Virtual Reality in rehabilitation of neglect after stroke, a survey among orthoptists and physiotherapists

Master Thesis

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

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

by
Julia Pirkl, BSc
1610756806

First advisor: Andreas Jakl, MSc

Vienna, 16.09.2018

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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Preface

During the first three semesters of the master programme ‘Digital Healthcare’, the new software ‘VR-Therapy’ was invented and developed. So, I first want to thank my project team members for creating such an innovation together.

Secondly, I have to thank all the orthoptists and physiotherapists, who participated in this survey. Without you, it would not have been possible to conduct this study.

Further, my advisor Andreas Jakl, MSc, helped a lot in organizing technical matters and improving this thesis. Thank you for your help.

Finally, a special thanks to my boyfriend, family and friends, for supporting me during the whole studies and especially while writing this thesis. Thanks for your patience and consideration.

Abstract

Objective: A prototype of a new virtual reality software for the rehabilitation of patients with neglect after stroke was developed. In this study, the prototype is evaluated, to find out what therapists think about it, if they would like to use it and what can be improved.

Method: Eleven orthoptists and nine physiotherapists participated in the study. After introducing the VR-Therapy software, they tested it from the perspective of the therapists and the perspective of the patients. In the end they answered a questionnaire about their assessment.

Results: In general, the software was rated positively, with only small differences between orthoptists and physiotherapists. Sixteen of the twenty participants would like to use VR-Therapy in their daily work with patients. Also, sixteen therapists think that the software is well suited for the therapy of neglect patients.

Conclusion: The results show that it makes sense to proceed with the project of VR-Therapy and some of the mentioned suggestions for improvement will probably be implemented in further development.

Keywords: neglect, rehabilitation, virtual reality

Kurzfassung

Ziel: Der Prototyp einer Virtual Reality Software zur Rehabilitation von PatientInnen mit Neglekt nach einem Schlaganfall wurde entwickelt. In dieser Studie wird der Prototyp evaluiert, um herauszufinden was TherapeutInnen davon halten, ob sie ihn verwenden wollen würden und was daran noch verbessert werden könnte.

Methode: Elf OrthoptistInnen und neun PhysiotherapeutInnen haben an der Studie teilgenommen. Nachdem ihnen die VR-Therapy Software vorgestellt und erklärt wurde, konnten sie alles sowohl aus der Sicht des/der TherapeutIn, als auch aus der Sicht des/der PatientIn testen. Im Anschluss füllten sie einen Fragebogen zur Einschätzung der Software aus.

Ergebnisse: Generell wurde die Software von allen TeilnehmerInnen positiv bewertet, wobei sich nur geringe Unterschiede in den Ergebnissen der OrthoptistInnen und PhysiotherapeutInnen zeigen. Sechzehn der zwanzig TeilnehmerInnen würden VR-Therapy gerne in ihrem Arbeitsalltag verwenden. Ebenfalls sechzehn TherapeutInnen denken, dass die Software gut auf die Bedürfnisse von NeglektpatientInnen zugeschnitten ist.

Schlussfolgerung: Die Ergebnisse zeigen, dass es auf jeden Fall sinnvoll ist, das Projekt VR-Therapy weiter zu verfolgen. Einige der Verbesserungsvorschläge aus der Studie können bestimmt bei der Weiterentwicklung der Software eingearbeitet werden.

Schlüsselwörter: Neglekt, Rehabilitation, Virtual Reality

Table of Content

1 Introduction

VR-Therapy is a new modern Virtual Reality (VR) software, developed for a customizable therapy in the rehabilitation of neglect.

Since the number of strokes and therefore also its long-term consequences such as neglect are increasing, also the therapy of those diseases has to adjust to the modern standards. For this reason, more and more technical solutions are used and new therapy systems are developed. One major component that is already in use for that purpose is VR. VR means to have a completely virtual three-dimensional environment in contrast to augmented reality, where virtual objects are put in a real-life environment. Because VR is a relatively new technical trend, many people are interested in it but there are not too many systems and studies created so far.

In this thesis, the new software called VR-Therapy is presented and tested for the first time. It was developed to make therapy exercises in rehabilitation better adjustable for each patient. This way, the motivation of patients should be increased to get better results or at least have more fun during the therapy, compared with conventional rehabilitation exercises. Primarily, it was made for patients with neglect after stroke, but it is planned to increase the range of exercises and make VR-Therapy usable for the rehabilitation of more different disease patterns.

VR-Therapy consists of two parts: an Android VR app used with a Google Daydream compatible phone and a VR headset, that puts the patient into a virtual environment, where he/she can perform different exercises. Secondly, an iOS app on an iPhone or iPad makes it possible for the therapist to control everything the patient sees in his/her virtual environment. This way, different parameters can be adjusted whenever it is useful, to customize each exercise to the patients' needs. Also, the iPad app shows an overview of all exercises and achievements the patient made so far.

In this study, the first prototype of VR-Therapy is tested with twenty therapists (orthoptists and physiotherapists). Therefore, one evaluation exercise was created. That exercise provides the conventional exploration training in a virtual environment, where the patient has no distraction from the real environment around him/her.

The **goal** of this study is to find out what therapists think about VR-Therapy, if they would like to integrate it in their daily work with patients and how the software can be improved, to make it even better for the rehabilitation of neglect patients.

For this purpose, the following **questions of research** were framed:

Are orthoptists and physiotherapists interested in using the VR-Therapy software for rehabilitation of patients with neglect?

Do therapists think that patients with neglect are able to use the VR-Therapy software?

What possible improvements do the therapists see in VR-Therapy?

Is there already VR software that is used for rehabilitation?

For answering these questions, the following **methods** were used. First a literature research provided the theoretical background about neglect following stroke, conventional therapy methods and VR systems that are already used for rehabilitation. In the evaluation part of the thesis, therapists could try VR-Therapy in a usability test out of the therapists' and the patients' view. That is followed by a questionnaire to get their assessment and suggestions for improvement.

1.1 Structure of the Thesis

After this introduction to the thesis, a chapter called 'Methods' explains the exact procedure of the research, usability test, survey and evaluation.

Then the findings of the literature research are collected in the chapter 'Theoretical Background and State of the Art'. There the medical basics of stroke and neglect, as well as the state of the art in technology and especially VR in rehabilitation are outlined.

The next chapter named 'VR-Therapy – the App' explains the development of VR-Therapy. It pictures the used hardware and software and introduces the first exercise for VR-Therapy, which was used for this evaluation.

The following chapter 'Results' shows and describes the results of the survey. While the results are analyzed, interpreted and related to literature in the next chapter named 'Discussion'.

All that is followed by the chapter ‘Conclusion and Summary’ which answers the questions of research and outlines the next steps for VR-Therapy.

In the Appendix an original questionnaire and the answers to the closed questions can be found.

2 Methods

This chapter describes the methods used to create this master thesis. From literature research over usability testing to developing and evaluating the questionnaire.

2.1 Literature Research

To expand on the knowledge of stroke and neglect, the library at the University of Applied Sciences St. Pölten was searched to get scientific books about neurology and the conventional therapy of neurological diseases. Also, the online databases PubMed, IEEE, CINAHL, Springer Link and ACM were searched for scientific articles about VR in rehabilitation.

This way it should be found out more about already existing VR systems used in rehabilitation in general. Especially VR systems that are already in use for the therapy of neglect are interesting. They can be compared to VR-Therapy and might also show new aspects that can be integrated in VR-Therapy in the future. Also surveys about the opinion of therapists and patients on VR in rehabilitation in general and specifically on VR systems used for the therapy of neglect were searched, to be able to compare them to the results of the survey made for this thesis. So, the opinion of the therapists on how patients might think about VR-Therapy can be related to the opinion of patients who tested other similar VR systems for their rehabilitation.

2.2 Usability Test and Survey

For evaluating the new VR-Therapy software, voluntary orthoptists and physiotherapists were recruited. They should test the app from two perspectives: therapists and rehabilitation patients. Afterwards, they had to answer a short questionnaire. All participants tested the same exercise called ‘evaluation exercise’, to make the results comparable.

The following inclusion and exclusion criteria for test persons were defined.

Inclusion criteria:

- A completed study as an orthoptist or physiotherapist.
- A current job as an orthoptist or physiotherapist.
- A minimum age of eighteen years.

Exclusion criteria:

- Epilepsy

To find appropriate volunteers, emails were sent to orthoptists in eight different ophthalmology practices, to five orthoptists in hospitals, to physiotherapists in three different hospitals and to ten private physiotherapy practices. Finally, eleven orthoptists (six from ophthalmology practices and five from hospitals) and nine physiotherapists (four from private practices and five from hospitals) met the inclusion criteria and participated in the study.

For the usability test, a Google Daydream View headset plus controller, a ZTE Axon 7 mobile phone and an Apple iPad Air 2 were used.

As already mentioned, the recruiting process started with sending emails out to orthoptists and physiotherapists in different practices and hospitals. These emails contained a short description of the goal of this thesis and of the VR-Therapy system. After the twenty prospective participants agreed to participate in the survey, appointments for the usability test with each therapist had to be found. Each usability test had the same test procedure:

- First the goal of the whole survey including the questions of research and the purpose of VR-Therapy were explained.
- Then the handling of the hardware (iPad and Google Daydream View headset) and the menu navigation of the iPad app was shown. Also, the different adjustable parameters of the evaluation exercise were explained briefly.
- Next each participant had about five minutes to navigate through the iPad app by him/herself to see all different parts of the app and especially the possibilities the evaluation exercise provides for the therapy of patients with neglect.
- After testing the iPad app, the participants had about five more minutes to test VR-Therapy from the patients' view. During that time, they could see what the evaluation exercise looks like for the patient and how it feels to perform exercises in VR. While playing, the test coordinator also adjusted the different parameters so that the participant could see how that affects

the impression and the level of difficulty of the evaluation exercise for the patient.

- Finally, after the usability test, each participant received a printed-out questionnaire to fill out and return to the test coordinator.

For this survey, a positive ethics committee vote exists.

2.3 The Questionnaire

The questionnaire consists of three questions about the test person, to find out their profession (orthoptist or physiotherapist), their gender and their age.

That is followed by thirteen questions to evaluate the software using a five-point Likert scale. These questions are subdivided into the following four groups.

- The first group consists of four questions about the **usability of the iPad app**. The questions ask about how complicated it is to handle the app, how long it takes to learn how to use it, how self-explanatory it is and how clear the structure of the evaluation exercise and its parameters is.
- The second group consists of three questions about the **applicability of the software** in the daily work routine of the therapists. They ask whether the therapists want to use VR-Therapy in their daily work routine, whether the app is well suited for their needs and whether it shows a good overview on the patients' therapeutic process.
- The third group includes three questions about the therapists' assessment of the **neglect patients' compliance in using the software**. They ask if the therapists think that VR-Therapy is well-suited for the therapy of neglect patients, if they think that neglect patients would like to use it and if they think neglect patients might have problems using the system.
- And in the fourth group there are three questions on the **therapists' attitude concerning technical innovations** in rehabilitation of neglect in general. They ask whether the therapists think it is reasonable to use new technical methods for the therapy of neglect patients, whether they think it is reasonable to use VR for the rehabilitation of neglect patients and if they would like to use new technical methods to make the therapy for patients more versatile.

Then, two open questions follow these four groups of closed questions. The first aims to find out what problems might occur when the VR-Therapy software is used in the rehabilitation of neglect patients. The second open question asks for suggestions of improvements for VR-Therapy, to make an everyday use in rehabilitation easier.

At the end of the questionnaire, test persons get the opportunity to add further comments.

The original version of the questionnaire in German language can be found in the appendix.

2.4 Evaluation

For evaluation, the thirteen closed and the two open questions were regarded separately.

Since the closed questions could be answered by choosing from a 5-point Likert-scale, they can be evaluated quantitatively. For evaluation, each answer was coded with a number:

- agree = number 5
- rather agree = number 4
- uncertain = number 3
- rather disagree = number 2
- disagree = number 1.

So, the higher the score of a question or a group of questions, the more positive is the position of the participant to the evaluated topic. The questions were analyzed in the four groups 'usability of the iPad app', 'applicability of the software', 'neglect patients compliance in using the software' and 'therapists attitude concerning technical innovations'. The results of some questions will also be presented separately.

The answers of orthoptists and physiotherapists were analyzed altogether as well as separated from each other. For evaluation PSPP was used and then graphs were created with Microsoft Excel to visualize the results.

The two open questions were analyzed qualitatively, since there are no scales used, but the therapists could write down all their thoughts about VR-Therapy. The answers consist of bullet points by the participants. For evaluation, the different aspects were structured and repeatedly mentioned points were counted and summarized in tables. All other answers that were mentioned only once, were also considered and presented as bulleted lists.

Also, the comments each participant could add in the last section of the questionnaire are listed in this thesis.

All results of the evaluation are shown in chapter 5 ‘Results’. While in chapter 6 ‘Discussion’ they are analyzed, interpreted and related to literature.

3 Theoretical Background and State of the Art

This chapter describes the medical basics of stroke and neglect, as well as the conventional neglect therapy and rehabilitation methods. It also summarizes existing virtual reality treatments, used in rehabilitation.

3.1 Stroke

In the western industrial countries, strokes are on the third place of the most frequent causes of death, after heart attacks and carcinomas. They are also a reason for disabilities and care dependency (Berlit, 2013, p. 198).

3.1.1 Incidence and Risk Factors

Each year, 100 to 700 of 100.000 people decease with stroke in Europe, in Germany about 200. The older people are, the higher the risk of a stroke. Approximately half of the patients are more than 70 years old. Men are 30% more often affected than women. In Germany, 20% of people with a stroke die (Berlit, 2013, p. 198).

The main risk factor for strokes is arterial hypertension. Each 7.5 mm/Hg increase of the blood pressure doubles the risk of getting a stroke. Also, diabetes mellitus and lipometabolism diseases double the risk of getting a stroke. Smoking increases it by a factor of 1.8 (Berlit, 2013, p. 198).

3.1.2 Aetiology and Pathogenesis

An important cause of strokes is the arteriosclerosis of vessels that supply the brain with blood. In most cases, ischaemia is caused by emboli that block the blood supply and consequently the oxygen supply of brain areas. Therefore, the energy generation of the brain is limited or no longer existing, which leads to a loss of cerebral function (Berlit, 2013, pp. 199–201).

3.1.3 Symptoms

Before a stroke results in permanent damages, there are often volatile ischaemias. A volatile ischaemia in the anterior cycle can lead to a temporary contralateral sensory disturbance or paresis and to aphasia (speech disorder). A volatile ischaemia in the posterior cycle has more different symptoms, because the emboli can move on to different other vessels. Possible symptoms for that are vertigo, double images, speech impairments, hemianopsia and sensory and motor disorders of the extremities. Further symptoms of a stroke can be amaurosis fugax (a temporary blindness of one eye), drop attacks (falls without a loss of consciousness), headache and disturbed conciousness (Berlit, 2013, pp. 206–207).

3.1.4 Therapy

Already at the first suspicion of a stroke, the patient must get to a stroke unit as fast as possible, so that the acute therapy can start within 4.5 hours after the first symptoms occurred. In most cases, the therapy is a systemic lysis with rtPA (recombinant tissue-plasminogen-activator), to dissolve the embolus. It is most important to cure the cause of the stroke and medicate existing risk factors of vessels. As a secondary prevention after an ischaemic stroke, most patients get acetylsalicylic acid and if necessary, other medication to lower the risk of having another stroke (Berlit, 2013, pp. 212–214).

One possible consequence of a stroke can be a neglect.

3.2 Neglect

Neglect is a disorder, where people neglect respectively disregard one side of the environment and their own body in one or more terms (Pschyrembel, 2010, p. 1411). In most cases, the left side is affected (Berlit, 2013, p. 12).

A neglect can manifest, when a brain damage for instance a stroke occurs. In case of a lesion in the left cerebral hemisphere, primarily the right half of the body and environment are neglected. While at a lesion in the right hemisphere the left side is more neglected and, in this case, normally the neglect is more distinctive and persists longer. An explanation for this phenomenon is the attention hypothesis. It means that the right hemisphere is the dominant one. It perceives and controls both sides of the environment and body, while the left hemisphere only controls the contralateral side (Prosiegel & Böttger, 2007, p. 102).

When the patient does not perceive his/her own neurological deficits, he/she also suffers from anosognosia (Berlit, 2013, p. 12).

In the following section, the different kinds of neglect are described.

3.2.1 Types of Neglect

A neglect can occur in many different forms, in most cases it is a combination of symptoms, where each symptom can have varying severities.

Spatial Neglect: The patient ignores all stimuli coming from the neglected side. Often the head is turned to the not neglected side. Also, the patients eat only half of their food on the plate or paint half of the pictures they should reproduce (Haus, 2014, pp. 290–291).

Personal Neglect: The patient does not perceive his/her own extremities on the neglected side and cannot feel pain there (Haus, 2014, p. 291).

Visual Neglect: On the neglected side, no visual stimuli are perceived. The patient cannot see people, objects, or obstacles on this side, which can be dangerous for independent locomotion in wheelchairs. Within the first three months there is a good chance for recovery of the symptoms. The patient starts to perceive visual stimuli on the neglected side again. But then a simultaneous stimulus from the other side can extinguish the first one (Haus, 2014, p. 291).

Motor Neglect: The patient does not use the extremities on the neglected side (Haus, 2014, p. 291).

Sensory Neglect: On the neglected side, the patient cannot feel tactile stimuli such as temperature, pain or being touched (Haus, 2014, p. 291).

Auditory Neglect: The perception of sounds coming from the neglected side is reduced or can be extinguished by sounds coming from the other side, such as in visual neglects (Haus, 2014, p. 292).

3.2.2 Underlying Cerebral Lesions

85% of patients with neglect have a lesion in the right cerebrum and therefore a neglect of the left side. These kinds of neglect are not only more frequent, but also much more pronounced and persist for a longer time (Prosiegel & Böttger, 2007, p. 107). Most of the lesions are in the lobus parietalis of the right hemisphere. Furthermore, lesions in the frontal lobes, basal ganglia, thalamus and parts of the limbic system can cause a neglect (Haus, 2014, p. 292).

3.2.3 Clinical Diagnostics

To diagnose a person with neglect, there are some different methods.

The first method for diagnosing a patient with visual neglect is testing the attention by observing the head and eye movement while showing a stimulus on either the left or the right side (Prosiegel & Böttger, 2007, p. 110).

The next test is to show the stimulus on both sides at the same time and check if the patient reacts to both or just one of them, which would be a sign of the extinguishing phenomenon that often comes with neglect (Prosiegel & Böttger, 2007, p. 110).

Furthermore, there are some standardized test batteries including common neglect tests. An example for such a test is the cross-out test where the patient gets a text and has to cross out all ‘a’s or other letters, which the therapist has specified before. In another neglect test, the patient has to mark the center of a line, whereby the deviation of the patient’s center to the real one, allows conclusions about a neglect. Other tests for visual neglect can be copying a picture such as a flower or a clock, reading a short text, setting the time on a clock, sorting coins or something similar. In these tests, neglect patients will always leave out parts on the neglected side. Additionally, an examination of the visual field can be made, that will also show scotomas on the neglected side (Prosiegel & Böttger, 2007, p. 110).

For diagnosing an auditory neglect, the patient has to locate the side of sounds with closed eyes. The therapist offers the sound on the left and right side individually and on both sides at the same time. The same principle is used to diagnose a sensory neglect, whereby the left and right hands are touched instead of the sounds and the patient has to locate the touches (Prosiegel & Böttger, 2007, p. 111).

To find out whether the representation of the environment is impaired, the patient has to describe a room or something similar from memory. If there is an impairment, he/she will only describe the objects on the not neglected side (Prosiegel & Böttger, 2007, p. 111).

Finally, also the observations of others, such as relatives, are important to evaluate the impact of the neglect on the everyday life of the patient. Therefore, normed questionnaires are available (Prosiegel & Böttger, 2007, pp. 111–112).

3.3 Conventional Neglect Therapy

For neglect therapy it is advisable to have short therapy sessions of about twenty minutes, at least once a day. An interdisciplinary rehabilitation is important for an improvement in different fields of everyday life (Prosiegel & Böttger, 2007, p. 113).

Generally, the patient can be encouraged to give more attention to the neglected side, by offering stimuli on this side, like putting the TV there or people coming closer and talking to him/her only from the neglected side. In very severe cases of neglect, the patient does not realize anything that happens on one side and often cannot remember a therapy that only happened on the neglected side. That is why there should also be a stimulation on the perceived side, because it is doubtful if a not realized therapy is useful (Haus, 2014, pp. 292–293).

The following exercises are used in the rehabilitation therapy of patients with neglect after stroke.

Visual exploration training is usually the most common therapy, when patients do not perceive one side of their environment. It is used to make them aware of the things on that side. In visual exploration training, different objects, pictures, figures, or letters are shown to the patient, who has to describe all or find one special kind of them. There are different options of how to practice this kind of therapy. Either in small formats with pen and paper, on screens such as computer or TV monitors or in a bigger size as a projection with a beamer. The biggest weakness of exploration training is that it can only improve the visual neglect (Kerkhoff & Schenk, 2012, p. 1073).

A large problem of patients with neglect is an about 30-degree deviation of their head and eyes to the right side, so the perception of their own body in the environment is rotated. The best therapy methods to normalize this perception are optokinetic stimulation, neck-muscle vibration, caloric- and galvanic-vestibular stimulation and prism adaptation.

- **Optokinetic stimulation** works by showing objects or patterns to the patient, that are moving to the left side on a big screen. Because of the environment moving to the left, the patient's body feels as if it was moving to the right and tries to compensate this movement by rotating to the left side.
- **Neck-muscle vibration** works quite similar to the optokinetic stimulation. A person feels that his/her head is straight, when the neck muscles on both sides are stretched to the same length. A vibration on the left neck-

muscle makes the impression of an extension of this muscle, which makes the patient feel as if his/her head is rotated to the right and the body is rotated to the left. In this way, the awareness of the left side is increased.

- **Caloric vestibular stimulation** means that a rinse with cold water is made at the contralesional ear, which stimulates the vestibular system. That therapy method improves the neglect symptoms only for ten to fifteen minutes.
- **Galvanic vestibular stimulation** works in a similar way, but uses electricity applied with small electrodes behind the ears instead of cold water.
- A completely different therapy method is the **prism adaptation**. It works with special prism glasses, that transfer the image of the environment to the right side, in the patient’s perspective. In the prism adaptation period, while wearing the glasses, the patient has to point at objects on the left side, which is easier, because the whole picture of the environment is moved to the right. After taking off the glasses, the effect persists for a while, so that the patient automatically points to the left of the object he/she should point at. This is called the post-prismatic after-effect. Regularly repeated sessions of prism adaptation can lead to longer lasting benefits and improvement of neglect symptoms (Kerkhoff & Schenk, 2012, pp. 1073–1075).

Also, the following three therapy methods can be used to train the perception of the neglected side:

- So, another therapy method with special glasses is the therapy with **hemiglasses**. It means that the ipsilesional side of the patient’s glasses is covered, so that only the neglected side is transparent to search for stimuli. This therapy can be used only with patients that do not have a complete visual field defect on the neglected side (Prosiegel & Böttger, 2007, p. 115).
- Another way to influence neglect symptoms positively is **sustained attention training.** It can be made either by letting the patient sort any kind of objects such as cards or coins or by using special computer programs to train the sustained attention (Prosiegel & Böttger, 2007, p. 114).
- The most important aspect in the **therapy of anosognosia** is to make the patient aware of his/her disorder. The patient should face his/her everyday situations such as bumping against obstacles. Also, the

feedback of therapists, other patients and relatives or maybe via videos is essential (Prosiegel & Böttger, 2007, p. 116).

3.4 Virtual Reality in Rehabilitation

There are already some exercises that use VR for the rehabilitation of neglect after stroke. The effectiveness of using these methods is analyzed in several reviews.

3.4.1 Existing Virtual Reality Exercises for Neglect Patients

Kaluarachchi and Al-Jumaily describe a self-rehabilitation VR system for people with a paralysis of the upper extremities. The input of the system works through a Nintendo Wii and the game scenes are shown as a 3D picture on a regular television. Two games were already developed when the article was written. One is called ‘rolly game’, it shows a red crossbeam with a blue ball on it. The patient has to balance the ball on the beam by holding and moving the Wii controller in his/her stretched out arm. At a signal the ball should fall down onto the next beam and so on. The second game is called ‘Whack-a-Mouse’ and it shows a table with three holes in it, consistently mice emerge from the holes and the patient has to beat them by moving his/her stretched out arm with the Wii controller in it. Due to the authors, the VR gaming situation motivates the patients and increases the frequency and duration of training sessions (Kaluarachchi & Al-Jumaily, 2011).

RehabCity is a VR game that simulates a city that was created with Unity 3D. It provides different tasks that simulate the activities of daily living, like orientation in the city (Figure 1a) or scenarios in a supermarket (Figure 1b), a post office, a bank and a pharmacy. By completing different tasks, the patient receives points, for mistakes or additional help he/she loses points. The VR city is shown on a computer monitor with the patient about 60cm in front of it, the head position is tracked with FaceAPI through a webcam. For controlling the game, the patient uses an arcade joystick with different button colors, as they are used in the instructions of the game. In the end the game and face tracking data can be analyzed with Matlab (Vourvopoulos, Faria, Ponnam, & Bermudez i Badia, 2014).

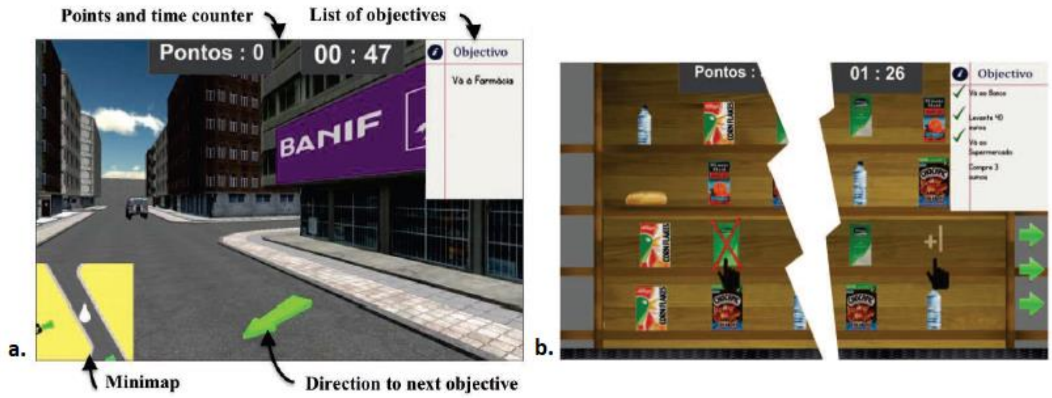


Figure 1 RehabCity a. Streetview, b. shelf in a supermarket with wrong selection (left) and correct selection (right) (Vourvopoulos et al., 2014)

The next VR system for rehabilitation after stroke is described in an article by Kaminer et al. For performing the game, a Microsoft Kinect, sensor gloves and an Oculus Rift are needed. The Kinect can track the movements of the body, arms and legs, by additionally using sensor gloves, also the small movements of each finger can be tracked. The game, which was created with Unity 3D, provides an exercise, that makes the patient grab four cylinders that are placed on shelfs around him/her and put them in a box in front of him/her (Kaminer et al., 2014).

The 'Neglect App' is one more VR opportunity for the rehabilitation of neglect. The only device needed to use it is an iPad. Neglect App is a platform with several exercises to choose from. The exercises show different locations of the daily life, such as a bar or an office, where the patient has to perform tasks. A therapist always chooses appropriate exercises for the rehabilitation level of the patient. One of the exercises is called 'Breaks spheres', there the patient has to touch all blue spheres in a room, while other colors might also appear for a higher level of difficulty. In another exercise the patient has to copy simple drawn figures as accurately as possible (Pedroli et al., 2015).

Tsoupikova et al. present another VR system for stroke patients in their article. It is also meant to train the upper extremities. The game is designed as a multi-user system so that up to four users can interact by seeing the other avatars and hearing them talk (Figure 2). The system runs on a usual computer and the users' movements are tracked by a Microsoft Kinect. Three multi-user games are already available. The first one is a ball game, where a ball gets hit by the users' hands so that it flies back and forth on the table all users sit around. In the second game, one user paints a 3D line into a cube with his/her hand and another user has to erase it by tracing the line. The last game is called 'Food

Fight'. There the users can grab different kinds of food and throw them onto the others (Tsoupikova et al., 2016).

Figure 2 Scene in multi-user VR game (Tsoupikova et al., 2016)

Another VR system for the rehabilitation of patients after stroke is presented in a study by David, Bouyer and Otmane. It is meant to use it for self-rehabilitation at home, so the user only needs to have a computer plus monitor and a Leap Motion infrared sensor to track the hand movements. The system shows a VR model of the users' hand on the screen. The game shows nine white buzzers in three rows in the center of the screen. Each time one buzzer turns blue, the user has to point at it, so it turns green, then the hand has to be moved back into a rest zone and another buzzer will turn blue. The goal is to reach as many buzzers in the shortest possible time (David, Bouyer, & Otmane, 2017).

Also, Huygelier et al. presented a VR game for the rehabilitation of patients with neglect. For performing this game, an Oculus Rift CV1 and Oculus touch controllers are needed, the game was created with Unity 3D. The game scene always shows a white disk, in which one of two different pictures appears, for example a red bug or a blue butterfly (Figure 3). As soon as one of these two pictures shows up, the patient has to decide whether it is the red or the blue one. If he/she decides for the correct picture, one point gets added to the score, if the wrong picture was chosen or the time was up, the try is failed. Then the next picture shows up in the white disk. For more motivation the pictures that show up and the backgrounds change in between the levels (Huygelier, Gillebert, van Ee, & Vanden Abeele, 2017).

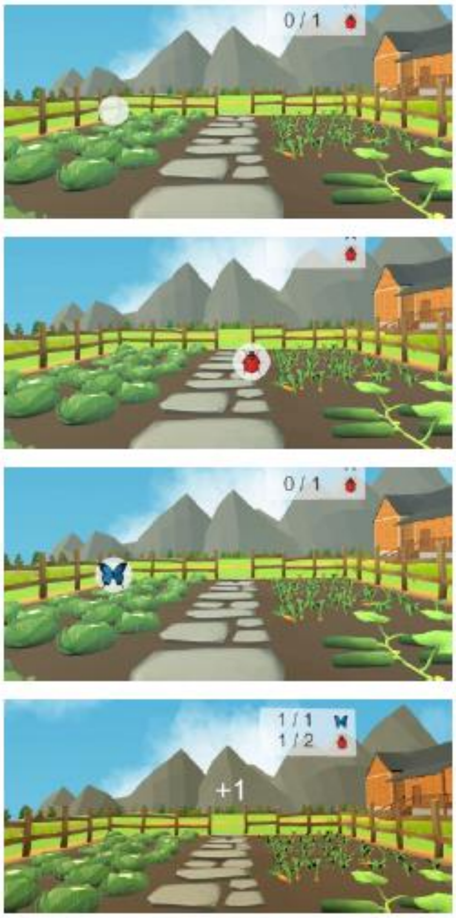


Figure 3 VR game showing red and then blue object in a white disk (Huygelier et al., 2017)

One more VR rehabilitation system, presented in an article by Achanccaray et al. is a combination of VR with a brain computer interface (BCI), used for the rehabilitation of the upper limb system. A BCI makes it possible to control a computer by measuring brain activity and transforming this data into control signals for a computer. In this case, the electrical brain activity was measured by an electroencephalogram (EEG), the data was processed, and a three-dimensional virtual reality picture was shown on a screen in the end. The goal of this exercise is to move a virtual arm from the position rest to flexion and extension, according to what was shown on the screen by an arrow (Achanccaray, Acuña, Carranza, & Andreu-Perez, 2017).

Another VR exercise is presented in a case study by Keime et al. It is used in treadmill-based rehabilitation, to help patients learn to walk again after they suffered from stroke. The system used for this VR exercise is a treadmill and an Oculus Rift VR headset, showing a virtual environment made with Unity. During the therapy session, the patient is wearing the VR headset, while walking on the treadmill. The virtual environment is changing according to the speed he/she is moving (Keime et al., 2017).

One more study by Kim et al. tested the effect of VR training for patients with neglect after stroke. In this case, the IREX system®[1] was used for VR therapy. For using this system, the patient wears special gloves and is filmed by a camera, so that the computer can recognize the patients' movements. Then, an avatar of the patient is put in a virtual environment on a monitor, where the patient can see every move he/she makes (Figure 4A). Additionally, the gloves transfer every hand gesture to the VR on the screen. Now, there are different exercises like little games, the patient can play. An example for such an exercise is 'Bird and Ball', where the patient must touch balls flying around in the virtual environment, when touched, they turn into birds (Figure 4B). In another exercise, the patient has to catch coconuts falling down (Figure 4C). And in a third exercise the patient has to pick up a box from a conveyor belt on one side and put it on another conveyor belt on the other side of him/herself (Figure 4D) (Kim, Chun, Yun, Song, & Young, 2011).

Figure 4 IREX system: A. setup, B. Bird and Ball, C. Coconuts, D. Conveyor Belt (Kim et al., 2011)

[1] http://www.gesturetekhealth.com/products/irex

3.4.2 Assessment of Existing Virtual Reality Systems

In some articles, also an evaluation of the used VR systems was made. In the following, the results of these evaluations will be outlined.

In a study by So et al, a VR headset was used for the patient to see a 3D image of the streets in Hong Kong, while they were walking on a treadmill. Out of 20 therapists that were testing the system, eleven agreed and five strongly agreed that the system could improve the rehabilitation of patients after stroke (So et al., 2011).

The survey by David et al. tested a VR self-rehabilitation system, where the patient has to point at presented buttons as described in chapter 3.4.1. In general the acceptance of all patients and therapists who tested the system was great (David et al., 2017).

In another study by Lozano et al., three patients tested a VR game that simulates activities of the daily living as a 3D image on an LCD monitor and is controlled with a joystick. All the three patients were very interested in it and motivated, especially because there were many levels of difficulty (Lozano, Gil-Gomez, Alcaniz, Chirivella, & Ferri, 2009).

The study by Jerome-Christian et al is about balance recovery after stroke. For the VR therapy, six patients used a Nintendo Wii with the Wii balance board and four patients used the Microsoft Kinect. They were training their balance while playing games where they could see an avatar of themselves in a VR environment on a monitor in front of them. After their up to fifteen therapy sessions, all patients said that they were more motivated because of the VR system and except one of them, all would like to go on using the system at home (Jerome-Christian, Rajaratnam, & Tian, 2012).

The VR system used in the study by Kaminer et al. is probably the best comparable one to VR-Therapy, because it also uses a VR headset. In the exercise the patient has to move cylinders placed around him/her into a box. The movements are tracked with a Microsoft Kinect and special sensor gloves (detailed description in chapter 3.4.1). For the study the system was tested by only one patient, who really liked it and would also recommend it to others, especially if they cannot travel to their therapy sessions regularly (Kaminer et al., 2014).

3.4.3 The Effectiveness of Virtual Reality Treatment Post Stroke

The VR exercise by Kim et al., explained in the former section 3.4.1, was also tested in a study, to find out how effective the VR training is for patients with neglect after stroke. Twenty-four patients with neglect after a stroke in the right hemisphere were randomly assigned to two different groups. All participants had the same amount of physical, occupational and cognitive therapy. One group additionally had conventional neglect therapy, while the other one used the VR system instead of the conventional neglect therapy methods. To check the therapeutic success, four different tests were made with all participants. Before the therapy, there was no significant difference between the groups in all four tests. After therapy, in two tests there was still no difference, but in the other two tests, the VR group showed more improvement than the control group with conventional treatment (Kim et al., 2011).

Lohse et al. studied the effect of VR on stroke patients. Twenty studies of controlled trials comparing VR and conventional therapy were included in the analysis. Both for body function and activity outcomes, there was a significant profit in VR in comparison to conventional therapy. (Lohse, Hilderman, Cheung, Tatla, & Loos, 2014).

Another review by Laver et al. compared nineteen studies with a total of 565 participants. Each of them showing the results of randomized controlled trials, comparing VR to another or no intervention in the therapy of stroke patients. The results show limited evidence that VR might show more improvement in arm function and actions of the everyday life compared to conventional therapy. There was not enough evidence to make a conclusion about an effect of VR on the gait speed (Laver, George, Thomas, Deutsch, & Crotty, 2015).

3.4.4 Existing Virtual Reality Solutions Compared to VR-Therapy

The new VR-Therapy system should be an opportunity to totally adapt rehabilitation therapy to each patients' needs. Hopefully it will also increase the motivation and consequently improve the results of neglect therapy.

In contrast to most existing VR solutions, the therapist that is exercising with the patient should always have the opportunity to intervene in the current exercise to adjust all exercise parameters at any time. The only other VR app where the therapist might interfere in the exercise in a different way than VR-Therapy is the multi-user system, where 4 users can be part of one exercise and interact with each other using a computer and a Microsoft Kinect system, connected via the Internet (Tsoupikova et al., 2016) (more detailed description in chapter 3.4.1). In this case the therapist can be one of the other users and interact with the patient in that way. A big advantage of that system is that the four different users do not have to be at the same place while exercising. So, one therapist might be working with three different patients at a time, while all of them can be at home or anywhere else and the patients can also use it from home without the therapist present. A multi-user system might also increase the motivation of the patients, because they can interact and talk with each other while exercising.

As it is planned for VR-Therapy, the Neglect App described in the article by Pedroli et al (2015), already has a platform with exercises for the therapy of neglect to choose from. These VR exercises run on an iPad and do not need any other devices for use (more detailed description in chapter 3.4.1). As most other VR rehabilitation methods, also the Neglect App has the disadvantage of using a screen for showing the virtual image which still lets the room around distract the patient. But that might also be an advantage, because the patients can also use the system alone at home. When wearing a VR headset, the orientation can be impaired, which makes a use home alone too dangerous for people with neglect symptoms. For that reason, VR-Therapy is only made for use in cooperation with a therapist, who chooses the appropriate exercises for the patient, sets the parameters and stabilises the patients' body during the whole VR-Therapy session. In the Neglect App also the therapist has to choose the appropriate exercises, but once chosen the patient can use it at home for self-rehabilitation.

A goal of VR-Therapy is also to be an easily portable system. As it needs a Google Daydream Headset, an iPad and a Smartphone, it is possible to carry everything in one bag and it is easy to set up the therapy setting in almost every place. Other systems using computers or TV monitors are usually set in one place and relatively inflexible.

4 VR-Therapy – the App

The VR-Therapy software was developed to elevate neglect rehabilitation to a new level. Therefore, an iOS app for the therapist to control all settings and an Android app for the patient to perform exercises were programmed. A platform should make it possible for every programmer, to create new VR exercises for patients, that make rehabilitation more interesting and customizable.

In the following, the hardware and software are described, and the first developed exercise is explained.

4.1 Hardware

For this study, an iPad was used for the therapist's app. Instead of the iPad also an iPhone can be used for the therapist's app. A ZTE Axon 7 smartphone was used for the patient's VR App, a Google Daydream View headset plus controller were used for the patient to control the exercise. The VR app works on every Google Daydream compatible phone. Instead of the Google Daydream View headset, also other VR headsets such as Google Cardboard or HTC Vive can be used.

Both devices, the iPad and the Android phone, must have an internet connection during use, for device-to-device communication.

4.2 Software

The whole software consists of an iOS app for the therapist to control all exercises and settings, and an Android app that shows the virtual environment to the patient, where he/she can perform the exercises.

4.2.1 iOS App

The app for the therapist was programmed with the development environment XCode[2] and the programming language Swift 4.0, both made by Apple.

The app gives the user the opportunity to develop new exercises and to publish them in the app. Every therapist then has access to a library of all published exercises.

With the therapists' app on one device, different VR devices can be connected. For the first connection, the user of the iOS app has to type in a code that is displayed on the respective VR device. After this first connection, the device is saved and reconnects automatically whenever possible (when both apps are started and have an internet connection).

When using the app for the first time, the therapist must register with a username and password. Then, for using the app, the therapist has to log in to get access to the saved data. On the first page after login, the therapist sees a list of the previously created patients (Figure 5). For adding a new patient to the list, there is a plus icon on top right of the screen, which leads to a page where the name and the ID of the patient can be filled in, so that it gets added to the list of patients.

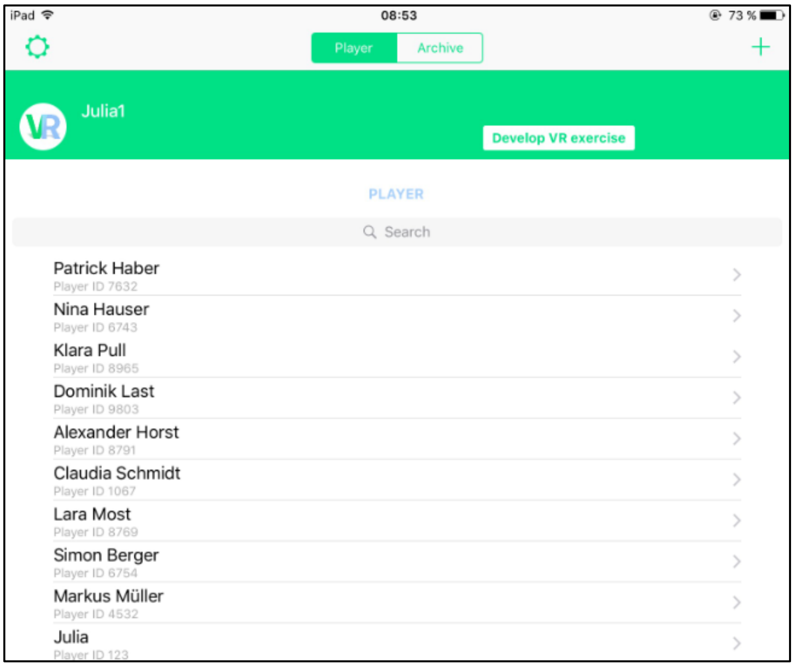


Figure 5 List of patients

[2] https://developer.apple.com/xcode/

Figure 6 shows the timeline of one patient, with a list of all exercises he/she has already finished, the date when they were performed as well as the scored points. The points are also shown in a line graph on top of the screen, to have a quick overview. The therapist can also take notes about each patient, by tapping on the button ‘Notes’ in the middle of the screen. In the patients’ overview, the button ‘Exercises’ on top right of the screen can be clicked at any time, to get to the list of exercises, for choosing one for the therapy session

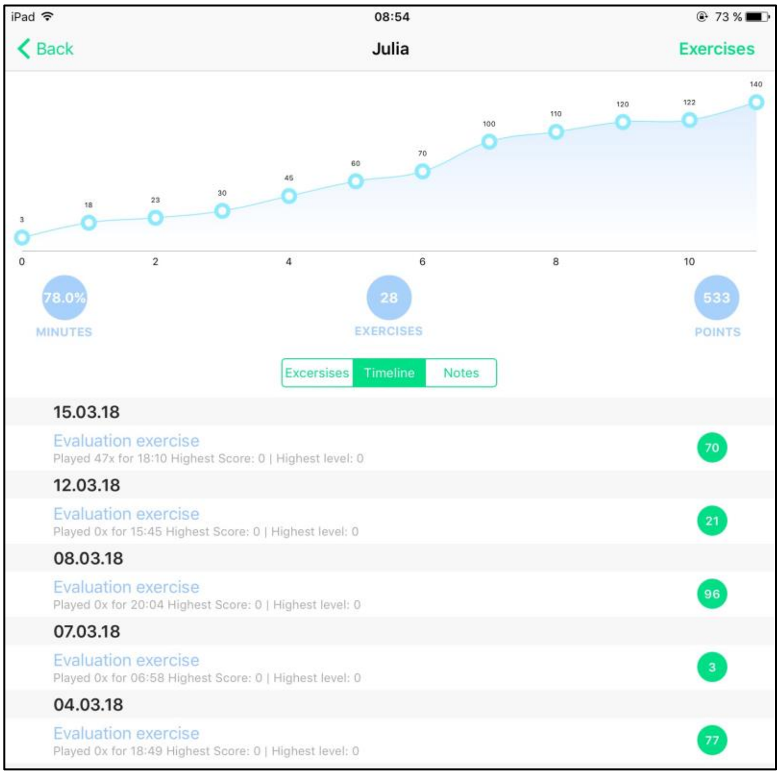


Figure 6 Overview and timeline of one patient named Julia

4.2.2 Android App

The exercises for VR-Therapy are made with Unity[3], a developer software for creating 3D games and apps.

The patient who uses the Android app only can play exercises, which the therapist has selected through the iOS app. Also, all settings are configured in the therapist’s app, the parameters can be adjusted at any time of the exercise. Therefore, data is constantly sent back and forth between the two devices. For data security, the data sent between the therapists’ app, the server and the

3 https://unity3d.com/de

patients’ app is encrypted. For the safe data transmission, Secure-Socket-Layer (SSL) certificates and Hypertext Transfer Protocol Secure (HTTPS) are used.

4.3 Evaluation Exercise

Until now, one VR exercise called ‘evaluation exercise’ is programmed and integrated in VR-Therapy. It is an exploration training, made for patients with neglect. The goal of the exercise is to find and shoot all objects of one kind, which has been configured by the therapist. For being able to adjust the exercise to each patients’ needs, different parameters were defined. Each parameter can be adjusted separately, whereby the level of difficulty can be changed.

On the first screen after choosing an exercise, there is an overview of all the adjustable parameters (Figure 7). In addition to the parameters, there is the number of reached points of the current session displayed on the top of the screen in the middle. This number increases by one, each time the patient shoots an object. On the bottom of the screen, in the middle, there is the button to start, pause and stop the whole exercise. While playing, it shows how long the exercise is already running. Additionally, on the bottom left, with the ‘save results’ button, the storage can be turned on and off, for instance to give the patient the chance to make him/herself familiar with a new exercise before starting. On the bottom right, the sounds can be turned on and off with the ‘game sound’ button.

All the other parameters are listed in the center of the screen. The first parameter ‘points goal’ has a slider, to easily change the number of objects, which the patient should find in the virtual environment. The last parameter called ‘add distraction objects’ can be switched on and off, to add or remove objects in another color, that make the whole exercise more difficult for the patient. All the other parameters in between can be adjusted by tapping on them, which leads to another page with different options to choose from.

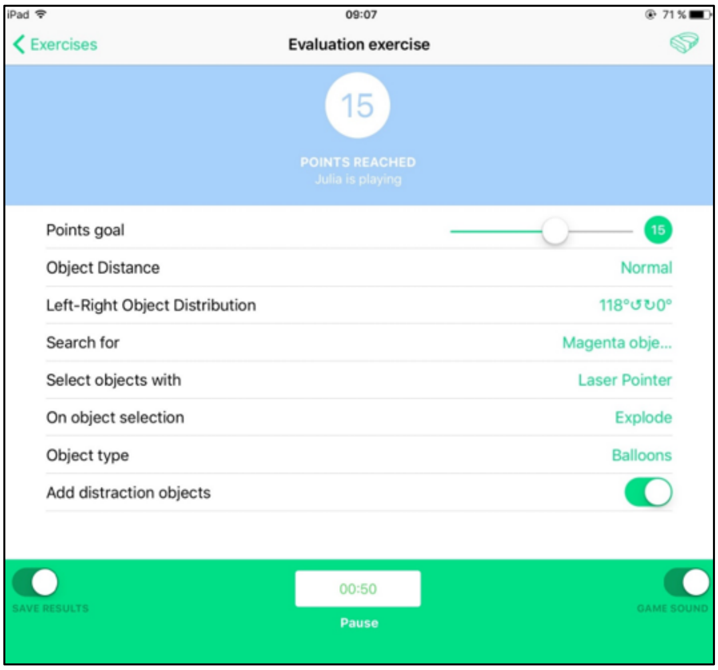


Figure 7 Overview evaluation exercise

Figure 8 shows these pages with selectable settings. The ‘object distance’ parameter (Figure 8a) lets the therapist choose between four distances. Either close, normal, far or flat can be selected, whereby the closer the objects are, the bigger they seem for the patient. Flat just means that all objects are in exactly the same distance.

With the parameter ‘search for’ (Figure 8b), the therapist can decide which color the objects that should be found, have. ‘Object type’ (Figure 8c) has the two options balloons and candies, so that the therapist can vary the objects shown in the VR app.

The next parameter ‘select objects with’ (Figure 8d) changes the shooting mode for the patient. Paper plane offers some kind of crossbow that shoots paper planes towards the objects. Laser pointer shows a grey line with a small dot at the end, that shows exactly where the patient shoots at, which makes it a bit easier than the paper plane mode, in which the patient has to estimate where the paper plane lands. And for patients who cannot hold the controller in their hands or who cannot push the button on the controller to trigger the shot, there is the look 3 seconds mode, where the patient sees a red dot wherever he/she looks at. This dot must be on an object for three seconds to make it disappear.

The next parameter 'on object selection' (Figure 8e) just changes the way the objects disappear after they were shot. Either they explode, they disappear by falling down or they turn green and then disappear.

The last adjustable parameter is named 'left-right distribution'. By moving the two blue circles shown in Figure 8f, the angle of where the objects are presented to the patient can be selected.

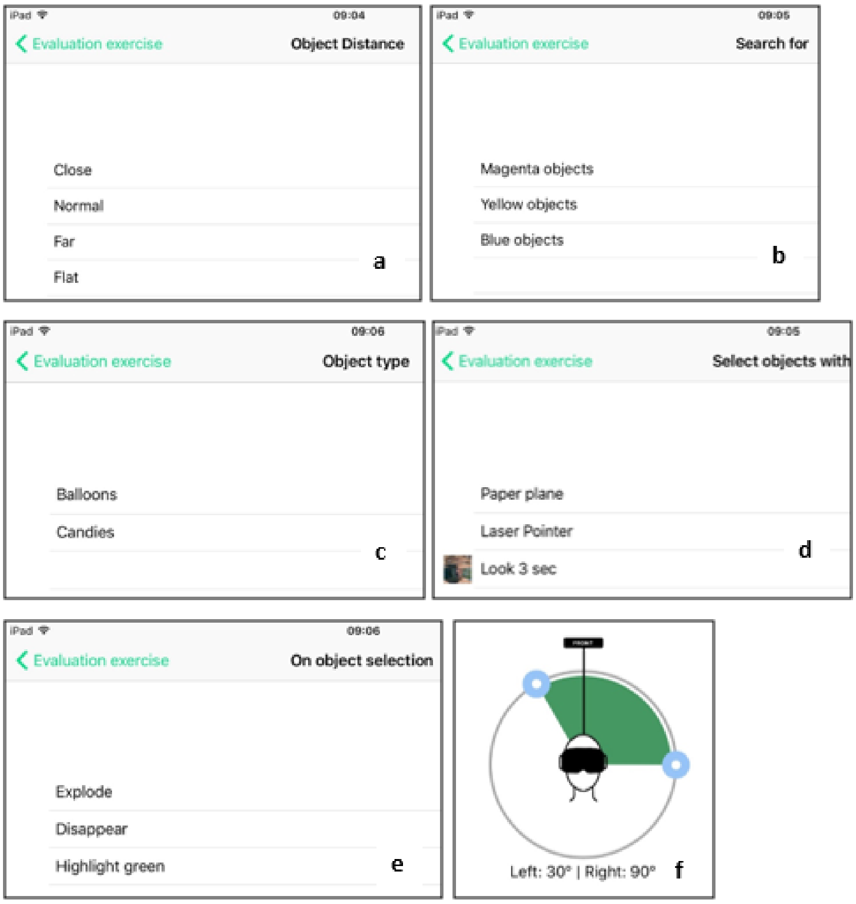


Figure 8 Parameter options for evaluation exercise: (a) Object distance, (b) Search for, (c) Object type, (d) Select objects with, (e) On object selection, (f) Left-Right-Distribution

Figure 9 shows the evaluation exercise with different selected parameters from the patients' view.

In Figure 9a, there are balloons (with distraction objects) in an angle of about 90-180°. In Figure 9b the balloons are switched to candies, which makes it more difficult to find the wanted color. It also shows the selection mode 'laser pointer'.

In Figure 9c, the distraction objects are removed, and the selection mode is changed to 'paper plane'. Figure 9d shows the third selection mode 'look 3 seconds' and the balloon in the middle of the picture is just highlighted green and will disappear soon.

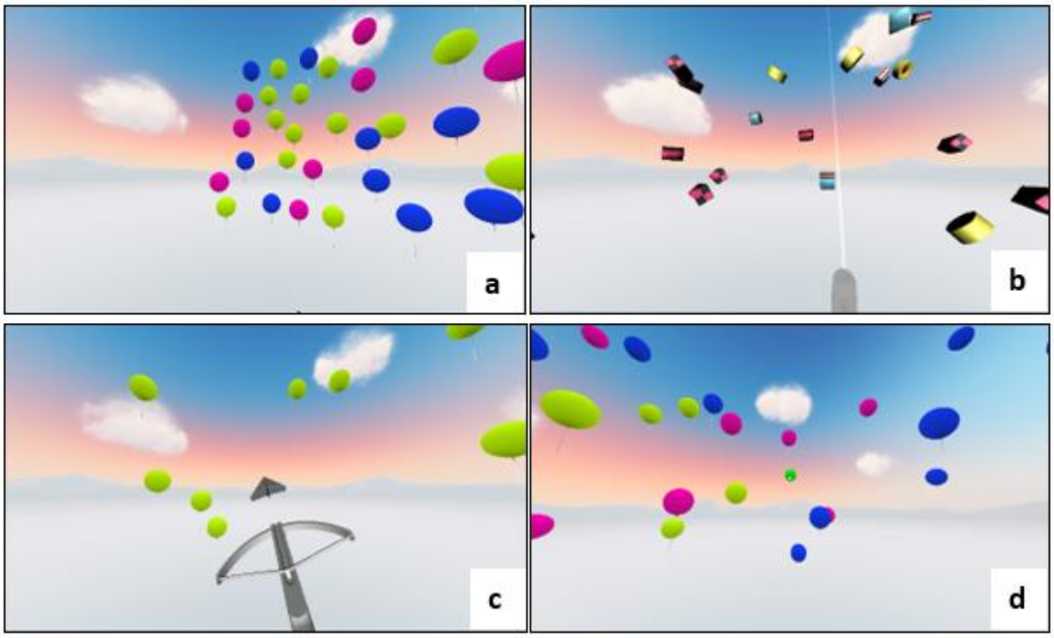


Figure 9 VR environment from patients' view: (a) balloons in angle 90-180°, (b) candies with laser pointer, (c) paper plane without distraction objects, (d) look 3 sec. and highlight green

5 Results

For evaluation, twenty completed questionnaires of eleven orthoptists and nine physiotherapists were analyzed. Sixteen of the participants were females and four males. Twelve participants fit in the age group of 21-30 year-olds, three in the group of 31-40 year-olds and five in the group of >41 year-olds.

Each one of the thirteen closed questions was answered by every participant, while the two open questions remained unanswered by some therapists. So, both questions, number fourteen about possible problems that might occur while using VR-Therapy with neglect patients and question number fifteen about improvements that can be made to make VR-Therapy easier to use in the daily work routine with patients, were answered by eighteen of twenty participants. Question number fourteen was left out by two orthoptists and question number fifteen was left out by one orthoptist and one physiotherapist.

The last section of the questionnaire, where the participants could add comments on VR-Therapy was used by only seven out of twenty therapists, five orthoptists and two physiotherapists.

The following subchapters show the results of all questions in detail, visualized in graphs, summed up in tables and listed with bullet points.

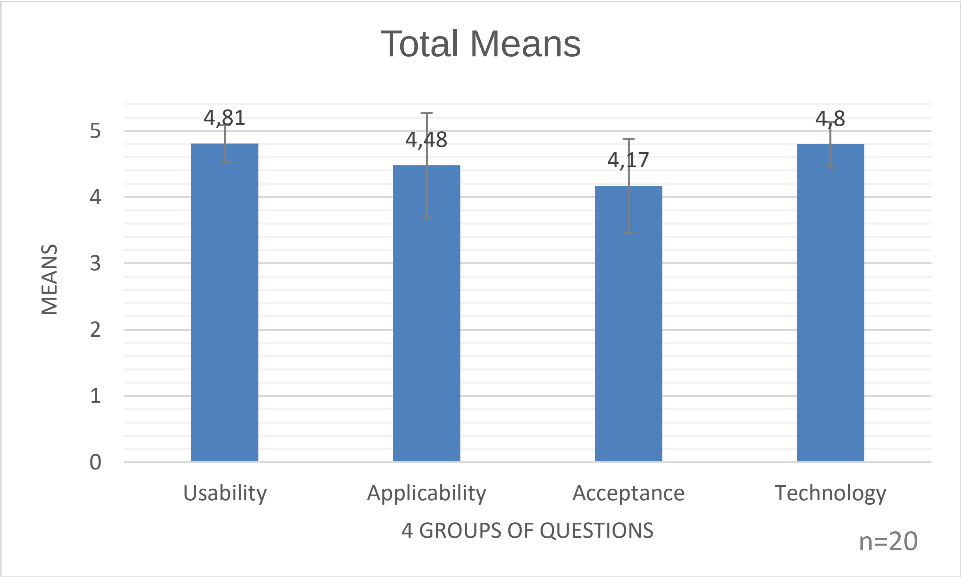
5.1 Assessment of the VR-Therapy App

This section shows the results of the first thirteen questions, within four groups. Each question could be answered by choosing from a 5-point Likert-scale. For evaluation, each answer was coded with a number. The numbers started from ‘agree’ = number 5 to ‘disagree’ = number 1. For analysis, these numbers were summed up, so the higher the score of a question or rather a group of questions, the more positive is the position of the participant to the evaluated topic.

The four groups, which the closed questions are assigned to, are:

- **Usability**: 4 questions about the usability of the iPad app for the therapist.
- **Applicability**: 3 questions about how it would be to use the VR-Therapy software in the daily work routine of the therapists.
- **Acceptance**: 3 questions about what the therapists think, how neglect patients would accept VR-Therapy.
- **Technology**: 3 questions about using technology in the rehabilitation of neglect patients in general.

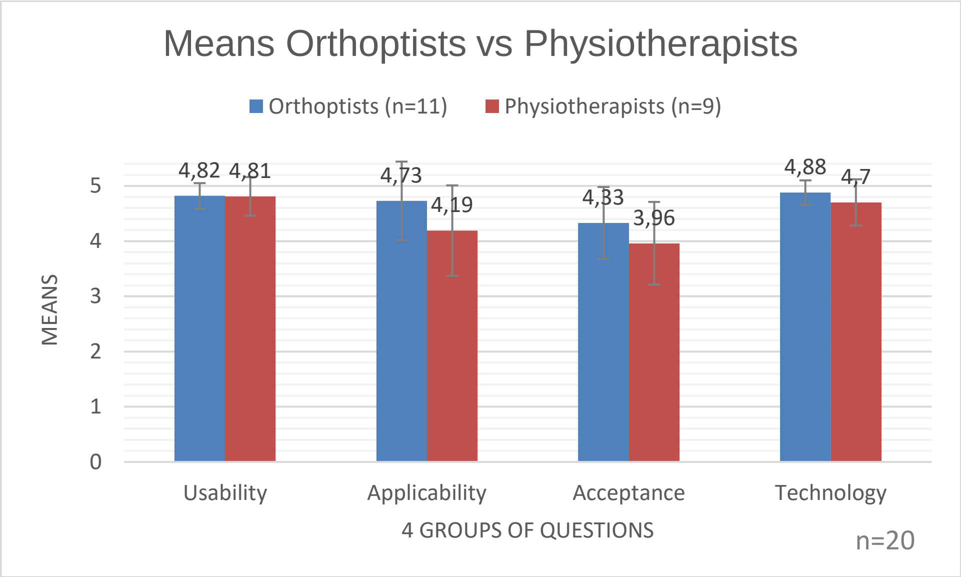
In Figure 10, the total means of the four groups of questions from all twenty participants are shown. Each category has a mean of more than four, which shows a very positive attitude of the therapists towards VR-Therapy.



	Mean	N	Std. Deviation
Usability	4,81	20,00	,28
Applicability	4,48	20,00	,79
Acceptance	4,17	20,00	,71
Technology	4,80	20,00	,33

Figure 10 Total means of the four groups of closed questions

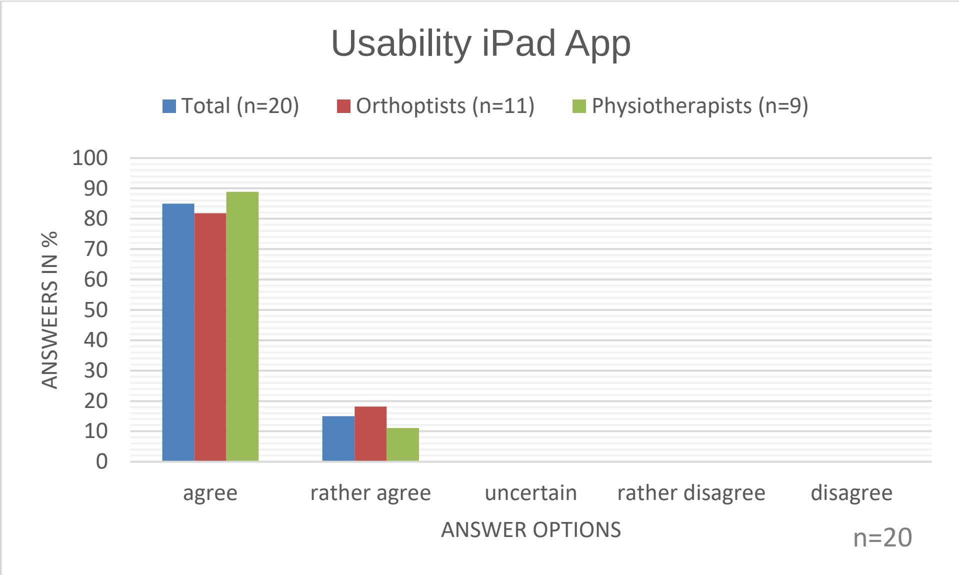
Also, the difference between the answers of the orthoptists and physiotherapists is minimal, as Figure 11 shows. In general, the orthoptists did rate a bit more positive than the physiotherapists.



	Profession	Mean	N	Std. Deviation
Usability	*Orthoptist*	4,82	11,00	,23
	Physiotherapist	4,81	9,00	,35
Applicability	*Orthoptist*	4,73	11,00	,71
	Physiotherapist	4,19	9,00	,82
Acceptance	*Orthoptist*	4,33	11,00	,65
	Physiotherapist	3,96	9,00	,75
Technology	*Orthoptist*	4,88	11,00	,22
	Physiotherapist	4,70	9,00	,42

Figure 11 Means of the four groups of closed questions: orthoptists vs physiotherapists

Figure 12 shows the answers to the question/statement of ‘The iPad app is easy to handle’ in percent. The graph shows that most participants agreed and some rather agreed with the statement, while no one was uncertain, rather disagreed or disagreed. The table shows exactly how many participants chose which answer. So, two orthoptists and one physiotherapist rather agreed with the statement, while all other seventeen participants totally agreed with it.

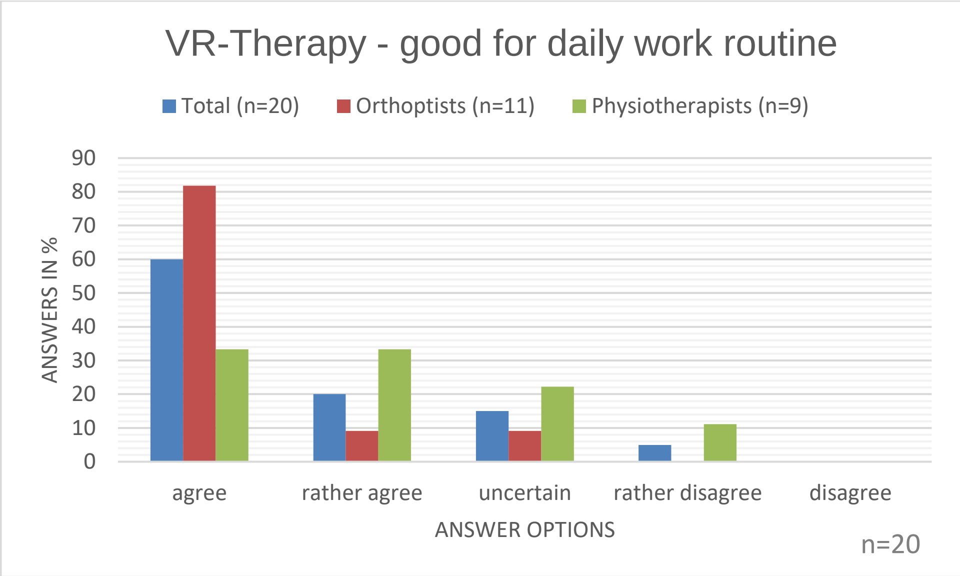


profession * f1 [count, row %, column %, total %]

Profession	f1: rather agree	f1: agree	Total
Orthoptist	2,00 18,18% 66,67% 10,00%	9,00 81,82% 52,94% 45,00%	11,00 100,00% 55,00% 55,00%
Physiotherapist	1,00 11,11% 33,33% 5,00%	8,00 88,89% 47,06% 40,00%	9,00 100,00% 45,00% 45,00%
Total	3,00 15,00% 100,00% 15,00%	17,00 85,00% 100,00% 85,00%	20,00 100,00% 100,00% 100,00%

Figure 12 Answers to: The iPad app is easy to handle.

Figure 13 shows the answers to the question/statement of ‘I would like to use the VR-Therapy software in my daily work routine’ in percent. The answers of the orthoptists and physiotherapists are compared to each other and all answers in total. The table below the graph also shows the absolute numbers of answers to this question. Nine of the eleven orthoptists chose ‘agree’ to the question (81,82%), while only three (33,33%) physiotherapists did so. Three therapists chose that they are uncertain and only one person, a physiotherapist, rather disagreed to the statement ‘I would like to use VR-Therapy in my daily work routine’.

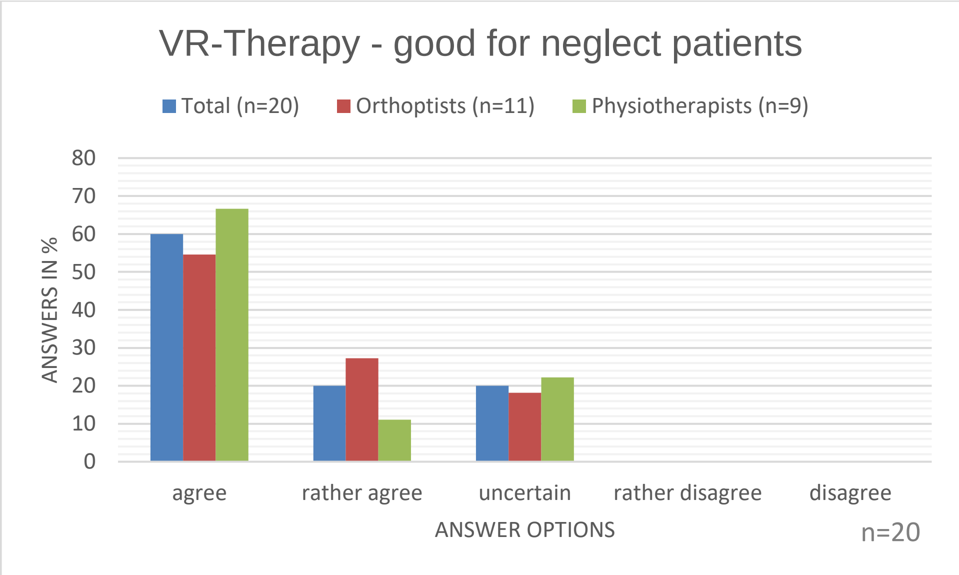


profession * f5 [count, row %, column %, total %]

	f5				
Profession	rather disagree	uncertain	rather agree	agree	Total
Orthoptist	,00 ,00% ,00% ,00%	1,00 9,09% 33,33% 5,00%	1,00 9,09% 25,00% 5,00%	9,00 81,82% 75,00% 45,00%	11,00 100,00% 55,00% 55,00%
Physiotherapist	1,00 11,11% 100,00% 5,00%	2,00 22,22% 66,67% 10,00%	3,00 33,33% 75,00% 15,00%	3,00 33,33% 25,00% 15,00%	9,00 100,00% 45,00% 45,00%
Total	1,00 5,00% 100,00% 5,00%	3,00 15,00% 100,00% 15,00%	4,00 20,00% 100,00% 20,00%	12,00 60,00% 100,00% 60,00%	20,00 100,00% 100,00% 100,00%

Figure 13 Answers to: I would like to use the VR-Therapy software in my daily work routine.

Figure 14 also shows the answers to a single question/statement in percent. In this case the statement is ‘I think that the VR-Therapy software is well suited for the therapy of neglect patients’. In total 60% (twelve of the twenty therapists) chose ‘agree’ and 20% (four people) chose ‘rather agree’. Also 20% were ‘uncertain’, but no one disagreed with this statement.

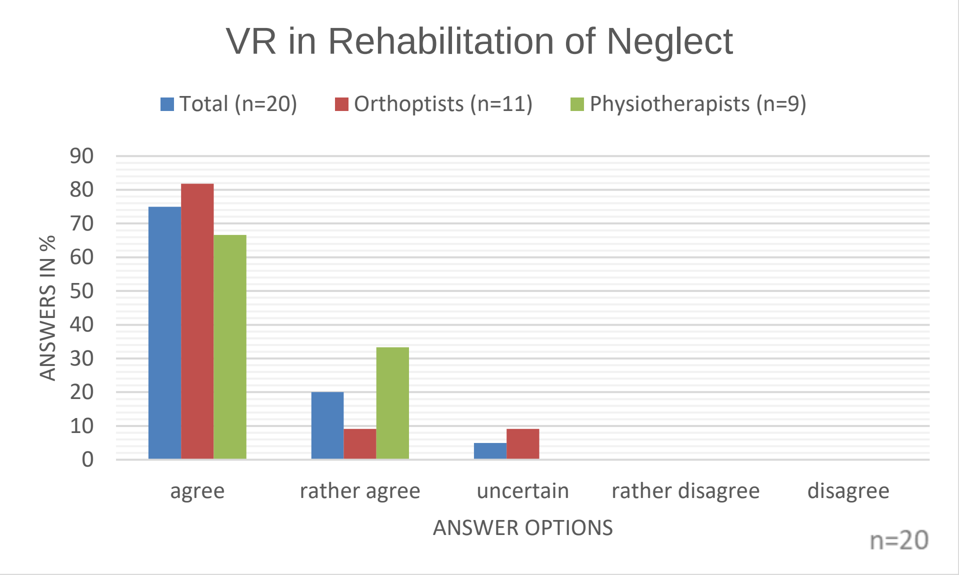


profession * f8 [count, row %, column %, total %]

Profession	f8 uncertain	rather agree	agree	Total
Orthoptist	2,00 18,18% 50,00% 10,00%	3,00 27,27% 75,00% 15,00%	6,00 54,55% 50,00% 30,00%	11,00 100,00% 55,00% 55,00%
Physiotherapist	2,00 22,22% 50,00% 10,00%	1,00 11,11% 25,00% 5,00%	6,00 66,67% 50,00% 30,00%	9,00 100,00% 45,00% 45,00%
Total	4,00 20,00% 100,00% 20,00%	4,00 20,00% 100,00% 20,00%	12,00 60,00% 100,00% 60,00%	20,00 100,00% 100,00% 100,00%

Figure 14 Answers to: I think that the VR-Therapy software is well suited for the therapy of neglect patients.

Figure 15 shows the answers to the question/statement ‘I think it is reasonable to use VR in the rehabilitation of neglect patients’. In the graph it is visible that none of the participants rather disagreed or disagreed with this statement. Though the table shows that one orthoptist was uncertain about it. Again, most of the participants (nine orthoptists and six physiotherapists) agreed.



profession * f12 [count, row %, column %, total %]

Profession	f12			Total
	uncertain	rather agree	agree	
Orthoptist	1,00 9,09% 100,00% 5,00%	1,00 9,09% 25,00% 5,00%	9,00 81,82% 60,00% 45,00%	11,00 100,00% 55,00% 55,00%
Physiotherapist	,00 ,00% ,00% ,00%	3,00 33,33% 75,00% 15,00%	6,00 66,67% 40,00% 30,00%	9,00 100,00% 45,00% 45,00%
Total	1,00 5,00% 100,00% 5,00%	4,00 20,00% 100,00% 20,00%	15,00 75,00% 100,00% 75,00%	20,00 100,00% 100,00% 100,00%

Figure 15 Answers to: I think it is reasonable to use VR in the rehabilitation of neglect patients.

By answering all thirteen closed questions, in total 65 points could be reached, if the answer ‘agree’ was chosen for each question.

As Figure 16 shows, three participants reached the highest score of 65 points, while the lowest score was 48. Twelve therapists had a total score of more than 60, six therapists reached between 50 and 60 points and only two therapists had a total score of less than 50.

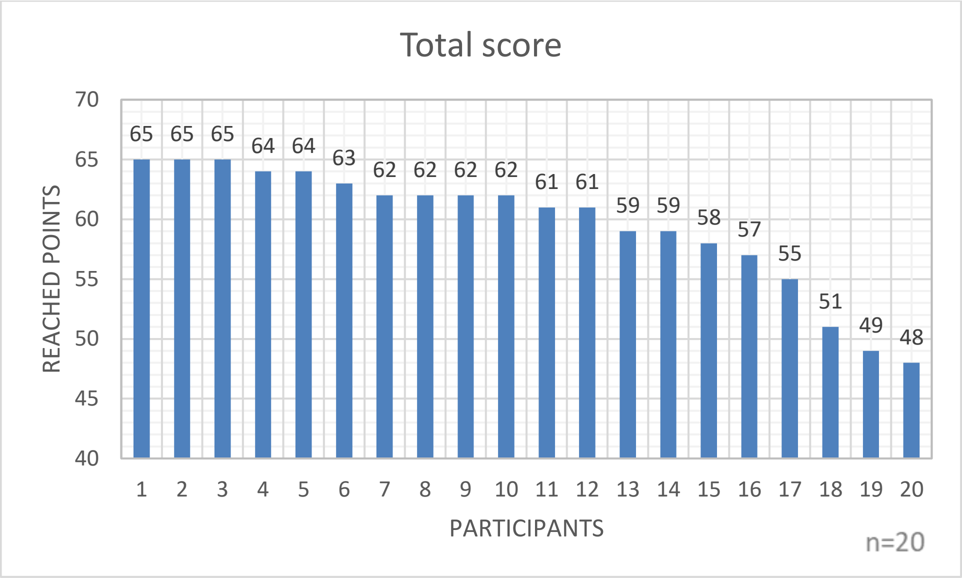


Figure 16 Total score of all questions.

The following subchapters show the results of the open questions.

5.2 Possible Problems of VR-Therapy in Rehabilitation

The first open question should find out what problems might occur when using VR-Therapy for the rehabilitation of neglect patients. The answers of the therapists were collected. The problems that were mentioned repeatedly were put in a table.

Table 1 Repeatedly mentioned problems and their number of mentions.

Problems	**Number of Mentions**
Compliance	3
Diplopia	3
No overview which objects were reached and which not	3
Skepticism about/aversion to new technology	3
Tremor	3
Understanding; reduced cognitive abilities; too complex exercises	3
Hygiene	2
Too little eye movements, too much head movement (in exploration training)	2
Vertigo, nausea	2

As Table 1 shows, six problems were mentioned by three different therapists. First, there might be a lack in the compliance of the patients. Also, diplopia can make patients not be able to see a three-dimensional VR picture. One more problem is that the therapists have no overview of which objects were seen and shot by the patients and which objects they could not find. Another big problem might be an aversion or skepticism about new technology, for both patients and therapists. Additionally, a tremor of the patient can affect the use of VR-Therapy. Patients with neglect often have reduced cognitive abilities, so it might be difficult for them to understand what to do or maybe the exercises are too complex. Table 1 also shows the three problems that were mentioned twice in the questionnaires. The hygiene of the VR headsets can be a problem. Also, two orthoptists think that there are too little eye movements and too much head movement compared to conventional exploration training. The last problem that was mentioned twice is that maybe vertigo or nausea can occur, when patients are using the VR headset.

Besides the repeatedly mentioned problems, there were the following ideas, each mentioned by only one participant:

- Data security.
- Handling of the VR headset for the patient.
- Maybe a faster fatigue.
- Missing alternatives to VR after rehabilitation.
- Provision of the Software for instance in private physiotherapy practices.
- Reduced visual acuity.
- Technical problems such as a software breakdown or a loss of the internet connection.

5.3 Suggestions for Improvement

The second open question asked for suggestions on how VR-Therapy can be improved, to make it easier to use in the daily work routine with patients. Again, the repeatedly mentioned suggestions were collected in a table.

Table 2 Repeatedly mentioned suggestions and their number of mentions.

Suggestions	**Number of Mentions**
Better alignment of the cursor	4
Solute technical problem: some objects do not react to the shot	3
Various backgrounds	3
Display error rate	2
More different exercises	2
Overview which objects were reached and which not	2
Therapist should also see the image, which the patient sees (for instance on a monitor)	2
Time limit for exercises or time stops automatically when all objects are shot	2

Table 2 shows that making a better alignment of the cursor was mentioned by four therapists, because often it felt as if they had to shoot next to an object to strike it. Another technical problem that should be solved is that some objects, especially in the upper field in far distance, do not react when they are shot. Three therapists mentioned that. Also, three therapists suggested to offer more different backgrounds to choose from in the exercise. This way they could make it more difficult or more realistic, for instance with environments from the everyday life. The rest of the suggestions in Table 2 were mentioned twice in the questionnaires. The participants recommended to display the error rate of the patient in the iPad app. They also suggested to develop more different exercises to choose from. Furthermore, an overview of which objects were reached by the patients and which not would be helpful. Another opportunity would be to let the therapist see the same picture, the patient sees, for instance on a separate monitor. The last suggestion that was mentioned twice was to add a time limit to the exercise or at least to make the exercise stop automatically, when all objects are shot.

Again, there are some suggestions that were mentioned only once in the questionnaires:

- Enlarge the visual field (without head movement).
- Larger controller.
- Less stimuli in the background.
- Offering higher and lower contrast to choose.
- Selection or suggestion of exercises, by typing in a diagnosis.
- Smaller objects, that are even further away.

5.4 Comments on VR-Therapy

The last section of the questionnaire provided some space for adding comments, that did not fit in at any other point. In the following, these further comments are listed:

- Certainly, a welcome change in the therapeutic daily routine.
- Fantastic idea.
- Fun in therapy/fun factor.
- It is fun and awakens the play instinct.
- Few devices which are easy to handle.
- New technologies strengthen the trust of especially the young patients, to receive a therapy of the latest scientific standards.

- Super, very useful project!
- The app is usable for various disease patterns and therapies (amblyopia therapy…).
- Very well adapted to neglect patients.

6 Discussion

In the following subchapters the results of the survey will be analyzed and put in relation with literature.

6.1 Discussion of Results

In general, the orthoptists and physiotherapists who participated in this study had a similar opinion on VR-Therapy. All of them were open for new technology in rehabilitation and felt positive about the VR-Therapy app. Also, the acceptance of the neglect patients was estimated to be good, though the app could not be tested with patients so far. This would probably be one of the next steps for VR-Therapy, to find out whether the patients in rehabilitation are able to understand and use it correctly.

Other studies with different VR systems are not directly comparable with this study, but they also showed positive results concerning the assessment of therapists and patients who tested the systems, as chapter 3.4.2 shows. These results and the positive evaluation of the therapists who participated in this study let hope for a good acceptance of patients concerning VR-Therapy.

6.2 Improvements

The problems reported in the survey that VR-Therapy currently has or might have in the future, as well as the suggestions for improvement will be very helpful to improve the system and to make it easier to use in the daily work routine of therapists and patients in rehabilitation. Some of the suggested improvements are already planned for implementation.

6.2.1 Improvements in Usability

There is a device called Google Chromecast[4], which makes it possible to transfer the virtual image the patient sees through the Google Daydream View glasses on another monitor, so that the therapist can see the same image. For this purpose, the Google Chromecast device is connected to a monitor via HDMI and to electricity supply via USB cable. Also, the VR device and Google Chromecast have to be in the same WLAN network.

In addition, it is planned to create a map that shows the number of objects the patient shot and how many he did not find, segmented in quadrants. This map should be integrated in the therapists' app, on the same screen where the adjustable parameters for the exercise are. The form of displaying the results in quadrants is also used in the Rahab City VR exercise, where a gaze map shows into which quadrant the patient looked the most in percent (Vourvopoulos et al., 2014).

Another suggestion was to use a larger controller. So, either a case for the Google Daydream controller can be formed via 3D print or another system with a larger controller must be used instead of the Google Daydream. There are already a lot of different types of controllers and other devices that use different controllers. Maybe also a sensor glove can be used instead of a controller, so that the patient does not have to hold anything in his/her hand during the whole therapy session. Such a glove is also used in the study by Kaminer et al in addition to the Microsoft Kinect, for a precise tracking of the finger, not only the movement of the whole hand (Kaminer et al., 2014).

For solving the technical problems that were mentioned in the results, the software must be reworked once again and the problems such as the inaccuracy of the cursor or the impossibility to shoot some objects will be improved as effectively as possible.

6.2.2 Improvements in Exercise Parameters

There were also some other very interesting ideas that can be integrated in the evaluation exercise in the future. For example, a time limit for the exercise can be added or the exercise can stop automatically when all wanted objects are shot. Also, more different and more realistic backgrounds, which three therapists wished for, can be created. Other VR systems for rehabilitation already use more realistic VR environments for their exercises. The VIROG system for example

[4] https://store.google.com/de/product/chromecast_2015

provides the two virtual environments of a supermarket and walking in the street (Lozano et al., 2009). While the ‘Let’s do groceries’ app shows a virtual shelf with products on it, while the number of products can be chosen according to the level of difficulty the patient needs (Ogourtsova, Archambault, & Lamontagne, 2017).

Also, the background in the evaluation exercise can be made more consistent. Therefore, the clouds and the mountains on the horizon can be removed for instance with an additional new parameter, which lets the therapist select different backgrounds.

Another suggestion was to make the contrast ratio adjustable. To integrate that into the exercise, another slider named ‘contrast ratio’ can be added to the parameters.

One more idea was a suggestion of exercises, for specific diseases. To implement that option, there would have to be a larger selection of exercises and someone would have to assign them to the appropriate diseases. When the software is further developed, maybe such a function can be added, but still the therapist has to decide which exercise is adequate for the patient in the end.

6.2.3 New Exercises for VR-Therapy

Of course, it is also planned to create more different exercises to choose from. For this reason, the system is planned to be designed as a platform, where everyone can program new exercises and publish them, so every therapist who works with VR-Therapy can use them.

Besides other exercises for training the visual exploration, also an exercise for optokinetic stimulation is planned, where objects are moving into the neglected side and the patient has to follow them as far as possible. Further some more physiotherapeutic exercises are planned to develop, for training the upright posture and movements with the neglected extremities to the neglected side. Besides all that also the prism adaptation as outlined in chapter 3.3 can be implemented in VR-Therapy. There is already an exercise like that, which is presented in an article by Kim et al. For their virtual prism adaptation system, an Oculus Rift DK 2 was used to show the virtual image with a deviation of the patients’ hand while prism phase and a non-deviated image while post-adaptation phase. Further a Leap Motion sensor controlled the head movement and functional near infrared spectroscopy was used to measure the brain activity (Won-Seok Kim, Nam-Jong Paik, & Sungmin Cho, 2017). This kind of exercise can also be implemented in VR-Therapy. So, the Android app can show objects the patient has to point at, while the therapist can set different deviations of the patients' hand in the VR image through the iOS app. Then the accuracy of the patient pointing at an object can be measured, saved and compared. So, the deviation of the hand in the VR image has the same effect as a prism in conventional neglect therapy.

Also, a completely new area of application was mentioned in the further comments, at the end of the questionnaire. VR-Therapy could be used for amblyopia therapy. Another word for amblyopia is 'lazy eye'. It means that one eye is weak-sighted even though there is no organic damage, or the damage is minimal, compared to the severity of visual impairment (Kaufmann & Steffen, 2012, p. 262). In amblyopia therapy, the eye with the better vision is covered with an eye occlusion plaster, for a certain period. In this way, the lazy eye must be used to see and thereby should become better. This kind of therapy is only effective when used during childhood. For grown adults, amblyopia therapy has no effect anymore. It is often difficult to make a child wear a patch on his/her eye for a longer period of time. Especially for children, the new technologies such as VR are very interesting. It would be easy to cover one lens of the VR headset or maybe render the image to only one eye, so that the child can play, seeing only with the lazy eye. That might be more interesting than just painting and is not as uncomfortable as a patch on the eye. Of course, the child will not have a three-dimensional effect, but because of the amblyopia, most of them are unable to see three-dimensional in real life either.

6.2.4 Difficulties

Data security is a delicate subject that was mentioned as a possible problem by one therapist. So, it is planned to store the patients' data only locally, it has to be encrypted and the data storage device must be locked safely by the therapists. Also, the data transmission during the therapy is encrypted as outlined in chapter 4.2.2.

A problem concerning the Google Daydream View headset is the hygiene, because most surfaces are made of textiles. The padding that gets in contact with the facial skin while wearing the headset is removable and can be washed. But in daily work, it will not be possible to wash the headset after every use and especially not to dry it until it is needed for the next patient. So, another solution must be found, such as a cover that can be changed or disinfected after every patient. Or another device that is easier to clean must be used instead of the Google Daydream View headset.

Furthermore, some possible problems were mentioned, which the developers and therapists might not be able to influence. The compliance depends on each patient, his/her attitude and the severity of the neglect. The skepticism about new technology can also affect the compliance of patients, but maybe in some cases also the cooperation of therapists. Other health-related problems such as diplopia, tremor, reduced visual acuity or reduced cognitive abilities, can make it impossible for some patients to use VR-Therapy. In these cases, the conventional therapy methods can be applied. Maybe for some people the use of VR can lead to vertigo or nausea. That has to be tested with each patient individually. And technical problems such as a software breakdown or a loss of internet connection can happen with every technical device

6.3 Innovations of VR-Therapy

Besides all these problems and suggestions, VR-Therapy is an innovation for rehabilitation of neglect patients. At the moment, there are already VR technologies used in rehabilitation, some of them are described in chapter 3.4.1. Most of these technologies show the VR environment on a screen and the patient in front of the monitor can control and watch an avatar moving in the virtual environment. In these cases, the patient never feels as if he was in this virtual world and still has the distraction of the room around him/her. In VR-Therapy, this distraction of everyday objects can be faded out completely or be added step by step.

Another advantage of VR-Therapy is that the therapist can completely control the exercise settings and adjust parameters at every moment, even during an exercise. VR-Therapy is structured in a way that makes the handling easy and intuitive, even a therapist with no technical skills can easily learn the use of this software.

A further innovation of VR-Therapy compared to other VR software for rehabilitation is that every programmer can develop new exercises and publish them. In this way, the exercise catalogue could become larger and more diversified within a short period of time, provided that many people use VR-Therapy and implement their ideas. So, in fact there is a huge spectrum of possibilities.

VR-Therapy, as it was used for this survey, also has the advantage of being easily portable, since the basic equipment consists of a Google Daydream compatible phone, a headset with Google Daydream plus controller and an iPad.

7 Conclusion and Summary

For answering the questions of research in this study, a literature research, a usability test and a survey were conducted.

The results of the survey show that most of the twenty therapists who participated are interested in using the VR-Therapy software for the rehabilitation of their patients with neglect after stroke. Only two therapists were uncertain and one therapist would rather not like to use it.

Most of the twenty therapists also think that VR-Therapy is well suited for the use with neglect patients. Twelve therapists totally agreed with that, four agreed and four were uncertain, but no one thought it would be inappropriate.

In general, the results show only little differences between the answers of orthoptists and physiotherapists. Twelve of the total twenty participants reached more than 60 of 65 possible points and only two participants reached less than 50.

An important part of the survey was to find out where possible problems of VR-Therapy are located and how the system can be improved to make a use in the rehabilitation of patients with neglect easier and more efficient.

The evaluation showed a lot of suggestions for improving VR-Therapy such as solving some technical problems, creating more exercises, adding more parameters to the existing evaluation exercise or making it possible for the therapist to see the VR picture on a monitor too. Some of them are already implemented, some are planned for implementation and others will be reconsidered in the further process.

Compared to other existing VR technologies that are already in use for rehabilitation, found in the literature research, there are some specific innovations in VR-Therapy. The software provides the opportunity of developing new exercises for everyone. Other existing VR software for rehabilitation often uses VR to put a three-dimensional image on a screen, while the patient sits in front of it. VR-Therapy lets the patient feel as if he/she really was in this virtual environment by using a VR headset. And VR-Therapy is easily portable since it needs no computer or big monitor.

As outlined in chapter 3.4.3, there are different studies about the effect of VR in rehabilitation, tested with different systems. Most of them show a better or at least an equivalent result as it could be attained with conventional therapy methods.

In conclusion, it can be said that it is reasonable to proceed with the project of VR-Therapy because of the positive reaction of the therapists in this study and because of the existing VR technologies for rehabilitation, that also got good feedback and reached good results in other studies. Though there will be a lot of work to do until this software can be used in rehabilitation routinely, it definitely makes sense to go on working with VR-Therapy.

The next steps will be to rework the whole app, started with improving the evaluation exercise by solving problems and adding new features. Then developing more exercises and starting the platform that makes it possible for other developers to add their own exercises. And then of course conducting more studies to test and improve VR-Therapy, until it finally might be released for the use in rehabilitation.

Literature

Achanccaray, D., Acuña, K., Carranza, E., & Andreu-Perez, J. (2017). A virtual reality and brain computer interface system for upper limb rehabilitation of post stroke patients. In *2017 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE)* (pp. 1–5). https://doi.org/10.1109/FUZZ-IEEE.2017.8015726

Berlit, P. (2013). *Basiswissen Neurologie*. Springer-Verlag.

David, L., Bouyer, G., & Otmane, S. (2017). Towards an upper limb self-rehabilitation assistance system after stroke (p. 20). Presented at the Proceedings of the Virtual Reality International Conference - Laval Virtual 2017, ACM. https://doi.org/10.1145/3110292.3110313

Haus, K.-M. (2014). *Neurophysiologische Behandlung bei Erwachsenen: Grundlagen der Neurologie, Behandlungskonzepte, Hemiplegie verstehen*. Springer-Verlag.

Huygelier, H., Gillebert, C. R., van Ee, R., & Vanden Abeele, V. (2017). The Design of a Virtual Reality Game for Stroke-Induced Attention Deficits (pp. 223–230). Presented at the Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play, ACM. https://doi.org/10.1145/3130859.3131308

Jerome-Christian, N. Z., Rajaratnam, B. S., & Tian, T. X. (2012). Can virtual reality integrated within conventional rehabilitation enhance balance recovery after stroke? (p. 34). Presented at the Proceedings of the 6th International Conference on Rehabilitation Engineering & Assistive Technology, Singapore Therapeutic, Assistive & Rehabilitative Technologies (START) Centre. Retrieved from http://dl.acm.org/citation.cfm?id=2501134.2501174

Kaluarachchi, C., & Al-Jumaily, A. (2011). Self-rehabilitation based on user interactive environment (p. 52). Presented at the Proceedings of the 5th International Conference on Rehabilitation Engineering & Assistive Technology, Singapore Therapeutic, Assistive & Rehabilitative Technologies (START) Centre. Retrieved from http://dl.acm.org/citation.cfm?id=2500753.2500814

Kaminer, C., LeBras, K., McCall, J., Phan, T., Naud, P., Teodorescu, M., & Kurniawan, S. (2014). An immersive physical therapy game for stroke survivors (pp. 299–300). Presented at the Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility, ACM. https://doi.org/10.1145/2661334.2661340

Kaufmann, H., & Steffen, H. (2012). *Strabismus*. Georg Thieme Verlag.

Keime, J., Hays, B., Vazquez, A., Mena, J., Sauerwald, J., & Shwket, H. (2017). Case study of custom virtual reality system for post stroke rehabilitation. In *2017 International Conference on Virtual Rehabilitation (ICVR)* (pp. 1–2). https://doi.org/10.1109/ICVR.2017.8007483

Kerkhoff, G., & Schenk, T. (2012). Rehabilitation of neglect: An update. *Neuropsychologia*, *50*(6), 1072–1079. https://doi.org/10.1016/j.neuropsychologia.2012.01.024

Kim, Y. M., Chun, M. H., Yun, G. J., Song, Y. J., & Young, H. E. (2011). The Effect of Virtual Reality Training on Unilateral Spatial Neglect in Stroke Patients. *Annals of Rehabilitation Medicine*, *35*(3), 309–315. https://doi.org/10.5535/arm.2011.35.3.309

Laver, K. E., George, S., Thomas, S., Deutsch, J. E., & Crotty, M. (2015). Virtual reality for stroke rehabilitation. In *Cochrane Database of Systematic Reviews*. John Wiley & Sons, Ltd. https://doi.org/10.1002/14651858.CD008349.pub3

Lohse, K. R., Hilderman, C. G. E., Cheung, K. L., Tatla, S., & Loos, H. F. M. V. der. (2014). Virtual Reality Therapy for Adults Post-Stroke: A Systematic Review and Meta-Analysis Exploring Virtual Environments and Commercial Games in Therapy. *PLOS ONE*, *9*(3), e93318. https://doi.org/10.1371/journal.pone.0093318

Lozano, J.-A., Gil-Gomez, J.-A., Alcaniz, M., Chirivella, J., & Ferri, J. (2009). Activities of daily living in a virtual reality system for cognitive rehabilitation. In *2009 Virtual Rehabilitation International Conference* (pp. 205–205). Haifa, Israel: IEEE. https://doi.org/10.1109/ICVR.2009.5174243

Ogourtsova, T., Archambault, P. S., & Lamontagne, A. (2017). Let's do groceries - a novel virtual assessment for post-stroke unilateral spatial neglect. In *2017 International Conference on Virtual Rehabilitation (ICVR)* (pp. 1–8). Montreal, QC, Canada: IEEE. https://doi.org/10.1109/ICVR.2017.8007515

Pedroli, E., Serino, S., Cipresso, P., Pallavicini, F., Giglioli, I. A. C., Guastafierro, E., … Riva, G. (2015). Neglect App. Usability of a new application for assessment and rehabilitation of neglect (pp. 139–143). Presented at the Proceedings of the 3rd 2015 Workshop on ICTs for improving Patients Rehabilitation Research Techniques, ACM. https://doi.org/10.1145/2838944.2838978

Prosiegel, M., & Böttger, S. (2007). *Neuropsychologische Störungen und ihre Rehabilitation: Hirnläsionen, Syndrome, Diagnostik, Therapie*. Pflaum.

Pschyrembel, W. (2010). *Pschyrembel Klinisches Wörterbuch* (262. Auflage.). Berlin: Gruyter.

So, R. H. Y., Wong, K. P., Yuen, S. L., Tang, J., Yeung, H., & Liu, J. (2011). Virtual reality gaming for rehabilitation: an evaluation study with physio- and occupational therapists (pp. 503–506). Presented at the Proceedings of the 10th International Conference on Virtual Reality Continuum and Its Applications in Industry, ACM. https://doi.org/10.1145/2087756.2087852

Tsoupikova, D., Triandafilou, K., Solanki, S., Barry, A., Preuss, F., & Kamper, D. (2016). Real-time diagnostic data in multi-user virtual reality post-stroke therapy (p. 8). Presented at the SIGGRAPH ASIA 2016 VR Showcase, ACM. https://doi.org/10.1145/2996376.2996387

Vourvopoulos, A., Faria, A. L., Ponnam, K., & Bermudez i Badia, S. (2014). RehabCity: design and validation of a cognitive assessment and rehabilitation tool through gamified simulations of activities of daily living (p. 26). Presented at the Proceedings of the 11th Conference on Advances in Computer Entertainment Technology, ACM. https://doi.org/10.1145/2663806.2663852

Won-Seok Kim, Nam-Jong Paik, & Sungmin Cho. (2017). Development and validation of virtual prism adaptation therapy. In *2017 International Conference on Virtual Rehabilitation (ICVR)* (pp. 1–2). Montreal, QC, Canada: IEEE. https://doi.org/10.1109/ICVR.2017.8007471

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Appendix

A. The Questionnaire used for this Survey

Fragebogen VR-Therapy

Bitte jeweils das zutreffende Feld ankreuzen ☒

Ich bin	☐ OrthoptistIn ☐ PhysiotherapeutIn				
	☐ männlich ☐ weiblich				
	Ich bin ________ Jahre alt.				
	Stimme zu	Stimme eher zu	unsicher	Stimme eher nicht zu	Stimme nicht zu
Usability der iPad App					
1 Die iPad-App ist für den/die TherapeutIn unkompliziert zu bedienen.					
2 Die Software erfordert für den/die TherapeutIn wenig Zeit zum Erlernen der Bedienung.					
3 Die Software ist für TherapeutInnen gut intuitiv und ohne fremde Hilfe oder Handbuch erlernbar.					
4 Die iPad-App bietet einen guten Überblick über die verstellbaren Parameter der Übung.					
Anwendbarkeit im Alltag der TherapeutInnen					
5 Ich würde die VR-Therapy Software gerne in meinem Arbeitsalltag verwenden.					
6 Die iPad-App ist gut auf die Anforderungen der Arbeit als TherapeutIn zugeschnitten.					
7 Ich denke, die iPad App bietet eine gute Übersicht über den Therapieverlauf des/der PatientIn.					

		Stimme zu	Stimme eher zu	unsicher	Stimme eher nicht zu	Stimme nicht zu
Einschätzung der Akzeptanz der NeglectpatientInnen						
8	Ich denke, die VR-Therapy Software ist gut für die Therapie von NeglectpatientInnen geeignet.					
9	Ich denke, NeglectpatientInnen werden VR-Therapy gerne verwenden.					
10	Ich denke, NeglectpatientInnen werden keine Probleme haben die Übungen auszuführen.					
Technik und Neuerungen in der Rehabilitation von NeglectpatientInnen						
11	Ich halte es für sinnvoll neue, technische Therapiemethoden für NeglectpatientInnen zu entwickeln.					
12	Ich halte es für sinnvoll Virtual Reality in der Reha bei NeglectpatientInnen einzusetzen.					
13	Ich würde gerne neue technische Methoden verwenden, um die Therapie für PatientInnen abwechslungsreicher gestalten zu können.					
Probleme und Verbesserungen						
14	Welche Probleme könnte es bei der routinemäßigen Verwendung der VR-Therapy Software in der Reha von NeglectpatientInnen geben? (sowohl aus Sicht des/der TherapeutIn, als auch aus Sicht des/der PatientIn)					

15	Welche Veränderungen/Verbesserungen könnten an der VR-Therapy Software noch vorgenommen werden, um sie im Alltag mit PatientInnen besser verwenden zu können?
	Sonstiges:

Vielen Dank für Ihre Mitarbeit!

B. Original answers to closed questions

The following table shows how many therapists chose each answer to the thirteen closed questions.

		agree (5)	rather agree (4)	uncertain (3)	rather disagree (2)	disagree (1)
Usability	Q1	17	3	-	-	-
	Q2	18	2	-	-	-
	Q3	14	6	-	-	-
	Q4	17	2	1	-	-
Applicability	Q5	12	4	3	1	-
	Q6	14	2	4	-	-
	Q7	15	3	1	1	-
Acceptance	Q8	12	4	4	-	-
	Q9	9	7	4	-	-
	Q10	5	8	6	1	-
Technology	Q11	17	2	1	-	-
	Q12	15	4	1	-	-
	Q13	18	2	-	-	-