connected to a virtual world. Where the user will receive both motivational and performance feedback information throughout the session inside the virtual created scenario. A group of people will participate in a formal test of the prototype and afterward answer an anonymous questionnaire.

This study is a part of a project with NTNU in Trondheim. This study will be based on a previous system, though several implementations and improvements will be done in hope to increase the overall experience. The aim is to do research on the participants perceived experience. How does gamification and gamification elements inside an virtual reality affect the performance and motivation of the user? After the practical part of the project is done, which is the implementation of motivational and performance enhancing information in real time, participants will be gathered and the system tested.

Introduction

Exercising have been a part of human culture through all of history, and even more so later years. As technology advances new and exiting ways to exercises occurs. There is advanced and not so advanced information to be revealed to the user through pulse watches, mobile phones and various ergometric machines. With the introduction of Virtual Reality there is an opportunity to not only create an immersive experience through gaming and video, but also an opportunity to create so-called exergames, an combination of both gaming elements and exercising.
With new possibilities, new questions arise. What effect does real time motivational- and performance feedback have on the Quality of Experience (QoE) during such an scenario? How does it impact the users experience (UX) overall?

Previous study shows separately how feedback and VR affects the QoE. This study will focus on the combination of the two and how it affects the QoE and UX.

When dealing with these questions, concepts such a QoE, and user experience provides a scope of which to work within.

Hypothesis

This study will focus on the following hypothesis:

How will motivational- and performance related feedback affect the QoE inside an virtual experience?

By combining Virtual Reality with an rowing ergometer and introduce real-time performance feedback to the user inside an virtual environment will result in an increase in both user performance and motivation.

Method and design

Cafe Media in EL-building at Gløshaugen NTNU will be used for the participants to test. The rowing ergometer and necessary computer equipment is already ready here.

Here each participant (in total about 40 participants) will be given instructions to row for a certain time or distance. Each participant will test the new VR scenario and the older ”default” scenario. Furthermore each participant´s experience will be measured by subjective means, a survey based on standardized questions and demographic questionnaire. This questionnaire will mainly be based on questions from the Nasa Task Load and (performance) and Temple/Lombard (presence).

Each participant will enter the testing area alone, at an scheduled appointment, so that there is no outside influences on the experience. The laboratory will be cleared and made as approachable as possible. Only the participant and the task master(s) will be present during the test. The participant will first be given a consent form, followed by a short descriptive paper of the experiment. After the the session the participant would fill out a questionnaire on a computer in the laboratory, letting the task master gather the data.

Results

Data from the two different scenarios will be randomized and compared with each other. The results will be analyzed by the use of each mean metric value of parameters given by the participants. By looking at the behaviour of the results, the hypothesis can be proven true or false.

D Consent Form

I have read the information for the study ”Virtual Reality in Sports”. I will participate in this study. I consent to the following data being collected about me during the study:

The questionnaire ”Evaluation - Virtual Reality - Rowing”

Have my picture taken
I approve that all recorded data will be saved and will be used pseudomized (e.g identification data will stored separately from recorded data and only be accessible to a small circle of authorized personnel) for research analysis. All data i give will be handled with care, and are not to be distributed to any other than the people invested in the project. All information will be used for research purposes only. Personalia will not be given to any third party.
I am aware that participating in the study is voluntary and I can withdraw at any time.
Lastly, I will not share the procedure of the study with future participants of the study. As that can potentially affect the results of future participants.

Name:..
Date:...
Signature:..

E Master thesis Experiment Conditions

One person will be in charge of conduction the experiment. When a participant enters the room, the responsible person greets the test subject and tells her or him to sit down. At this point, the previous session (if there was one) should be restarted and ready to go. The participant will then be handed an instruction/information paper. Furthermore the participant will be asked so sign a consent form. If there is no questions from the participant the experiment will be initiated. The task master should note that the participant is not the one being tested, but that the system is.

During the rowing session the task master will be available to help with VR goggles and potential questions etc.
After the participant have rowed the pre- determined distance he or she will be asked to fill out a questionnaire on a nearby computer, in which they will answer anonymously. The participant will then be asked if there is anything he or her were wondering about or if they would like to give some oral feedback. Also the task master would remind the participant that when answering the questions they should try to respond as impulsively as possible, as the experiment desires an non-technical review of the experience, rather than a technical point of view on the system.

The task master then gathers the information and bids the participants adieu and thanks them for the participating. Noting the name, date and what feedback the participant was experiencing.

NTNU

Norwegian University of
Science and Technology