Development and use cases for a supervised Virtual Reality training platform in healthcare.

Master Thesis

For attainment of the academic degree of
Master of Science in Engineering (MSc)

in the Master Program Digital Healthcare
at St. Pölten University of Applied Sciences

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Vienna, 11.05.2018

Declaration

I declare that I have developed and written the enclosed Master Thesis completely by myself, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. This work was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.

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Abstract

This thesis describes the technical development process of the mobile virtual reality (VR) training platform “VRTherapy”. Furthermore, an explorative pilot study among health professionals (n=10) evaluated acceptance for integration into their daily workflow with patients. After being introduced to the platform, the participants were asked to suggest possible training exercises that could be useful developments as a VR exergame. In total 27 health improving VR exercises for VRTherapy have been suggested. The interviewees consider VRTherapy a promising training tool that can lead to higher patient motivation and potentially faster recovery in some cases.

Results show that VR in healthcare seems more promising when combined with established treatment methods. The goal of VRTherapy is to become an open platform for VR health exercises which are used as additional treatment methods such as in stroke rehabilitation, phobias, traumas, pain management, and physiotherapy. Third-party developers can create and publish exercises for the VRTherapy platform via “Unity”, a software for app and game development. An API (Application Programming Interface) has been developed that allows VR exergames to be individualized to patients’ needs and controlled by a supervising health professional in real-time through a secondary device. The API is publicly available on GitHub[1], VRTherapy can be downloaded via the iOS App Store[2] and the sample VR exercise is available for Google Daydream[3]. Health professionals can not only customize game settings wirelessly while patients are playing, but also receive feedback about the player’s progress on their own device. This tracking helps them evaluate overall improvement over time throughout various exercises.

As available research shows a lack of large-scale studies with control groups researching the health impact of VR exercises compared to established methods, this platform can also facilitate conducting such studies with a high number of participants among various locations and devices. Such a supervised VR training platform would help to reach statistically significant conclusions about the impact of VR on specific treatments. Also, the effect on the result when using different VR

1 https://github.com/branddirections/VRTherapy

2 https://itunes.apple.com/at/app/vrtherapy-trainer-app/id1343276712

3 https://play.google.com/store/apps/details?id=eu.branddirections.VRTherapyDemo

headsets and controllers for the same exercise could be evaluated through this platform for the first time.

Kurzfassung

Diese Thesis beschreibt den technischen Entwicklungsprozess der mobilen Virtual Reality Plattform „VRTherapy“. Die Plattform hat das Ziel, VR Übungen von DrittentwicklerInnen mit dem Zweck der Gesundheitsverbesserung aus diversen Bereichen wie Schlaganfallrehabilitation, Traumabehandlung, Schmerzmanagement, Phobien und Physiotherapie gesammelt anbieten zu können. Darüber hinaus wurde in einer explorativen Pilotstudie unter GesundheitsexpertInnen (n = 10) die Akzeptanz für die Integration von VRTherapy im täglichen Arbeitsablauf mit PatientInnen evaluiert. Nach der Einführung in die Plattform wurden die TeilnehmerInnen gebeten, mögliche Trainingsübungen zu nennen, die als VR Übungen nützlich sein könnten. Insgesamt wurden 27 gesundheitsfördernde VR Übungen für VRTherapy genannt. Die Befragten halten VRTherapy für ein vielversprechendes Trainingsinstrument, das in einigen Fällen zu höherer PatientInnenmotivation und möglicherweise schnellerer Genesung führen kann. Bisherigen Studien zeigen, dass VR Übungen im Gesundheitswesen am vielversprechendsten erscheinen, wenn diese mit etablierten Behandlungsmethoden kombiniert werden.

DrittentwicklerInnen sind in der Lage, eigene Übungen mit dem 3D Programm “Unity“ zu entwickeln und diese für GesundheitsexpertInnen via VRTherapy zur Verfügung zu stellen. Dafür wurde eine API (Application Programming Interface) entwickelt, die es Gesundheitspersonal ermöglicht, VR Übungen individuell auf die Bedürfnisse ihrer PatientInnen in Echtzeit anzupassen, zu steuern und zu kontrollieren. Die API ist auf GitHub[4] öffentlich verfügbar; VRTherapy[5] kann über den iOS App Store geladen werden und die in dieser Thesis verwendete VR Übung[6] ist für Google Daydream verfügbar. Gesundheitsfachkräfte können nicht nur die Spieleinstellungen im Moment des Spielens anpassen, sondern auch Feedback über den Fortschritt des Spielers erhalten. Dies hilft dabei, die Gesamtverbesserung im Laufe der Zeit während verschiedener Übungen zu bewerten.

Die Plattform kann die Durchführung von größeren Studien zu VR Übungen an verschiedenen Standorten und Geräten erleichtern. Dies kann dabei helfen, zu statistisch signifikanten Schlussfolgerungen über den Einfluss von VR bei spezifischen Behandlungen zu gelangen. Auch die Auswirkung auf

[4] https://github.com/branddirections/VRTherapy

[5] https://itunes.apple.com/at/app/vrtherapy-trainer-app/id1343276712

[6] https://play.google.com/store/apps/details?id=eu.branddirections.VRTherapyDemo

Studienergebnisse bei Verwendung verschiedener VR-Headsets und Controller für die gleiche Übung könnte über diese Plattform erstmals ausgewertet werden.

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1 Introduction

Virtual Reality (in short VR) is a lonely place. Nowadays, VR is mostly known for gaming but might also be useful in the future of healthcare and rehabilitation. Until now, most studies indicate that health improvement through virtual reality seems limited in comparison with the traditional treatment methods. However, it is not yet possible to draw any final conclusions about the effectiveness of VR in the healthcare sector. One reason is the lack of large-scale studies and the rapid improvements of the available hardware.

1.1 Problem

Before 2016, virtual reality hardware was a complicated toy that required computers and cables in addition to the headsets. Nowadays, VR can be experienced even with mass-market smartphones at an affordable cost. The technological improvements envolved from tethered VR devices to mobile solutions with standalone headsets. Tethered VR solutions require a PC connected to the VR device which renders the VR view in real-time and sends it to the VR device. In comparison, a mobile device renders the VR view directly on the device where it is displayed on.

Currently, extensive online research did not show any training platform, which focuses only on VR exercises for healthcare (also called exergames) using the advantages of mobile VR hardware. Such a service would allow health professionals like physiotherapists or psychologists to discover and download exergames that could be a useful addition to their treatment sessions with patients. Therapists (in this thesis also called trainers) can choose and play a variety of exercises with their patients. Such a platform can be installed on a secondary device separate from the VR device (e.g., on a trainers iPad). While playing, the trainer's device connects with the VR game to exchanges data wirelessly in real-time. That enables the trainer to customize game parameters to the patients need.

All exercises are developed with the focus to help reduce specific disabilities of their patients (in this thesis also called player). Such deficits could be motoric, psychological or visual. As exercises are played via the same platform, a patient’s improvement rate over time could be tracked throughout all played games.

For example, a physiotherapist in the role of the trainer is exercising with a patient. They train to improve the patient's motoric capabilities after a stroke by adding several VR mini-exercise as an addition to the traditional therapy methods. Such a platform solution could also provide a valid basis to conduct large-scale studies and evaluate how and which VR exercises have a beneficial impact. Instead of creating a closed system, even third-party developers could be able to publish health related games on such a platform. This can be enabled by providing these developers with the tools needed via an API (Application Programming Interface).

This thesis describes the technical development of such a platform. The project has been named “VRTherapy.” It started as a student project in the master's program of Digital Healthcare in the University of Applied Sciences of St. Pölten/Austria. This platform was developed due to a lack of a platform for VR exercises that are specially developed for the healthcare sector. One main feature of VRTherapy is that trainers can customize all available exercises to their patients’ needs without any technical knowledge. They can define or individualize game parameters (such as the number of objects to be found and their distance from the player) in real-time through a secondary device. Such a concept of game control through another device has the advantage that the VR player is not forced to take off the VR Device between exercises or when game parameters are changed by the trainer. The trainer also receives feedback on the players progresses via their device from the VR game. The feedback can be the player's improvement rate, accomplished points or failed attempts. Such a mobile solution can be used anywhere and is not confined to only one specific VR platform, and even gives players the ability to continue their training at home[1].

1.2 Goals

The goal is to describe the development process and highlight possible bottlenecks while engineering the VRTherapy exercise platform. This work focuses on the process of real-time data exchange for health exercises between a trainer’s and player’s app. This combination enables supervised and personalized training in VR. Furthermore, this thesis describes the process to creating an API for VRTherapy.

An API is a set of features and functions which gives developers the ability to connect to another service (In this case to enable data exchange between the

VRTherapy platform and the third-party developer’s VR app). The API developed for VRTherapy is openly available which means anybody can develop an exercise for this platform. It allows developers to integrate VRTherapy's real-time connection features to their VR exercises.

Additionally, 10 professionals will participate in a usability experience evaluation of this platform. They enter the role of trainers and then will be asked which VR exercises they consider useful to be integrated into their daily workflow. As VRTherapy is focusing on applying individual settings to a game through the trainer's app, they were also asked, which settings they would like to have available in the trainer app to individualize each exergame. Lastly, they are required to answer what feedback information suits them best to evaluate the players progress over time.

1.3 Pivotal question

Can a supervised virtual reality exercise platform be a useful tool to be integrated into a health professionals’ workflow?

1.4 Method

As this thesis details the technical development of VRTherapy mainly focusing on the technical development stages and possible use cases of the VRTherapy platform. Additionally, an explorative pilot study with 10 health professionals that match the defined including criteria will be conducted. This study was authorized by the ethics committee of the federal state Lower Austria. Patients will not participate in this survey. After an individual introduction to the VR Therapy platform, the data will be collected in a qualitative study by filling out an open question survey. A qualitative study approach has been chosen as it is well suited to identify main design issues at the projects current beta stage[2].

The goal of this qualitative study is to evaluate which exercises the surveyed health professionals consider a useful supervised VR exercise. The focus is on already existing exercises, which seem useful to be transformed as a VR exercise.

Evaluation happens after 10-15 minutes of introduction to the VRTherapy trainer app and the VR app. The VR app is currently a sample exercise that has been derived from a standard exploration game to treat patients suffering from neglect after a stroke.

1.5 Outcomes

This thesis aims to provide leads to how to conduct further research on VR in healthcare. It should also serve as a tool to define which aspects must be considered when introducing virtual reality in healthcare from a healthcare professionals' perspective. The final investigation should therefore provide a method of orientation in understanding which direction VRTherapy can be improved and which exercises health professionals consider useful enough to be available on this platform.

1.6 Structure of the thesis

This thesis starts by giving an overview of the state of available academic research about virtual reality in healthcare and introduce some current VR products used in healthcare in 2018. The central chapter describes the technical development of the VRTherapy platform. It is sorted by the principal components highlighting design and development decisions and displaying bottlenecks which occurred during planning and programming. In the last chapter, 10 healthcare professionals were interviewed (e.g. physiotherapists) to evaluate which health exercises from their current workflow they could viably use as a VR exercise with their patients. This thesis focuses only on virtual reality and doesn't include Augmented Reality.

2 Virtual Reality in healthcare

The first virtual reality systems for the healthcare sector appeared in the 1990's [1]. Back then, these systems were often bulky and expensive toys. Due to the low graphics and processor power available compared to today's standards, users often suffered from nausea [3] while using these devices due to delays and low resolution. Since then, an ever-increasing yearly number of academic papers with research about the impact of VR on the health sector have been published. From around 2015, a new wave of virtual reality devices entered the mass market. Hardware was becoming able to deliver the required processing power for a pleasant VR experience with an affordable price tag below 1000 USD.

The most popular VR devices currently on the market are the Oculus Rift, Samsung GearVR, HTC Vive, Play Station VR and Google Daydream [4]. The advantage that even a smartphone can be used nowadays as a VR device is that the consumer only needs to purchase a compatible headset instead of an additional device. Most VR headsets include a controller to enable user interactions. Deutsche Bank has predicted in a study that the worldwide use of virtual reality devices will rise from nearly 10 million people in 2017 to almost 25 million by 2020 [5].

2.1 State of the art

Most VR apps are made for gaming and are not targeting the healthcare sector. The simple reason is that there is more money to be made faster in the gaming sector compared to healthcare [6], where the processes to enter the market with a medical product are often time-consuming, costly and bureaucratic.

Nevertheless, as virtual reality is now entering the mass market due to the lower purchase price, there might be a new surge of companies, start-ups, and developers trying to create VR apps for healthcare. To avoid the bureaucratic processes in getting approval as a medical product, they might focus at first on creating more fitness or well-being related apps. These apps do not require any permissions as they are not directly used to treat or improve a person's medical condition. Some VR devices can be used at any location, as they do not require much additional hardware nor technical knowledge. Therefore, it becomes apparent that there are many use-cases to include virtual reality in rehabilitation, training, and treatment. Also, for the health education sector, VR is a very promising tool to train medical students for surgeries or emergency situations. According to the results of the literature research in the following sections, available research and products for VR in healthcare often focus on the following areas:

1. Stroke rehabilitation (upper limb function, upper limb activity, phantom limb pain)
2. Post-traumatic stress disorder (PTSD)
3. Phobias
4. Medical education
5. Pain relief and pain management

2.1.1 Literature review

Huang et al. [1] predict from their bibliometric research about VR related healthcare publications that virtual reality in the field of rehabilitation will see a fast development and even solve problems in this field. More than fifteen thousand research papers related to VR have been written between 1996 and 2015 and therefore classified in their bibliometric research. Many of these papers try to evaluate if VR technology may help in rehabilitation. However, even if this technology offers a new way of exercising for the rehabilitation sector due to its technological improvement, proper exploration and evaluation still need to prove if patients can recover faster using VR compared to other treatment methods. Furthermore, the findings of Huang et al. show that VR treatments did not have any significant positive effect on treatment. It thus may indeed be relevant to note that the specifications of the used VR hardware have not been considered in their classification. However, this might have a direct effect on the outcome of the overall effectiveness of VR treatment and therefore could have influenced their findings. Due to the rapid change of technology, it might therefore be useful to compare the hardware specifications like resolution, weight, and field of view (in short FOV) with each studies outcome to evaluate how much hardware capabilities can influence treatment results.

A systematic review of sixteen studies conducted in 2015 by Li et al. analyzing balance improvement in 428 patients after stroke showed that those participants with virtual reality exercises improved significantly better than the control group. Their meta-analysis evaluated the outcumes of the “Berg Balance”-Test and a “Timed Up and Go”-Test. The former is a clinical test to evaluate a person’s balance abilities. The latter, as “Timed Up and Go”- Test, is a standard test to assess a person’s mobility and risk of falling [7].

Laver et al. [8] evaluate the efficiency of virtual reality in stroke rehabilitation compared to alternative intervention on upper limp function and activity. The study consists of 72 separate trials which involved in total 2470 participants. Based on their grading system they conclude that the evidence remains “low quality”, which concludes that virtual reality and video gaming did not show any benefits in improving upper limb function when compared to alternative therapy methods. Most of these 72 included studies outcomes were not statistically significant. Furthermore, most studies lacked a statement regarding their risk of bias. The only statistically significant difference between groups could be observed when virtual reality was used as an additional therapy method to usual care. This case applies to only 10 of the reviewed studies with a total of 210 participants.

Dockx et al. [9] conducted a study to evaluate the rehabilitation for virtual reality in Parkinson’s disease. It involved 263 people from 8 trials. Almost all results of the studies have been graded as “low”. This means results reached 1 or 2 points out of four on the authors grading system. In this case the “confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect”. The only improvement found was a moderate improvement in “step and stride length” of the participants. The researchers also tested the improvements in gain, balance, and quality of life which all showed a low amount of increase with VR. In general, there are too few studies available at the moment to create a valid evidence base for VR exercises to help improve Parkinson disease.

Wiederhold et al. [10] quantified pain management of virtual reality. They state that the human brain has a limited capacity about how much information it can process at the same time. Therefore, humans have less attention capacity dedicated to pain receptors because more parts of their processing capacity are assigned to the virtual reality world. The distraction from pain can even be stronger by allowing the users to interact with the virtual reality world through a controller. This pilot study had 10 participants who were exposed to different levels of pain such as thermal pain (cold or heat) and light electroshocks. The participant's pain sensation was evaluated with and without virtual reality. The results state that all subjects reported a drop in pain sensation while exposed to virtual reality.

2.1.2 Existing Virtual Reality solutions for healthcare

With the surge of academic papers about virtual reality, hardware devices also tried to enter the market. However, these devices never sold on a mass market scale. One reason was that technology had not yet been advanced and affordable enough [11]. With improving technology, a new wave of VR products appeared at the beginning of the 2000's. They were very specialized and expensive solutions around 50.000 USD [12]. In the third and current wave of VR, which started around 2015, devices are now ready for mass market at affordable cost. With the ability to download VR apps now through existing app stores such as Google Play or Steam, developers can publish to a worldwide market. Compared to older VR solutions, developers can nowadays reach a broader audience without the need to sell any hardware devices. All VR systems introduced below in this chapter are currently available:

The software “Bravemind” created by Skip Rizzo in 1999 [12] was initially funded by the United States Department of Defense with the goal of helping relieve PTSD (Post-traumatic stress disorder) symptoms of soldiers. The best results were observed in a combination of playing the VR war-game with talk therapy. These games can recreate situations soldiers have experience in Iraq or Afghanistan. The American Psychological Association claims that the founder of the game has made an outstanding contribution to the treatment of trauma with this software.

The Virtual Reality Medical Center in Belgium[7] specializes its research in various fields such as pain distraction, PTSD treatment and medical training. The institute collaborated with NATO to research how VR can help returning troops coping with PTSD and blast-related traumatic brain injury. They also offer software systems to treat a variety of phobias such as vertigo, claustrophobia and the fear of various animals like snakes or spiders [13]. The institute claims this way of treatment is faster than traditional therapy and more cost effective because no real-life experiences need to be arranged to start treatment. Their treatment procedure usually involves 8-12 sessions of phobic stimuli at increasing intensities. They connect the patients with real-time physiological monitoring to evaluate the patient's stress levels during treatment.

For chronic tinnitus treatment, interactive technologies such as VR proved to be efficient in different clinical scenarios. There seem to be analogies between the treatment of subjective tinnitus and phantom limb pain. This is because the treatment approach is based on pain relief therapy in VR: Distraction and occupation of the person's information capacity with information from the virtual world [14].

The companies Amblyotech and Ubisoft introduced a game named “Dig Rush” in 2016 which is a VR game aiming to help children with amblyopia. Amblyopia is the “Dimness of vision, especially when occurring in one eye without apparent physical defect or disease, also called lazy eye” [15]. This malfunction in the eyes affects

[7] www.vrphobia.com

3% of all children. By playing this game, a child’s brain will work better together with their eyes to avoid their “lazy eye” syndrome. In this game, doctors also need to define individual settings for each child before playing the game to be effective [16].

Not only for patients, but also for medical students, virtual reality can be beneficial in the field of training. The simulation game “Pediatric Sim” [17] is an emergency room training for students to learn how to cope with situations like respiratory failure or septic shock. In this game setting and scenarios can be adjusted based on the students skill level.

Apart from the educational purpose, virtual reality games for health personnel might also be helpful in the understanding of the benefits and limitations of VR. This could in turn lead to better definition of treatment approaches and research impulses directly from doctors on how this technology could be applied in the treatment of patients.

2.2 Virtual Reality exercise platforms with supervised training

By definition, the word "supervised" could be misleading to some readers as it is currently heavily appearing in the tech world when referred to "supervised machine learning." In short, machine learning is an artificial intelligence technique to answer questions with data. Nevertheless, in general, the term supervised means to "watch and direct". In connection with virtual reality training, it is referring to the trainer watching and directing the player (for example a patient) during a virtual reality training session.

As virtual reality devices have entered the mass market in recent years, the concept of publishing VR apps via dedicated app stores emerged. These platforms have the advantage of reaching a worldwide audience and facilitating the possibility of global app sales for developers. Currently, most available VR apps in app stores focus on gaming. Only a small number of VR apps currently available are dedicated to health and well-being. As more and more people can conveniently use their own smartphone as VR devices, a mobile platform specifically made for health training – weather in a supervised setup or for home training alone – could be beneficial.

There are different VR platform approaches on the market in relation to the healthcare field: Since August 2017, the VR Health Institute[8] aims to rate and study the health impact of virtual reality exercises. It gives a rating to submitted VR apps and publishes these specific results on their website. Their goal is to investigate the calorie burn and health impact of selected VR games [18]. They stress that gaming should not just be connected to an unhealthy lifestyle and antisocial behaviour, but also that specific games could indeed have health benefits.

The company “Applied VR”[9] wants to focus on distraction, and pain relief for people who are forced to spend an extended time in clinics or hospitals. They want to take advantage of the fact that VR is now also mobile and immersive and can be used for people that lack the mobility to experience relaxing situations such as being in nature or at the beach. They offer a complete solution for hospitals with hardware and software platform to encounter different relaxation situations. The goal is to transport patients out of the hospital through the immersive VR experience without the need to leave their bed for distraction [19]. The company attempts to outline their effectiveness by conducting several studies to show how their software can help to reduce anxiety and lead to pain relief [20].

“Eon reality”[10] offers a platform with the aim to empower a non-technical user to create VR Apps in minutes. They provide a toolbox with 3D objects create VR apps for health education [21]. This platform could be a useful entry point for people working in health education, who are not familiar with programming but would be interested in creating their own basic virtual reality app for health-related educational purposes.

The platform “WiseMind” [12] wants to optimize patients’ compliance for treatments by simulation through avatars. Interacting with avatars could mean that a patient in VR is anonymously talking to a doctor that could look like a rabbit. Their software is currently in beta testing with Stanford and Columbia Universities. The goal is that patients create a strong connection with the avatar that their brains form new neural pathways in the direction of the optimal behaviour to follow doctors’ orders better. By following a doctor's orders better, it would help patients to reduce their symptoms .

[8] www.vrhealth.institute

[9] www.appliedvr.io

[10] www.eonreality.com

2.3 Conclusions from Virtual Reality in healthcare

At the moment, there is no platform dedicated explicitly to health-improving exercises in VR that also grants access to third-party developers to publish their exergames on. Such a platform – weather as a website or an app – could be specifically designed to the needs of their target audience: Healthcare professionals that want to add virtual reality exergames to their current patients' treatment. A target user could be a physiotherapist working in a rehabilitation center, who would like to implement some of the VR exercises available on such a platform in their daily workflow with patients. In general, such a platform might help to overcome several of the current obstacles observed in the literature review.

It would also be a useful starting point to evaluate the potential of VR in healthcare on a bigger scale due to its worldwide access. The platform could also be able to track a patient's improvement over time among various exercises. Until now, most VR exercises are only assessed individually. It seems a useful tool to create an algorithm that evaluates a patients' overall performance increase from all played health games when treating a specific issue (for example phantom limb pain or subjective tinnitus). Such a platform can create a standardized way to receive, collect and display feedback data from the exergames played. A similar - but non VR – approach to boost large-scale health studies has been taken by Apple when introducing their "ResearchKit" framework. It allows reviewed studies to use data collected by wearables and mobile devices from conscenting users for large-scale studies [22].

When a therapist pre-defines a patient's home training schedule, this platform can combine the use case for supervised training with additional home exercising. Continuing with the sample case, the physiotherapist could for example train once a week together with their patient and introduce them to new exercises. It is like when a teacher introduces students to a topic in class but then giving them specific exercises to improve and strengthen their knowledge. The therapist selects which VR training can be performed at home and defines appropriate exercise settings and specifications. They can also specify the overall goal to reach until the next session. Among others, this could be time-related (10 minutes per day) or points related (Increase your score by 100 points until the next session). The patient can then try to complete the given home training until the next meeting.

Developers and healthcare professionals could also communicate with each other through the platform to evaluate the need for specific exercises from a healthcare perspective. Not only to demand specific exercises but also to suggest possible parameters health professionals would like to be able to customize an exercise during a supervised training session. This could have the possibility of improving the effectiveness of exercises over time.

A large number of research published over the last twenty years is available in the field of virtual reality in healthcare and rehabilitation. However, there seems to be a lack of high-quality, large-scale studies that conclude the usefulness VR treatment in comparison with current treatments. Most studies suffered from small sample size and didn't include any control groups. Furthermore, many papers did not provide any information about the level of bias of their study. A vast amount of the published articles included in the bibliometric research of Laver et al. [8] suggests in their conclusion as a next step to conduct relevant clinical trials. In most cases, it was unclear whether any further trials ever happened. Most articles did not provide any follow-up studies. It appears to be difficult for researchers to conduct studies on a larger scale as they are costly and difficult to organize. Another restriction with conducting clinical studies with a high number of participants might be that studies take place mostly at one location. The technological improvements in VR hardware could have made some of the used VR solutions in those studies obsolete. That could change in the coming years due to more mobile VR devices without cables that are available and priced at under 1000 USD. There have been significant technological advances in recent years that have improved hardware specifications and have had a direct effect on creating a more immersive user experience in virtual reality. Older hardware often became obsolete. The used equipment might affect the outcome of studies on both patient acceptance and therapeutic results.

Many studies do not state what their used hardware specifications were. It is unclear if there are any studies available where different VR hardware was used deliberately to evaluate if results vary in a significant way according to the device used. Weaknesses in the specifications such as low screen resolution or display delays during head movement could impact results. Other specifications can be the field of view (FOV) measured in angles, resolution, sound, comfort, dimensions, weight and mobile vs. tethered VR solutions.

In general, patients did not seem to have any problems using a VR device itself. However, especially for VR in healthcare, the specific limitation of a patient has to be taken into account. These limitations could create individual problems that could prevent a health professional from using virtual reality training on a patient. For example, a person in a wheelchair might only be able to train exercises from a static player position. If a specific health game requires the player to move around in a room, it might render the treatment useless. As most exercises have a controller for user interaction, it is crucial to not forget the importance of the design and ergonomics of those controllers. Notably, usability for patients with motoric difficulties in their hands with grabbing an object might be limited. Therefore, other solutions like attaching the controllers to their arm or using tracking gloves could be a solution.

All in this chapter introduced VR exercise platforms introduced platforms try to focus on a similar goal: Creating a useful VR software that has a positive health impact. When writing this conclusion in Spring 2018, there seems no solution available that is based on the idea to create a platform for healthcare professionals to exercise VR exergames for a variety of treatments in combination with real-time supervised training. A centralized platform made for mobile VR devices could lay the grounds to conduct larger-scale studies about the benefits of VR and track improvement results throughout several exercises.

3 VRTherapy design & development

The idea of VRTherapy is to develop a supervised mobile VR platform as described in the previous chapter (see 2.2). It provides a variety of health-improving exercises, which can be used by health professionals such as physiotherapists, ergo-therapists or psychologists. As the VR exercises are available for different therapeutic purposes through a single platform, the trainers only need to learn how to use one VR platform and can then add this software in their daily treatment workflow with patients. Overall, the focus was to design a platform that doesn't require any technical knowledge by its users. The user interface should be self-explaining and safe to use. Health professionals can choose from different exercises and play them with their patients. They can customize settings in each game and track improvement results throughout several sessions. They can use and control the platform independent of the VR devices of their patients with a secondary device, like an iPad. With the VRTherapy trainer app, they can evaluate a patient's improvement over time while playing a variety of exercises.

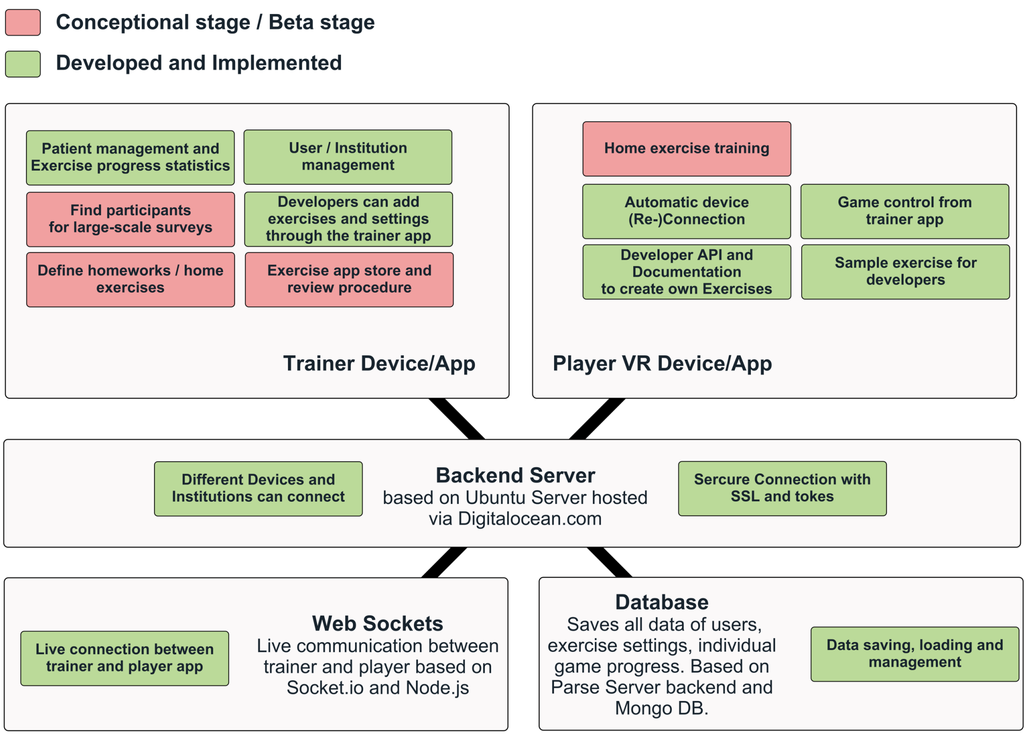


Figure 1: Overview of developed and conceptual elements of the VRTherapy platform.

Work on this software initially started for patients recovering from stroke rehabilitation only. It then became clear that the originals app's main feature - to update settings in real-time in VR from a secondary device - could be useful if also applied to other VR health exercises. A crucial function during development was to not only focus on one specific training but to create a platform that can provide a variety of exergames, all customizable and trackable through the same trainer app.

VRTherapy is now designed to be an open platform, where developers can create and publish health exercises with the 3D software "Unity". Health professionals can then discover and download these apps through the VRTherapy platform. This concept is taken from the well-known app stores that give consumers the possibility to find, download, purchase and review apps. For developers, it provides immediate access to a worldwide market and therefore offers a better financial incentive to start developing exergames for health-related purposes. For now, VR Therapy focuses on apps for healthcare in virtual reality only but could be extended augmented reality if useful.

3.1 Use cases for the VRTherapy platform

VRTherapy aims to make it as simple as possible for health professionals to add virtual reality exercises to their current workflow. The primary goal was to create a mobile solution that gives each therapist (also described as "trainer") the possibility to select from a collection of exercises and mini-games. The VRTherapy platform is designed to be used in a supervised setting where a trainer can influence and control exercise parameters in real-time through an app while being next to their patient. Each health exercise consists of a different amount of settings which can be customized at any moment of training to adapt to patient's needs. The therapist can adjust parameters even while their patient is playing the game. The trainer's app aims to have a user-friendly and straightforward design, without the need for any technical knowledge. For example, the therapist can select a specific angle to define where objects should be placed in the game to have the patient pay more attention to specific areas of their sight. The goal is that players stay motivated and keep exercising longer in VR. This can be achieved because more creative and diverse game elements can be used for training compared to "real world"-exercises. As the trainer can adjust all settings through a secondary device in the moment of playing, the player is never forced to leave their immersive experience. It enables them to always stay in the virtual world.

Furthermore, the app tracks long time improvement levels throughout different exergames played. The tracked variables vary and depend on the game. The most basic example to monitor progress would be the times played per exercise plus points reached in comparison to a player's overall attempts to succeed. This monitoring feature helps therapists to determine patient's improvement over time and might also help lower their workload of manual documentation as the software does it for them.

The combination of the trainer and VR app can be used and might be beneficial for the following scenarios:

1. In rehabilitation centers: The initial approach was to offer a software solution that can be used by health professionals in rehabilitation centers. Therefore, all current patients (also called players) of a rehabilitation center are visible to all therapists working in that specific institution. This is based on the fact that a patient might have training sessions with different health professionals. Profiles of patients that are no longer in active treatment can be archived or deleted.
2. In stroke rehabilitation: Visual training and stroke rehabilitation are more about distribution objects in specific areas of their field of view a player has to find. Therefore, the game could have additional contrast and color combination settings. It could help to improve motoric capabilities, decrease sufferings from neglect and upper-limb (phantom) pain. Common games like exploration training against neglect can be applied in a virtual world. Limitations would need to be considered in case the patient suffered from any kind of reduced sight.
3. In physiotherapy: Physiotherapists are mostly working on motoric deficits with their patients. These require specific game features that allow them to move, throw or catch objects while making different arm, hand or body movements. Therefore, physical elements such as gravity, falling, and drag are important settings used for physiotherapy.
4. In psychology: Psychologists can use VRTherapy to threat phobias of animals or heights. VRTherapy can also help to re-live through traumatic experiences in a safe but individualized environment. In this case, it might be more about just experiencing specific situations instead of directly performing motoric movements or exercises in combination with a controller.
5. Pain management and pain distraction: Patients can use specific exercises of VRTherapy to distract them from pain. By providing activities that are both focused on being calming and diverse (for example a beach), people

can be distracted by the VR world. This can be useful for patients staying longer in hospitals or while being at the dentist. The visual distraction can help these people focus less on their pain or fear. In this case, they would be less dependent on therapists pre-setting their scene. Pain management exercises could also be used to evaluate and document a person's subjective feeling of pain.

6. Additional home training: Trainers can create a set of exercises and make a collection of home exercises for their patients. Patients can finish these exercises until the next session. The trainer can then define a goal that is a bit better compared to the achievements of their last session, so patients can try to improve their motoric capabilities from home without being dependent on the trainer. This could be compared to a fitness trainer giving their client an introduction to the machines, but then they do their workout alone. Occasionally, the fitness trainer trains again and observes if movements during exercises are still correct.
7. Large-scale VR studies: Because VRTherapy allows multiple decentralized training units to be used at the same time for a variety of causes and exercises, it might offer a useful base to collect and evaluate data to help conduct large-scale studies. In general, this platform approach can help developers and health professionals to team up and create exercises together. In case there is an ongoing study using a specific VR exercise, other health professionals playing the same exercises with different patients could be invited to and therefore raise the number of participants. A feature that will enable providing consent forms for participants could be integrated. This would be a reciprocal benefit as study results for exercises can be added to an exercises profile. This helps health professionals to make better decisions about which exercises to add to a therapy.
8. Evaluation of exercise progress: If agreed, each players achievement can be tracked and saved. It would not only track which exercises have been played by which player, but also which settings have been applied. Furthermore, the improvement over time can be tracked. The health professional can access this data to evaluate their patient's progress and highlight where there is still room to improve. By providing an appealing way to display improvement and errors directly to players, awareness can be created to be more cautious in the next training session. That could be helpful especially for motoric enhancements.

3.2 Required hardware

The cheapest combination of hardware needed currently costs around 800 USD, considering the basic configuration that requires an iPad[11], one ZTE Axon 7[12] (used as the VR device) and the Google Daydream View[13] headset (see Figure 2). In general, all used devices need a stable internet connection. The internet connection is needed to connect to the backend server which manages the live connection between devices and saves user- and exercise data. Additionally, a Google Chromecast device can be used to transmit what the player sees on any screen with HDMI input. The following setup can be used, where the user is either static (seated or standing) or moving around in the room (only possible if the used VR headset supports room position tracking):

1. iPhone or iPad for the trainer app.
2. Google Daydream compatible phone (as of April 2018, there are 10 Smartphones models available like Google Pixel, ZTE Axon 7 and Samsung S8/S9) with Google Daydream View headset and controller.
3. Or, a standalone VR headset such as the Lenovo Mirage Solo with Daydream.
4. or on other VR Platforms: such as the HTC Vive, Oculus Rift or a Samsung smartphone with a GearVR headset. This is only possible if the player's VR exercise is optimized for these platforms and their controller's actions.
5. Additionally, a player's VR view can be streamed live on a monitor from the Google Daydream device to with Google Chromecast.

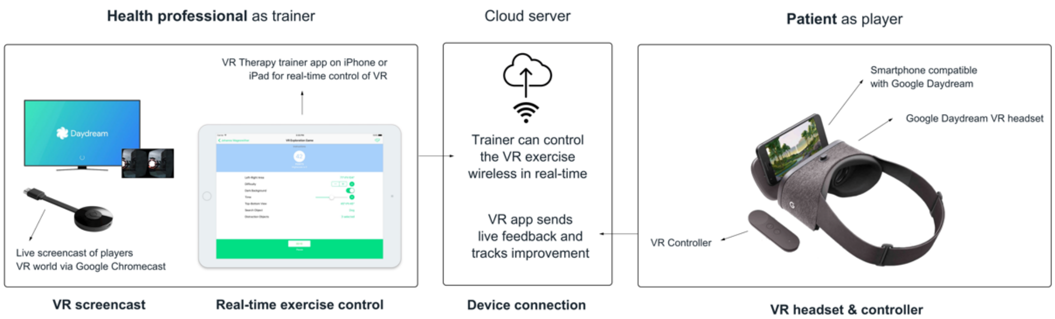


Figure 2: Hardware setup for VRTherapy

11 www.apple.com/ipad

12 www.zteusa.com/axon-7

13 www.vr.google.com/daydream/smartphonevr

At first, VRTherapy was designed for HTC Vive, which is a tethered VR solution. The HTC Vive quickly turned out to have disadvantages in mobility as it requires a time-consuming setup with additional technical equipment such as a computer with a powerful graphics processing unit and sensing devices distributed throughout the room. Also, the Vives's controllers are bigger and seem bulkier compared to other controllers. In 2016, Google introduced their VR platform called “Daydream” made for smartphones. It is crucial that VRTherapy is mobile and not dependent on expensive hardware. Using Daydream instead of the HTC Vive turned out to be a more cost-effective and portable solution for VRTherapy. Even though VRTherapy is currently optimized for Daydream, exercises could also be played on a different device such as the HTC Vive, Samsung Gear VR or the Oculus Rift. All VR exercises are created with the software Unity which allows deploying a VR app for different platforms.

3.3 VRTherapy trainer app for iOS

The trainer's app is made for iPhones or iPads. It is natively programmed with XCode and Swift 4.0 programming language. XCode is Apple's software to develop apps for their operating systems. Swift is a programming language also made by Apple for native iOS development. In theory, the VRTherapy trainer app could also be developed for Android devices.

The VRTherapy trainer software aims to fulfill five primary goals:

1. User management between trainers, players, and institutions. This could be a rehabilitation center, a clinic or a hospital. (see chapter 3.3.2)
2. Providing a library of exercises (see chapter 3.3.1.1) published by third-party developers sorted by different treatments categories (physiotherapy, psychological, stroke rehabilitation)
3. Managing the connection between multiple VR devices and trainer apps (see chapter 3.5.1)
4. VR game control in real-time during exercise sessions (see chapter 3.5.2)
5. Longtime tracking of a player's progress in specific exercises and overall progress in a treatment category (see chapter 3.6.2)

Trainers can see all exercises published by developers. VRTherapy can be used to train for different reasons and levels as it is an open and modular system. Therapists can keep track of a patient’s performance even when different exercises are played over time. They can start, stop and pause the game via the trainer app and set general game settings. They can also decide if results should be tracked and saved. Furthermore, they can control and change the difficulty of each exercise in real-time based on the current challenge. It is possible to define the type of goal to be achieved for each exergame. Such a goal could be a certain amount of points reached in a specified amount of time while committing as few errors as possible.

3.3.1 Usability considerations

While developing the trainer app, it was intended to use standard user interface (UI) elements of iOS as much as possible to create a self-explaining user experience for the trainer's game control screen (see Figure 3b). Among others, there were two essential elements which had to be designed and programmed from zero: The first was a UI element which allows setting angles for exercise settings in an intuitive way. The second element involved an entire process flow: Creating a self-explaining setup when connecting a new VR device with a trainers app.

3.3.1.1 UI Elements for real-time exercise control

The goal was to create a useful UI element to set angles. Deciding areas by angle is a reappearing element needed throughout multiple VR health exercises. For example, it is useful to define the area where objects should be distributed in a player's world. Of course, a trainer could just enter the number of degrees from the middle point to the left and right (for example 45 and 60), to set the angles. However, this did not seem an intuitive approach. Therefore, a touchable angle selector had to be programmed from scratch to enable left-right or top-bottom angle definition. The trainer can now drag the blue dots (see Figure 3c and 2d) from the middle line to define the active area.

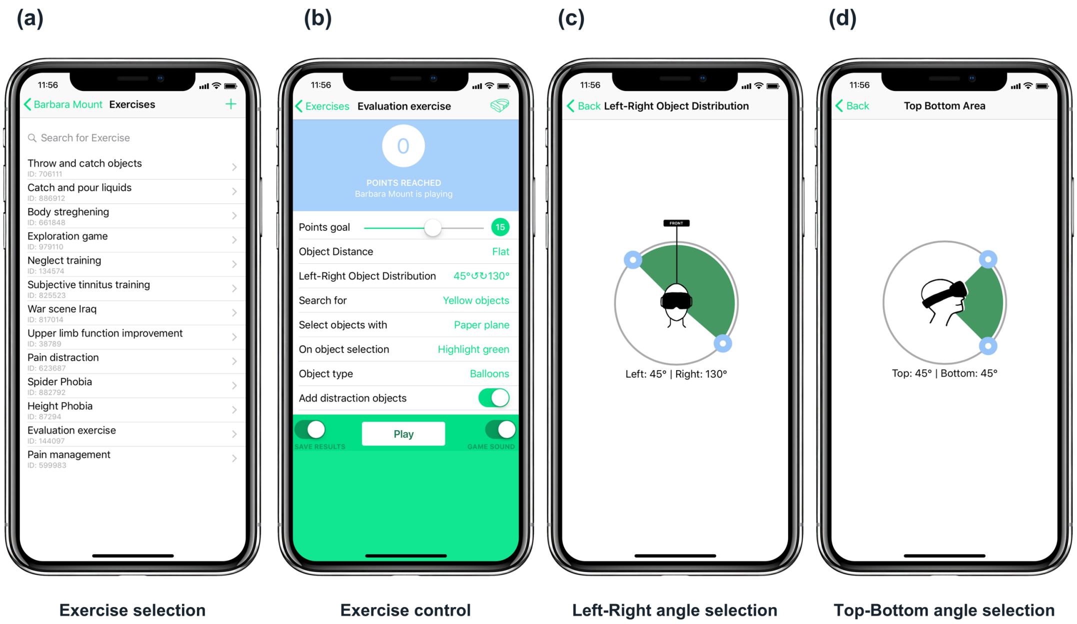


Figure 3: Exercise selection and control with angle selection UI elements.

In total, there are six different types of UI elements (see Figure 4) that can be integrated in any combination to customize an exercise through the trainer app. These elements are:

1. Single selection from a list (e.g., the distance of objects from the player)
2. Slider with minimum and maximum number (e.g., number of objects)
3. Stepper with minimum and maximum number (e.g., intensity level)
4. Multiple selections from a list (e.g., which type of objects should be displayed)
5. Angle selection from the players middle point (e.g., left-right and top-bottom angle of random game object distribution in an area)
6. On/Off Switch (e.g., Animated or static objects)

As seen in Figure 3, each developer can create a VR exergame and then choose to add different types of settings for this exercise.

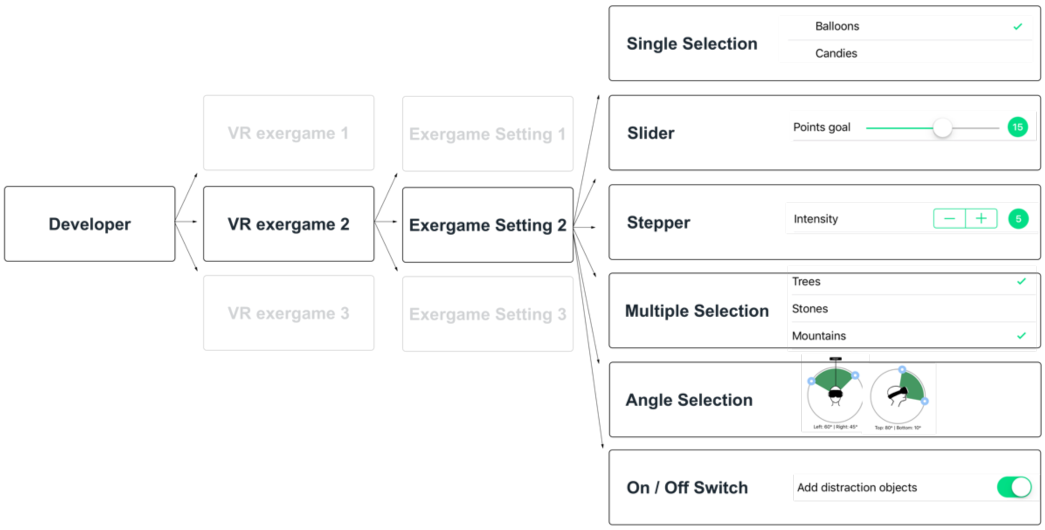


Figure 4: VRTherapy UI Elements for exergame control

Developers can add new game setting elements directly in the trainer's app, without the need for any programming on the iOS trainer app. They first enter the apps “developer mode” by pressing the VR glass symbol on the top right in the game control screen. Then, each setting will display an ID below the settings name, which is required to synch in Unity. The developer can now manage the game settings. Existing settings can be edited or deleted, and new settings can be added.

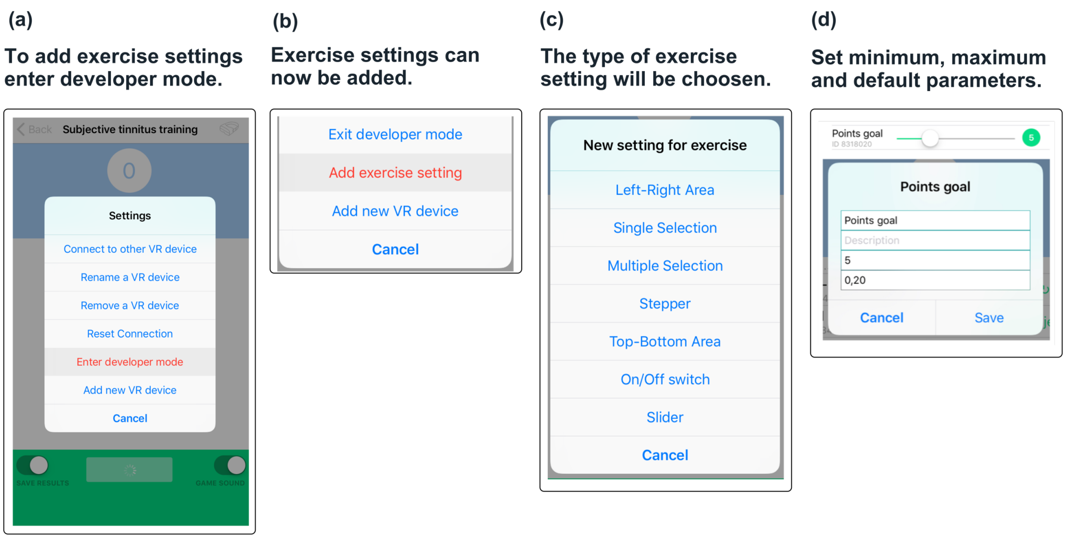


Figure 5: Adding exercise settings in the trainer app without programming.

When adding a new setting, developers are first prompted with a screen to choose which of the available settings type they would like to add. Next, the according setup screen for each setting appears.

3.3.1.2 An intuitive connection of VR devices with trainer apps

It was essential to come up with a simple and intuitive way to connect a VR device with a trainer's app. Any text input through the VR device should be avoided as this is a slow process and feels unintuitive. Also, instead of connecting a VR device only once statically with a trainer app, the trainer's app needs to be able to reconnect to multiple devices. This is because the trainers and players devices can change between sessions. Therapists might control an exergame through a different device when provided by a rehabilitation center, or players use different VR devices between exercise sessions if they are not playing on their own smartphone.

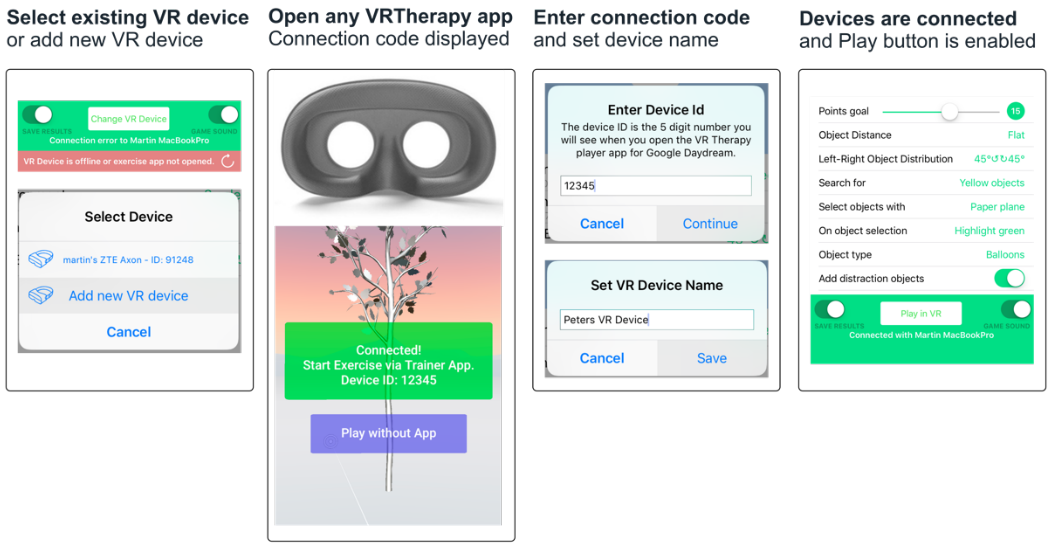


Figure 6: Connection process between the VRTherapy trainer and VR player devices.

When a VR device is used for the first time, the trainer must enter a connection code displayed in the VR app to connect the two devices. This code has to be entered just one time per device. Therefore, when a player opens a VRTherapy compatible app for the first time, it registers the devices UUID (a unique identifier of the device itself) to the backend database and saves it. While registering the ID of the device, a connection code similar to a flight booking code will be created by the server and displayed to the user back on the VR device's screen. The trainer's app can now connect to the VR device by entering the displayed connection code in the trainer's app by pressing "Add new VR device." A name for the VR device can then be set in the trainer's app. As every third-party developer can publish their own VR app, it was essential to create a connection process that is independent from which app is currently opened on the VR device (if compatible with VRTherapy). To solve this problem, every time a VRTherapy compatible app is opened, the server will be asked if a device with the respective UUID is already registered in the database.

In future sessions, a trainer app will always try to connect automatically to the last used device. This only works if both devices are currently connected to the internet, and the VR device has a VRTherapy compatible app opened. Otherwise, an message will be displayed in the trainer's app that informs the trainer to open the exercise app in the VR device. The option will be given, to select from another device previously added or connect to a new device. In case the internet connection is lost and reestablished, the trainer's app and player's app react automatically when internet connections are restored to start the reconnection process automatically.

3.3.2 Trainer and player role management

When using VRTherapy, each trainer creates a user account which can be linked to an institution, for example, the rehabilitation center they work in. Trainers then can add players (in this case patients) or select an existing player (see Figure 8 and chapter 3.3.2). Once the player is added/chosen, they can select the exercise to play.

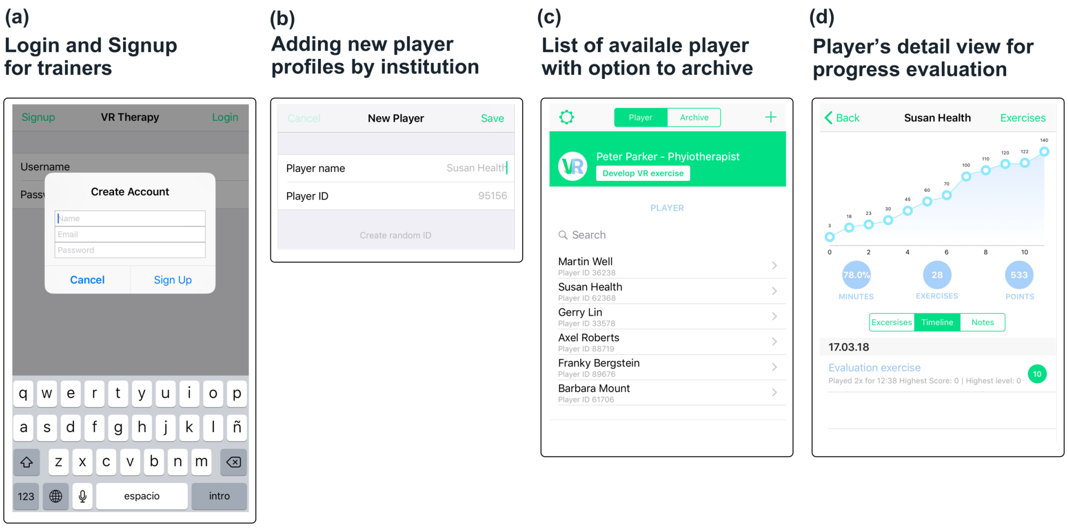


Figure 7: Trainer and player role management in the VRTherapy trainer app.

The role of the player does not require any administrative tasks. The player does not have to create a user account with a password or email address. In case a therapist selects some games for home training the homework will be available directly on the player's device.

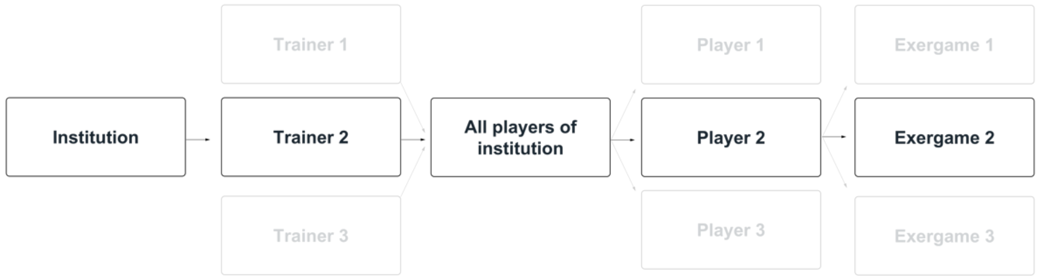


Figure 8: Role and User management scheme of VRTherapy.

3.3.3 **Prototype**

VRTherapy is currently a prototype and not used commercially. The prototype had been released on the iOS App Store and therefore complies with Apple's requirements for app distribution. Even though a prototype, all feature in this app release are working. The platform is ready for real-time evaluation with therapists and – after potentially required etical or medical approval – evaluation with patients. An unlimited number of VR devices and trainer apps can connect at the same time on this platform.

However, some features described in this thesis are currently in a conceptual stage (see Figure 1) and not yet released on the public version. Unreleased features are the home exercise extension, sharing of exercise settings between therapists and that developers can publish their created exercises to other health professionals on the platform. As VRTherapy is just the platform where exercises can be created and published on, each exercises game developer is responsible if any approval for using with patients might be required.

3.4 VRTherapy player VR app

VRTherapy exercises are created with the software Unity. Unity developers can create 3D games even with little knowledge of programming. One of the software's biggest strengths is the possibility to export (compile) the VR app for different platforms. In this case, a VRTherapy exercise can be made available for the Google Daydream platform and the Steam platform without the need to develop the application twice. Only smaller platform-specific programming modifications are needed. For example, such modifications are required to respond to specific controller actions.

The VRTherapy framework gives developers the possibility to create a VR exercise app for healthcare. Already existing health-related exergames can be optimized to be compatible with the VRTherapy trainer app by including its API (Application Program Interface). The API is publicly available on GitHub[14] and includes documentation[15]. The documentation describes how to integrate this code into a Unity project. This API's job is to automatically establish the connection between the VR app with the trainer app and to send all relevant communication – such as an updated game variable – back and forth when needed. The user of the trainer app controls each game remotely through the trainer's app. Minimum controls are starting, pausing and stopping the game. Furthermore, specific game settings can be updated before the game starts or even while the VR user is playing. Because parameters can be changed on-the-go via the secondary app, the person wearing the VR headset is neither interrupted between games, nor forced to leave the immersive virtual world.

Each developer can create their own VR app with Unity and publish it on the app store of their choice based on the MIT Licence[16]. Among others, this could be the Google Play Store or Steam. In case developers do not want to allow the download of their app to be for free, they can define a price on the app store they choose to publish in the same way as with any regular app. The API was designed to enable multiple exercises or games in one app if made by the same developer. However, as every third-party developer is obligated to publish their separate VR app, a player might have installed several virtual reality exercise apps on their device. Each of these apps will then automatically connect to the VRTherapy trainer app.

Thanks to this API, health professionals can then choose from all published exercises made by third-party developers. The following three steps are required that an app can be publicly available to the VRTherapy platform:

1. The VRTherapy API has to be included in the apps Unity project. They follow the steps from the API documentation. They add the VRTherapy script that manages all communication with the trainer app and the games key events such as to start or stop actions. Also, each exercise has a unique identifier created automatically when developers create a new

[14] https://github.com/branddirections/VRTherapy

[15] https://branddirections.eu/vrtherapy/vrtherapy-api-v1.pdf

[16] https://mit-license.org/

exercise in the trainer app. This identifier is used in the player app to listen on updates from the trainer app. When an update is received, the trainer can decide what should happen with the received value. Lastly, developers can send feedback to the trainer app in case points should increase or the game time is up.

2. A new exercise has to be set up once through the developer mode (see Figure 5a) in the VRTherapy trainer app and will be saved directly on the back-end database. First, the developer adds the apps basic information such as the exercises name, description, screenshots and the VR app store link. Afterwards, the developer set’s up all remotely controllable exercise parameters and their respective standard settings for this exercise in the trainer app. Then an individual amount of controllable parameters can be added (see Figure 5a). First, the type of UI element desired (see Figure 5d) has to be selected. Second, the settings name, description and default selected value (see Figure 5d) can be defined.
3. To submit, the finished VR app must already be published on the Google Play Store and include the ‘Ready for Daydream' batch. That means that the app has undergone a more extensive review by Google Play Store team to ensure the app is optimized for VR. Developers then add the download link to the exercises profile page on the VRTherapy platform and enter the build number of the app. The build number becomes essential when the VR app is updated by the developer. In a future version, each published exercise should also be reviewed by the VRTherapy team to ensure the exercise is accurate for healthcare. Only after review has been passed, the exercise should be published to all users on the VRTherapy platform.

In the case a published VR app version receives an update, it is essential that the version available in the VRTherapy platform is equal to the version number published in the selected app store. In this case, the build numbers have to match both in the exercises profile and the published VR app. The trainer app has checks integrated to see if the right app is opened on the players VR device and if the build numbers are identical. In case a lower build number is used, the app uses the game settings of the previous versions, as each exercise settings are saved seperately by version number on the backend server. That ensures consistency when tracking player feedback and improvement parameters. Also, the user receives a warning in the VRTherapy home screen in case the opened VR app on the player’s device isn’t identical with the selected exercise by the trainer.

3.4.1 **Usability considerations**

The platform consists of a collection of different exercises made by various developers. It can have several exercise apps made for VRTherapy which are deployed for a variety of VR hardware such as Google Daydream View or the HTC Vive. That also gives health professionals and developers the possibility to choose the best-suited platform for the desired exercise. Evaluating the ideal platform can be dependent on criteria such as the required controller inputs, whether the player needs to move freely around in the room or which hardware criteria (e.g. weight of the VR headset) is acceptable.

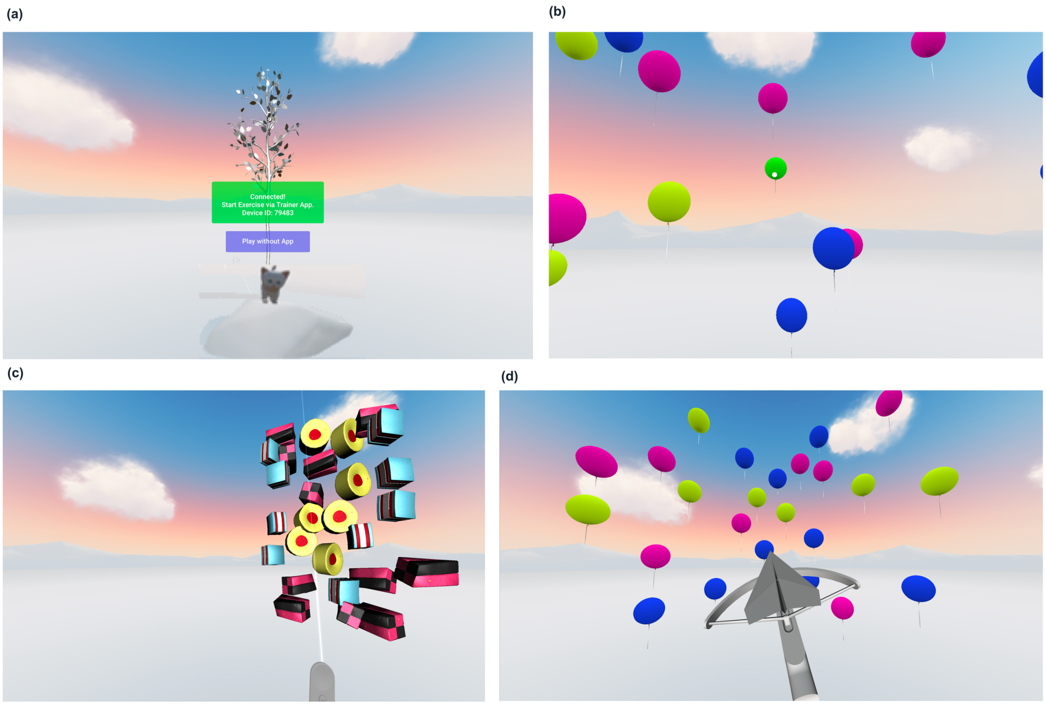


Figure 9: Player's view of VRTherapy home screen and different settings of the VRT sample exercise during playing.

Usability considerations in VR are paramount as it is a new platform and people should not be confused with UI elements not optimized for VR. VR exercises can use more interactive and diverse game elements to keep the motivation level of players higher than with conventional exercises [23]. The raised motivation can be achieved by integrating unique game elements and therefore create surprise moments for the player. Nudging, a technique to lead and motivate people to perform a task without the feeling of obligation [24], can be well included in VR exercises.

All VRTherapy compatible exercises start with the VRTherapy home screen. It is supposed to look the same among all the different exercise apps. The user sees a harmonic landscape with trees in an evening sky. The goal of the consistent home scene is to create comfort by continuity for the user throughout the different exercises apps. As some VRTherapy exercises are dependent on angles and areas, it is vital for players to define and understand where the center line in the virtual world is. Instead of adding arrows or lines, the decision was to place a cat in front of the user (Figure 9a). The little animal serves the purpose to define the center point of the game and to make the user familiar with the touch inputs of the controller. To learn how to use the controller before starting the game, the sitting cat stands up when touching the controller's touch area and jumps on clicking. Using the cat is an example of applying the technique of nudging as the user is naturally tempted to look at the cat which is at the same time the viewer's center point. In general, useful guidance about usability issues about text input, menu interaction is provided by Google. Their usability guide for Google Daydream apps[17] offers the do's and don'ts in a VR with plenty of usability considerations. It can directly help developers to learn to understand where problems occur when designing user interfaces for VR compared to classic smartphone UI design.

Exergames for healthcare do not have the goal to be a motion intense ego-shooter without any health improving purpose. The use of strong motion or too many elements might not always be useful. It is vital creating a responsible combination of a motivating exergame without forgetting that user should improve their health in a specific way with each game.

3.4.2 Controller interactions

The used controller's ergonomics, weight, and dimensions are significant for the results of acceptance and easiness-of-use for each VR system (see Figure 10).

[17] https://vr.google.com/daydream/

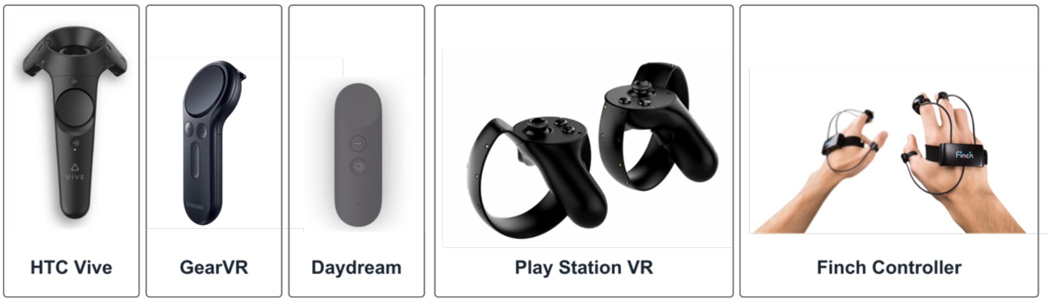


Figure 10: VR controllers by system vary in weight and ergonomics.

An introduction of different controllers for the platforms and possibilities such as wearing gloves instead of controllers, conduct eye tracking in the VR glasses or measure a player's body rotation compared to the head rotation might increase tracking possibilities. However, for each of these technological advancements, an evaluation needs to carefully consider if the increased amount of tracking and technical equipment attached to the player's body will also lead to a faster or more effective cure. Another approach to improve a user's tracking is the combination of physiological devices attached to the player of VR exergames. They could measure their skin conductance during exercising to evaluate their level of arousal or track a user's pulse.

There might be a possibility for a more diverse controller market. Controllers should be allowed and might be needed more specifically for the healthcare and rehabilitation sector. Further studies could investigate which type of controller might be most suitable for which exercise. A system like VR Therapy might benefit from being used in combination with a glove system with accurate finger tracking: it might show improvements in the quality of feedback available from players to trainers to evaluate their motoric improvement over time [25].

Feeling objects or pressure of virtual objects through controllers with force feedback is currently not yet available with mass-market products. First prototypes are becoming available to feel force or pressure, but it is unclear when these products are mass market ready. There is currently a prototype made by dextarobotics available that aims to create such a glove[18].

A deficit on programming VR exercises for different platforms in Unity is that VR controller events (such as clicking a button or receive the controller's position) are currently not accessible through unified code. Therefore, the app's source code has to be adapted depending on the deployed platform. Hopefully, this will change

[18] www.dextarobotics.com

in a future version of Unity, as most controller events are technically the same, no matter the platform.

3.5 Implementing the VRTherapy API to VR exercises in Unity

The VRTherapy API intends to provide third-party developers with functions and scripts to connect their – also existing - VR apps to the VRTherapy platform. This API has the goal to fulfil the following task:

1. Automatically manage connection between the third-party developer's VR game device to the VRTherapy platform device.
2. Manage essential game controls such as start, stop, pause, sound, and switch between exercises.
3. Listen to updates from the trainer's app and call the appropriate function to update the required settings of the VR game.
4. Send feedback information from the VR app to the trainer app about the players progress. This could be increasing points, failed attempts, time playing.

The VRTherapy API can be downloaded via GitHub[19] and offers a detailed technical documentation about the integration into a Unity project. The API also offers a predefined set of tools that provide playing concepts which might reappear throughout multiple exercises. One of these features is called "Object selection". This enables the trainer to choose the mode how to select an object. Trainers can choose between a laser pointer to select an object, a visual selection by seeing a projectile in the middle of their view and looking over the target for a defined amount of time; or by shooting the object with a paper plane (see Figure 9). Developers also have the pre-defined option to set how elements react when selected. The selected game elements can explode, fall to the floor or just disappear. This is intended to help people that may perceive the fast motion of an explosion as too intense.

3.5.1 General setup for a new VR exercise

Once the downloaded VRTherapy API is imported into the third-party developers Unity project, it basically consists of four scripts. The *VRTConnect* script (see Figure 11) manages the connection between the app and the server. The

[19] https://github.com/branddirections/VRTherapy

VRTExercise script automatically controls the game and switches between the standardized VRTherapy home scene and the chosen exercise. It also is the script that receives the information about changed exercises. Therefore, changes to game objects are received and delegated from this script.

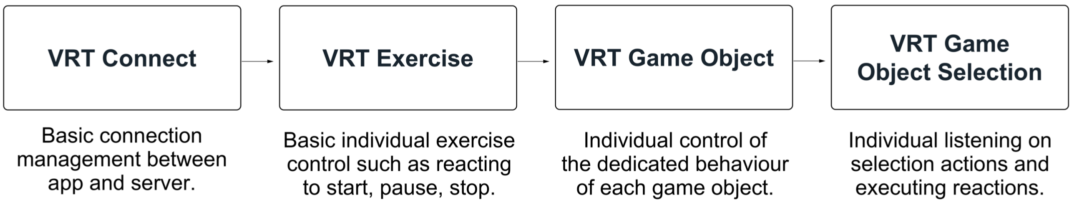


Figure 11: Hierarchy of VRTherapy Scripts in an VR Exercise in Unity.

The *VRTGameObject* script needs to be applied to every object that is selectable. The *VRTGameObjectSelection* needs to be called when a script is hit. This manages actions to increase points and react appropriately on selection with animations such as explosions or disappearing.

3.5.2 Receiving and updating exercise settings from the trainer app in real-time

Exercises are received in the *VRTExercise* script. They are separated between predefined and custom exercise settings. Each setting has automatically a dedicated ID assigned while adding the setting parameter in the trainer app. With this identifier the API can target the correct setting to be sent, saved or read in real-time.

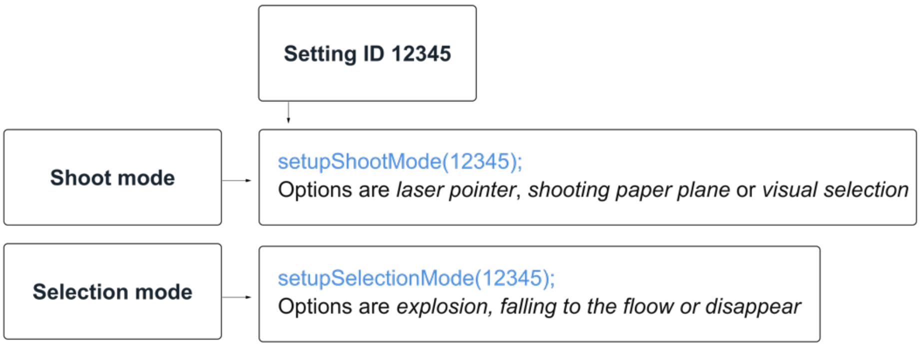


Figure 12: Listening on predefined exercise setting through the VRTherapy API.

A detailed documentation has been written to enable third-party developers to follow a step-by-step guide to understand how to implement the VRTherapy API into their Unity project[20]. Different functions from the API are available to listen on the receiving of parameters from the trainer app. Developers can add default parameters of exercises such as shoot mode, explosion modes and goal settings (see Figure 12). Developers can also call an individual value from the available UI Elements in the trainer App (see Figure 4) by calling the according function (see Figure 13) and the automatically assigned setting identifier. This setting identifier appears below each game setting in the trainer app when entered in *developer mode* (see 3.3.1.1 UI Elements for real-time exercise control).

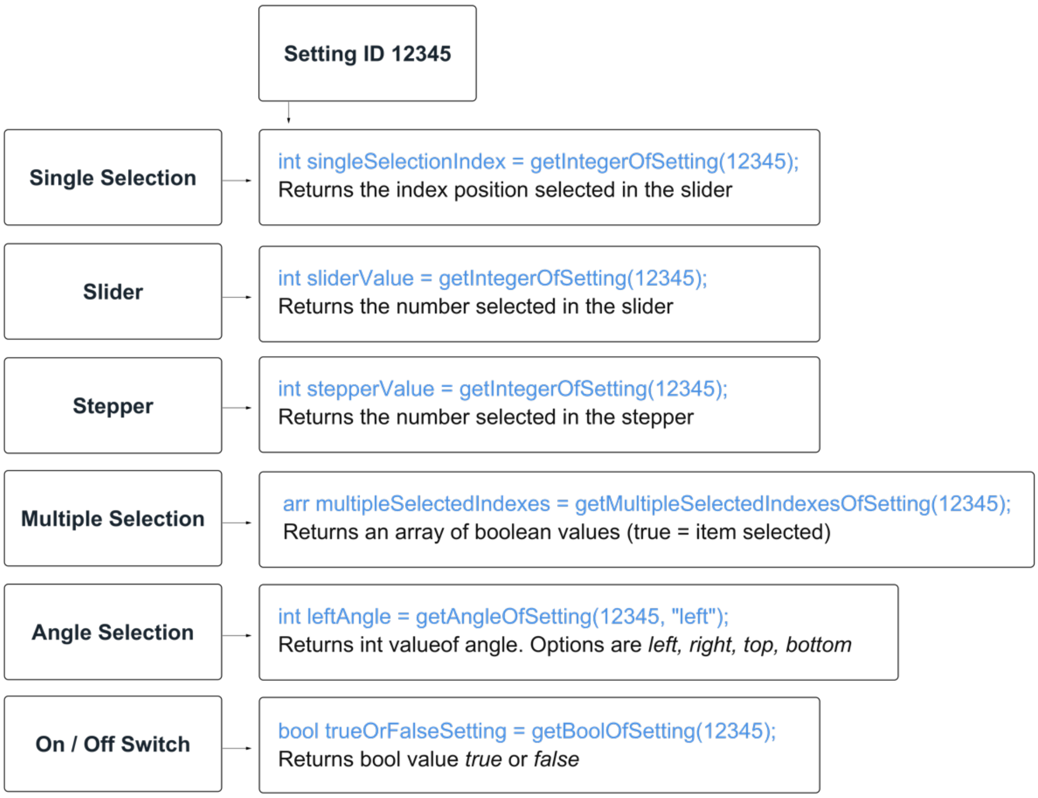


Figure 13: API functions to receive settings in from the trainer app.

3.5.3 **Sending feedback parameters to trainer App**

As different exercises have different goals to reach, it appeared to be the best idea to allow developers to increase or decrease points at any moment while the exercise is played from the VR game in the trainer app through a dedicated

[20] https://github.com/branddirections/VRTherapy

function. Exercise developers can increase or decrease points by calling the function *increasePointsBy(1*) and setting a positive or negative integer value (see Figure 14). Feedback parameters are currently collected in points. By counting successful actions in the currency of points, developers have flexible ways to define when and where users can decrease or increase the chance of winning or losing. By calling the function *stopExerciseWithId(12345)* a currently running exercise can be triggered to stop directly from the VR app (see Figure 14).

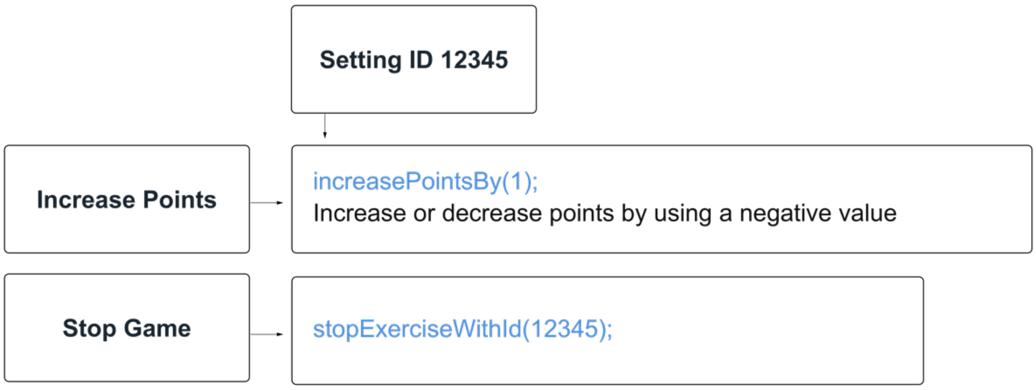


Figure 14: Sending responses from VR game to trainer App

Evaluating which feedback parameters work best for tracking a player's progress depends on each exercise. In general, it seems relevant to not only track a user's improvements but also to compare it to their unfavourable actions. For example, in a game where objects have to be found, it should be tracked how many incorrect objects have been selected in addition to tracking a correct finding. Time and points are a common choice in combination with negative points.

3.5.4 Virtual Reality exergame prototype

The sample VR app can be downloaded for mobile devices that are compatible with Google Daydream from the Google Play Store[21]. The prototype exercise is based on a standard exercise applied when people suffer from visual neglect. People affected are not able to sense and see one side of the body nor their environment. Patients with visual neglect are often not aware of their deficiency [26]. A common exercise used to help patients to learn to cope with visual neglect is exploration training.

During the prototyping process, the required parameters for the trainer's app have been defined together with two orthopedicians and one physiotherapist. These

[21] play.google.com/store/apps/details?id=eu.branddirections.VRTherapyDemo

settings should provide the trainer the possibility to customize the exercise to their patient's requirements without providing an overdose of settings. The goal of the exercise is to find as many objects as possible in a pre-set amount of time. The following settings have been set to be customizable:

- Number of objects to be found
- Type of object (Balloons or candies)
- Showing other objects to distract the user
- Floating or rotation of objects
- Color of the object that should be found and selected
- The distance of the objects from the player and if they should be distributed evenly or in various distances (for example 5-8 meters from the user)

The prototype also includes the VR Therapy home screen and was created with the VRTherapy API. It was a proof of concept to ensure that the API is working to create exercises and can be applied in a real development case.

3.6 Backend and server-side

A web server is used to connect the iOS Trainer App and the Players VR app in real-time. Therefore, both devices require a stable internet connection over a wireless network at all times during use. VRTherapy runs with two different connection services which are based on different server techniques. The first (based on Parse Server[22], an open source version of the Parse backend that can be deployed to any infrastructure that can run Node.js) serves three purposes: User management, game results tracking and loading of exercises and their settings. The second service is dedicated to the live connection between the iOS Trainer app and the VR player App through web sockets.

3.6.1 Architecture

The reason to split services between these two connection services was to enable an open platform with different health exercises made by different developers. At the same time, database access is kept on a minimal level to reduce safety risks. Therefore, all communication with the backends' database service runs exclusively on the web server and the iOS App as these two systems cannot be modified by outside developers.

[22] https://github.com/parse-community/parse-server

All available settings for a VR exercise are first loaded from the backend on the trainers iOS device and then sent to the player's device when starting the exercise. When data is saved automatically during and after each training session, the information is first transmitted back from the player's device to the trainer's app. A player's VR app can on purpose never communicate directly with the database. If game result should be tracked and saved, only the trainer app can then send data to the server where it will be validated and then saved in the backends database.

A remote web server is used because of two main reasons:

1. For example, in a rehabilitation center, one patient trains with different therapists due to their work schedule. They must be able to access the patient's individual exercise history through their user accounts. That allows them to continue exercising with the last exercises setting of the previous session and observe training process, even if it was conducted by a colleague. Therefore, a web server is used to collect data centralized and manage which therapist is entitled to see who's players profile and progress.

2. The second reason for using a web server is the possibility to expand this platform with a home exercise tool in the future. Therapists can define a goal for patients to reach at the end of each session and create a "workout" of exercises with individualized settings to be completed until the next session. Therefore, the access to exercise data of patients is required at different locations. When the patient trains at home, the data is already saved in real-time instead of the need to be downloaded and updated by the therapist manually. In case the user has no internet connection at home, the data will be saved on the device and uploaded when an internet connection exists (for example at the next therapy session).

Alternatively, it would be possible to provide the platform on a local server without the need of an internet connection. Using VRTherapy without an internet connection could be achieved by running the backend software on a "Raspberry Pi W" mini computer. This computer includes a Wi-Fi chip where the trainer and player apps connect to. Then the solution can be used only locally without any data every leaving the local environment.

3.6.2 Data transmission

The backend service is based on “Parse Server”, a free open source backend solution based on a MongoDB[23] database system. Parse has the advantage to provide user management and asynchronous database querying, reading and writing for multiple platforms such as iOS, Android, Java and Unity [27]. Due to its open source character, the platform's source code has to be manually installed on the used web server. Therefore, the developer stays ins full control over the code and security measures needed. Another advantage of Parse is proper ACL (Access Control List) handling. ACL means that all information that is written to and read from the database can include a precise definition of which users are allowed to read or write this information. ACL can be set between different on each column of a database.

The real-time connection between the trainer and the player app is established via a node.js script based on “socket.io”[24]. These two components in combination allow asynchronous data being sent and received only when new data needs to be transmitted instead of repeatedly checking for new data.

3.6.3 Data privacy

Data privacy is an important requirement that should always be considered already in the planning stage of each software project. Personal information related to healthcare is regarded as sensitive data and therefore deserves a higher level of protection. Apart from being an obligation by the European data privacy law [28], each developer should follow the approach of privacy by design. Privacy by design describes the process to include all possible measures of data protection into systems and services from the beginning of IT services [29].

In the specific development process of VRTherapy, the following measures of privacy by design and privacy by default have been taken:

1. The server is based in Frankfurt/Germany to ensure data is only saved within the European Union.
2. Encrypted Communication between trainer app, server, and player VR app though SSL (Secure Socket Layer) and encrypted HTTPS connections.
3. Using the open source backend solution “Parse platform” as a database and backend service to stay in control of the included source code of third parties.

[23] www.mongodb.com/what-is-mongodb

[24] www.socket.io

4. Encrypted token authentication for real-time live communication service between players and trainer app. Only registered users in the database can listen to real-time events transmitted through web sockets.
5. Players names are only IDs based on numbers by default, but names can be specified if desired.
6. Trainers can decide if the game result should be tracked (saved) or not at any moment.
7. User profiles can be archived or deleted at any time entirely directly through the trainer app.

No sensitive health data is being saved directly on the VRTherapy platform. The platform is based on an online server to enforce its mobile character that ensures to be as independent as possible of the devices and platforms the software can be used.

4 Evaluation

4.1 Aim of the survey

The survey conducted in this thesis aims to evaluate the usefulness of the supervised virtual reality platform “VRTherapy”. The focus is to determine if such a platform seems a beneficial tool for health professionals and if they consider it a useful addition to include in their workflow with patients.

Further, it will be evaluated which traditional currently practiced exercises could be a promising virtual reality exercise. The idea is to find out which type of exercises could have better therapeutic results when practiced in VR. This can be achieved by providing the player with a more diversifying and individualized experience as the trainer can customize game settings in real-time. That likewise might have the potential to increase the motivation of patients and therefore help them to reach the overall training goal faster. This investigation does not include any trials with patients. It focuses solely on evaluating what are health professionals first impressions about VRTherapy in combination with their professional experience and expertise. Taking this into account, it can thereby not be estimated in this thesis whether a specific exercise would provide better treatment results in VR on patients. The goal is instead to provide guidance for further studies to define which (types of) exercises should be developed.

4.2 Main research question

Can a supervised virtual reality exercise platform be a useful enough tool to be integrated into a health professionals’ workflow?

4.3 Description of method of this examination

4.3.1 Used research method

An explorative pilot study with qualitative research among 10 health professionals matching the inclusion criteria was conducted. Each participant was introduced to the VRTherapy platform. During this introduction, each interviewee was introduced to both the trainers iPad app and the player's VR app. The VR app consists of a sample exercise similar to the classic “exploration game” used for patients suffering from neglect. By experiencing both perspectives during introduction, it gives the interviewed the possibility to better understand both roles (player and trainer) before naming possible use cases.

The following items (questions) were asked:

1. I consider it useful to integrate virtual reality exergames in my daily workflow with patients?
2. The training motivation of my patients can be raised through virtual reality exercises.
3. The training success of my patients can be raised through virtual reality Exercises.
4. Which classic exercises (that you often utilize with your patients) do you consider useful as a virtual reality exercise?
    a. Which exercise settings would you like to be able to set for each the exercise named above?
    b. What feedback information would you like to receive on the trainer’s app to evaluate your patient's training progress?

Questions 1-3 are surveyed on a scale from 1-7, where one means “I do not agree” and seven means “I fully agree.” The range from 1 to 7 was chosen to receive better nuances in the answers. All participants answered the open questions in written, textual form.

4.3.2 Survey Schedule & Agenda

All evaluation sessions happened separately between March and April 2018. Each participant was introduced for 10-15 minutes to the VRTherapy platform, and allowed to try, use and test the platform with it’s sample exercise. Immediately after this, the questions have been answered.

4.3.3 Method of sampling and inclusion criteria

10 health professionals participated in this explorative pilot study. They consist of five physiotherapists, two ergo-therapists and one orthoptist.

- Inclusion criteria: Health professionals like Physiotherapists, Ergo-therapists or Orthoptists that work in the field of rehabilitation. All participants are required to practice active rehabilitation training with patients.

- Exclusion criteria: Patients, no interest in VR, not feeling comfortable wearing a VR device, health professionals not working in a direct training or rehabilitation context with patients.

4.3.4 **Study setting & technical equipment used**

During the introduction to the VR Therapy platform, the health professional is introduced to both the trainer's iPad app as well as the player's VR app to experience a possible patient's perspective. Next, the data is collected in a qualitative study by conducting an open question survey. The questions are focused on evaluating the following items.

Google Daydream VR is used as the virtual reality platform. It consists of the headset, a small controller and one smartphone certified for Google Daydream. The VRTherapy trainer app is made for iOS and therefore is used on either an iPad or iPhone. Further, a stable internet connection is required, as VRTherapy communicates via a web server.

The used VRTherapy sample exercise is made available through the Google Daydream platform. Google Daydream specifications depend on the Smartphone used. In this trial, an ZTE Axon 7 was used, which provides an AMOLED Screen with a screen size of 1440x2550 pixel (538 PPI resolution).[25] The view angle in combination with the Google Daydream View headset is approximately 90 degrees. The Interpapillary distance cannot be adjusted and is fixed at 64mm.[26] The phones weight is 175g plus the weight of the headset of 310 grams. This total 486g on the user's head (and is the currently lightest option available). The controller user weights 20g. No headphones were needed as the sound comes directly from the phones stereo speakers.

[25] www.gsmarena.com/zte_axon_7-8067.php

[26] www.digitaltrends.com/virtual-reality/google-daydream-view-vs-samsung-gear-vr/

5 Findings and Results

Five participants are male, five female. 8 of 10 participants were medical professionals aged between 20-30 and all participants had used a VR headset before this evaluation at least once. It can be considered positive that the participants had already used a VR device before, in order to reduce possible over-excitement about experiencing the technique as new and giving more reflected answers. The young age of the participants prevented this evaluation from drawing any conclusions about the opinions of health professionals of higher age. Older people sometimes might tend to be more sceptical to new technologies especially when they have more years of work experience and are more used to applying their own established methods based on their knowledge over time [30]. Therefore, due to the participants younger age, the surveyed answers could be biased more towards a positive direction. 8 out of 10 participants are physiotherapists. One ergo-therapist and one orthoptist also participated. All participants are in direct contact with patients.

5.1 Usefulness of virtual reality exercises

Participants have been unclear if they consider integrating virtual reality exercises into their daily workflow as a useful tool. Half the answers either had positive or negative tendencies, none were neutral. The survey seems to support the findings of previous surveys where higher motivation when training in VR compared to convenient methods could be expected from patients. The participating health professionals seem to confirm an increase of patient motivation. There is a positive reception among participants that the training success of their patients can be improved with VR exergames. No negative approval rating (scale 1 or 2) have been given in question 3. As the answers were very similar, the data has been accumulated in Figure 14.

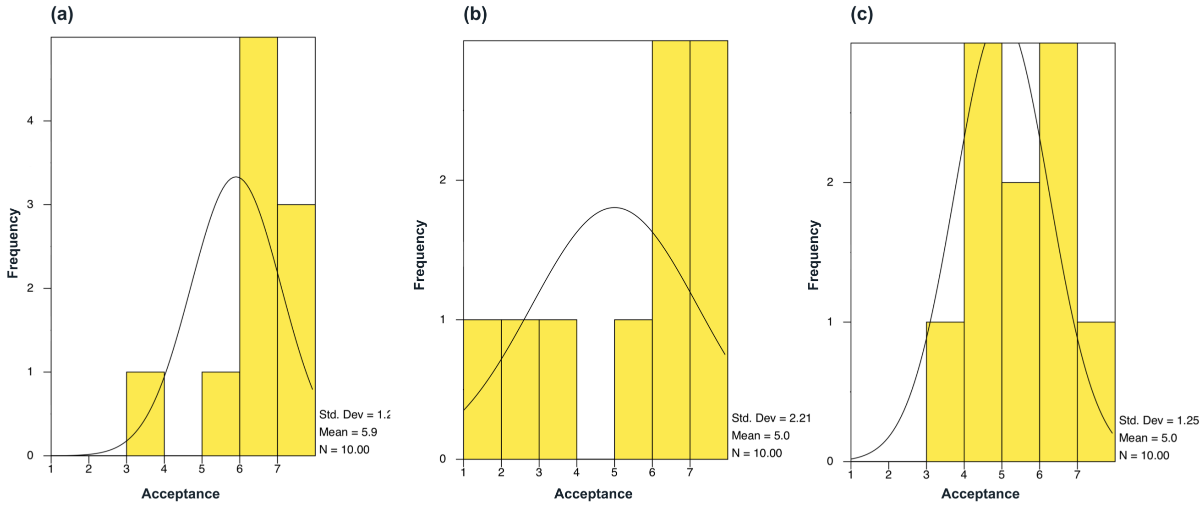


Figure 15: Survey results of questions 1-3 about patient motivation and training success.

Three questions regarding a patient's motivation and their training success were asked:

- Q1 (see Figure 15a): I consider it useful to integrate virtual reality exergames in my daily workflow with patients.
- Q2 (see Figure 15b): The training motivation of my patients can be raised through virtual reality exercises.
- Q3 (see Figure 15c): The training success of my patients can be raised through virtual reality exercises.

Table 1: Accumulated data of patient motivation and training success of VR exercises (a) with statistical evaluation (b) and accumulated bar chart (c).

(a)

Acceptance

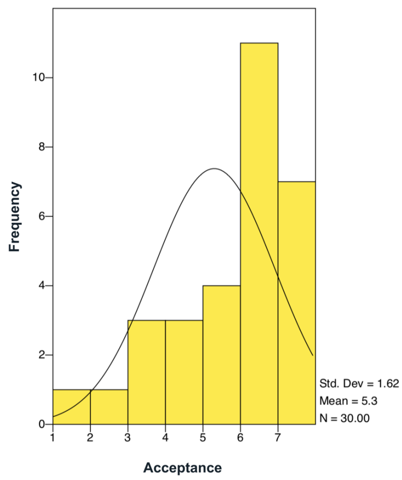
Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	1	1	3.33	3.33	3.33
	2	1	3.33	3.33	6.67
	3	3	10.00	10.00	16.67
	4	3	10.00	10.00	26.67
	5	4	13.33	13.33	40.00
	6	11	36.67	36.67	76.67
	7	7	23.33	23.33	100.00
	Total	30	100.0	100.0	

(b)

Acceptance

N	*Valid*	30
	Missing	0
Mean		5.30
S.E. Mean		.30
Std Dev		1.62
Variance		2.63
Minimum		1.00
Maximum		7.00
	50 (Median)	6

(c)



5.2 Exercises

All interviewed health professionals suggested at least one exercise that they considered a useful VR exercise. Results are not statistically significant because of the size of the sample (n=10), but provide conclusions about how to proceed in further studies to evaluate supervised VR healthcare platforms and possible useful exercises thereafter. It would also be important to evaluate if it is more promising to translate existing exercises into VR exergames (and make objects more diverse and interchangeable) or to come up with entirely new exercises from scratch which may better embrace the technological advantages of VR.

5.2.1 Suggested exercises

The following exercises have been proposed by the interviewees to question 4:

Q4: Which standard exercises (that you often utilize with your patients) do you consider useful as a virtual reality exercise?

1. Objects falling from the top. The player has to catch them, for example with a bowl, and then put them in a basket on the floor. The therapists should be able to decide where the objects are dropped from (angle, height and speed) and where the basket should be put. This could be useful in physiotherapy for arms training and coordination.

2. Balance exercises that include weight shift

3. Posture exercises: E.g. the participant sees bent or crooked walls. By leaning over or putting their back in the correct upright position the wall therefore also becomes straight. (This could be easily being achieved with the included gyroscope sensor of the headset)

4. Looking over objects: The person sees a wall that ends at a certain height. They need to stretch their back in order to be able to look over. Further, their hand needs to be lifted to shoot objects behind the wall to reach them.

5. Coordination exercises that include two different controllers where the player has to shoot different objects with a different hand at the same time. E.g. all red balloons must be shot with the left hand and all green balloons with the left hand.

6. Recreating everyday situations e.g. as a kitchen scene where people need to cook, virtually cut objects, grate cheese and grip objects. Other everyday situations could be virtual woodworking or other scenes from the workplace where manual movements can be trained. (These exercises could be achieved with a tracking glove better than a controller maybe)

7. Objects come closer to the player and the player has to move out of their way by moving their body to the left or right. This could be a skiing race in a seated situation.

8. Objects can come closer by conducting certain body movements or head movements. (for example, bending forward)

9. Looking down from a platform and bending over to see objects below. (Similar to exercise 4)

10. Touch or collect different non-static objects that are lying on the floor at different distances.

11. A ladder is lying on the ground and the player has to virtually walk over it without touching the ladders rungs. The trainer could define the distance between rungs.

12. General exercises where reaction speed of the player can be progressively trained and improved.

13. Adding virtual obstacles in gait training. The trainer can define the quantity of objects, how quickly they appear/reappear as well as their velocity as the objects move towards the player. Additionally, how much time they are allowed to react and from how far away they start appearing can also be controlled.

14. Attach controllers to the players feet or legs to use their feet for playing. For example, to reach objects with the legs by stretching them out towards other objects or goals.

15. Create exercises that can be played while lying down or while turning from facing up to facing down.

16. Cutting objects virtually.

17. Exploration training.

18. Pouring and emptying liquids.

20. Strengthening upper extremities.

21. Torso strengthening.

22. Carrying soup while maintaining balance without spillage.

23. Opening locks by putting keys into keyholes.

24. Visual field enhancement exercises and visual field support.

25. Exercises that promote the shifting of the body's center of gravity.

26. Balance exercises and others weight shifts.

27. Phantom limb training: The players body is extended in VR virtually and is able to move their limbs by just looking at them. For example, a player's left leg can be moved or bent with a simple glance. The trainer could define which extremity reacts and the starting position.

5.2.2 Suggested exercise settings and feedback parameters

Exercise settings are game options and elements a health professional (trainer) can influence in real-time through his secondary device in the patient's (player's) game. Exercise settings vary by the exercise suggested in the previous chapter. The following exercise settings have been named by the interviewees and could therefore be a useful checklist for exercise developers:

- Amount of objects
- Speed
- Color / Type of object
- Size of object
- Distance from Player
- Distance between objects/goals
- Angles / Areas / Quantiles
- Frequency of appearing / reappearing
- Defining tolerance areas

Feedback parameters are the information sent from the VR game to the trainer's own device in real-time. This allows the trainer to evaluate the player's progress in real-time. Each exergame can consist of different feedback information sent back to trainer to evaluate progress. Some of the parameters mentioned below should be considered for the purpose of evaluating the long-time progress only. Other parameters can be applied to evaluate the progress and capabilities for the current training session only. The following feedback parameters have been mentioned by the interviewees:

- Points reached
- Time played
- Clicks vs. successful hits
- In which area, an object has been hit
- Speed
- Amount
- Failed vs. successful attempts/clicks
- Failed vs. Successful attempts as a percentage
- Distance between goals

6 Discussion and Conclusion

The conducted survey among health professionals considers the supervised virtual reality exercise platform “VRTherapy” to be a potentially useful tool for their daily workflow. A variety of exercises would be needed to serve for a broad spectrum of treatments. Virtual reality can’t provide the right treatments and rehabilitation for everyone; but there are some leads for use cases of VR in healthcare where it can help to improve a person's overall health status. It is “convenient” when a patient’s motivation can be increased through VR exercises, but what matters in the end is a statistically significant long-term improvement of a patient's health.

Compared to a single VR game, VRTherapy’s platform approach (that manages everything around an exergame) is overall considered a beneficial tool by the interviewed health professionals for their daily workflow. VRTherapy could be supplemented with additional home-training tools and connected with physiological measuring devices while in use, which can help to provide more complete tracking of a patient’s improvement over time.

A supervised virtual reality platform could be useful for the healthcare sector because health professionals only need to learn to use one software for different treatments. The tracking of results also allows them to better compare long-term improvement rates. The sharing of ideal exercise settings between therapists can help to fine-tune exercises and also raise awareness among developers about what kind of exercises therapists need to have available in order to create useful VR exercises for healthcare.

VR hardware is now ready for the mass market even on mobile devices, but the technology still has room to improve. If demand is high enough for manufacturers to keep improving their hardware in the near future, the next generation will hopefully offer a more detailed screen resolution and wider field of view. Improved hardware might directly affect the outcome of a patients training results. Apart from the headsets, the controllers used can be a crucial element for positive health impact. If controllers were more interchangeable between platforms and also attachable to various body parts, it would help to broaden the possibilities of VR exercises made for the healthcare sector.

Many studies about health exercises in VR are available, but few are statistically significant due to the low number of participants. Being able to conduct larger-scale studies with control groups and different hardware used for the same exercises would help to reach more certain conclusions on how virtual reality can be beneficial for patients' health. Furthermore, studies using VR hardware in their testing setup should include more information about the device and respective specifications used to make results more comparable. Lastly, future studies about VR should define and describe in more detail their level of bias. The focus on improvement should not only be on the exercise itself but also shift to observe patient acceptance rates and comfort of different VR headsets and controllers. It might be possible that the same exercise when played on a different headset and a different controller can produce different therapy results.

Patients in rehabilitation usually spend more time with a physiotherapist than their doctor. Therefore, the therapist's experience and expertise can add vital suggestions to improve VR exercises. Health professionals should be incentivized to work together with developers on optimizing and fine-tuning these VR exergames in order to accelerate patient recovery. Virtual reality might then have the potential to show increased improvement rates when compared to conventional treatments. These health exercises can therefore become more efficient by adhering to a repeating cycle of feedback collection, evaluating and implementation.

As a next step, the most promising exercises suggested by the interviewees should be developed for the VRTherapy platform. In a qualitative follow-up survey, the mentioned exercises should be categorized by type, setting and purpose and then evaluated by health professionals on their feasibility. It also would be relevant to conduct a validated and controlled clinical trial with patients to assess the usefulness of VRTherapy with specific exercises separated by therapy approaches (physiotherapy, psychological, etc.). VRTherapy could be used to conduct a larger-scale study on various locations and different device types.

The therapists participating in the study testified to a positive tendency towards including the VRTherapy platform into their daily workflow. However, they expressed a certain amount of skepticism regarding whether VR would work on all their patients. The ability to influence game parameters in real-time through a secondary device seems intuitive to all surveyed therapists and has been accepted unanimously as a useful tool.

Current studies indicate that the health benefits of VR exercises seem to be low for areas like stroke rehabilitation but show efficiency in the treatment of phobias and post-traumatic stress disorders.

The overall outcome has strongly suggested that virtual reality exercises are indeed a worthwhile and beneficial tool to be used by medical professionals. The full extent of this remains to be discovered; but what is fundamentally undeniable is the potential of VR in healthcare treatment and rehabilitation. It becomes self-evident to shift the question from “if” virtual reality can improve treatment to “how”.

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Appendix

A. Survey

1- Ich arbeite als

PhysiotherapeutIn		ErgotherapeutIn		OrthoptistIn		Anderes	

2- Ich bin

Männlich		Weinblich	

3- Mein Alter

20-30		30-40		40-50		50+	

4- Wie oft haben Sie ein Virtual Reality gerät benutzt / ausprobiert?

0 mal		1-3 mal		> als 3x	

5- Ich halte es für sinnvoll, Virtual Reality Übungen in meinen Arbeitsalltag mit PatienInnen zu integrieren.

Trifft nicht zu **Trifft zu**

1	1	1		1	3	3

6- Durch Virtual Reality Übungen kann die Trainingsmotivation meiner PatientInnen gesteigert werden. (0-trifft nicht zu / 7- trifft zu)

		1		1	5	3

7- Durch Virtual Reality Übungen lässt sich der Trainingserfolg meiner PatientInnen schneller erreichen. (0-trifft nicht zu / 7- trifft zu)

0	0	1	3	2	3	1

8- Welche Übungen könnte man Ihrer Meinung nach als Virtual Reality Übung umsetzen, die Sie derzeit in Ihrem Arbeitsalltag an Ihren PatientInnen anwenden?

8A - Welche Übungseinstellungen für die Trainer App halten Sie bei dieser Übung als besonders wichtig?

8B - Welche Rückmeldungen zur Beurteilung des Spielerfolgs möchten Sie von der Virtual Reality Übung auf der Trainer App erhalten?

B. Survey Data

1- Ich arbeite als

PhysiotherapeutIn	8	**ErgotherapeutIn**	1	**OrthoptistIn**	1	**Anderes**	0

2- Ich bin

Männlich	5	**Weinblich**	5

3- Mein Alter

20-30	8	**30-40**	1	**40-50**	1	**50+**	

4- Wie oft haben Sie ein Virtual Reality gerät benutzt / ausprobiert?

0		**1-3 mal**	9	**> als 3x**	1

5- Ich halte es für sinnvoll, Virtual Reality Übungen in meinen Arbeitsalltag mit PatienInnen zu integrieren.

Trifft nicht zu **Trifft zu**

1	1	1		1	3	3

6- Durch Virtual Reality Übungen kann die Trainingsmotivation meiner PatientInnen gesteigert werden. (0-trifft nicht zu / 7- trifft zu)

		1		1	5	3

7- Durch Virtual Reality Übungen lässt sich der Trainingserfolg meiner PatientInnen schneller erreichen. (0-trifft nicht zu / 7- trifft zu)

0	0	1	3	2	3	1

8- Welche Übungen könnte man Ihrer Meinung nach als Virtual Reality Übung umsetzen, die Sie derzeit in Ihrem Arbeitsalltag an Ihren PatientInnen anwenden?

8A - Welche Übungseinstellungen für die Trainer App halten Sie bei dieser Übung als besonders wichtig?

- Kräftigung Obere Extremitäten
- Atemtherapie mit Spirometer verbinden. Z.b. er atmet kerze ausblasen
- Kräftigung Rumpf
- Gesichtsfeldverbesserung, Gesichtsfeldtraining
- Aufmerksamkeitstraining
- Neglekt
- Gleichgewichtsübungen
- Etwas kommt auf die Person zu und man muss ausweichen
- Wie schnell bewegt sich etwas auf einen zu

- Wie weit muss man ausweichen
- Objektgröße
- Toleranzbereich festlegen
- Erfolg: Wie viele Treffer
- Gewichtsverlagerung
- Gleichgewicht halten ohne Schutzschritt
- Schwerpunktverlagerung
- Wand oder Schiefe Wand hinüberlehnen und Objekte finden
- Virtuell Brot schneiden
- Suppe tragen
- Schlüssel in Schlüsselloch und aufsperren
- Objekte fallen hinunter und müssen gefangen werden
- Flüssigkeiten ausleeren
- Haltungsübungen
- Langsames gehen auf laufband – Auf Objekte zugehen
- Objekte kommen näher zum Spieler indem eine Extremität bewegt wird
- Übungen beim Aufrichten
- Alltragssituationen nachstellen
- Arbeitssituationen
- Küchenarbeiten
- Übung beim Drehen von Bauch in Rückenlage
- Virtuelles Bein oder Objekt bewegt sich beim reinen anblick
- Extremität auswählen
- Ausgangsstellung
- Sitzen oder stehen
- Wie of
- Einstellung ob Übung liegend oder sitzend oder stehend ist
- Objekte müssen erreicht werden durch hochgreifen
- Einstellen wie weit der Spieler auslagert
- Wie wirkt sich die Bewegung auf das Bein aus
- Holz hobeln
- Käse reiben
- Virtueller Kreisel
- Controller auf den Füßen
- Er muss die Balance auf dem Kreisel halten
- Labyrinthspiele mit Füßen
- Spieler steht auf einer Platform
- Dinge berühren, die am Boden liegen
- Reaktionsübungen und schnelligkeitsübungen
- Hindernisüberwindung bei Gangschulung
- Wie viele Objekte
- Erscheinen Objekte während der Übung

- Wie schnell kommen sie
- Wie viel Zeit hat man zum Regieren
- Wie viel früher erscheinen die Objekte
- Mit dem Bein Tapsen und Gegenstände berühren
- Geschwindigkeit der Objekt
- Z.B. Käfer zertrete und er Bewegt sich
- Tempo
- Größe
- Fortschritt messen: Wie viel in gewisser Zeit getroffen
- 3x Controller auch an Bein anbringen
- Über eine Leiter am Boden Steigen
- Wie oft wird es geschafft ohne Sprosse
- Abstände zwischen Sprosse
- Wie breit ist die Leiter
- Koordinationsübungen mit zwei controller
- Zwei Objekte gleichzeitig abschießen
- Schnelligkeit
- Winkel
- Distanz zwischen den Zielen
- Wie viele Versuche und Fehlversuche
- Akkomodationstraining ist nicht möglich
- Aufgrund des gerineren Sichtfelds ist es schwer in eine Richtung zu schauen ohne den Kopf zu bewegen
- Explorationstraining

8B - Welche Rückmeldungen zur Beurteilung des Spielerfolgs möchten Sie von der Virtual Reality Übung auf der Trainer App erhalten?

- Fehlerquote in Prozent
- Wie oft wurde geklickt vs. wie oft wurde getroffen
- Fehler anzeigen
- Zeit
- Punkte
- Fehlerhafte Klicks
- Geschwindigkeit
- In welchem Qadranten wurde getroffen
- Zeitgoal
- Punktegoal
- Atmung