The Impact of Virtual Reality Training on Patient-Therapist Interaction

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Abstract. This paper presents the development and evaluation of a Virtual Reality Kitchen to study the impact of VR rehabilitation on patient-therapist interaction in comparison to conventional rehabilitation. The study was conducted on 10 patients; 5 in an experimental group and 5 in a control group continuing with their conventional rehabilitation at NeuroRehab Centre Sydvestjysk Sygehus in Grindsted, Denmark. The therapists at NeuroRehab were supervising the test sessions for physical and verbal guidance over a period of four weeks requiring the patients and therapists to use the system three times per week for 30 min. A semi-structured interview was conducted with each participant from both groups. Additionally, each test session was video recorded to observe the physical and verbal interaction between the patient and the therapist and possible conversations. The outcome of this study indicated a clear difference between the therapists and their way of interacting with the patients. The therapists with experience in VR rehabilitation approached the patients, as in a conventional training session, utilising verbal and physical guidance, including hand gestures and commands, whereas the therapists with no VR rehabilitation experience did not.

Keywords: Interaction · Motivation · Patient-therapist interaction
Stroke · Virtual reality rehabilitation

1 Introduction

According to Hjerneskadeforeningen [1], approximately 12.000 people are suffering a stroke every year in Denmark with a surviving rate of 70%. To this end, over 75.000 people are living with consequences of a stroke, who need regular medical supervision, which is a significant expense for the government. In 2013, the Danish government spent 73 billion Danish kroners on disability and rehabilitation, and the costs are increasing year by year. Conventionally, a stroke survivor will be placed in a rehabilitation centre, facilitating both physical and cognitive rehabilitation in close collaboration with different therapists. A regular rehabilitation process in these centres can last up to 6 weeks. Afterwards, some of the patients return to their homes while others remain institutionalised. Within the last few years and with the release of diverse commercial Head-Mounted Displays (HMDs) researchers have been shifting their focus towards Virtual Reality Rehabilitation, due to its opportunities.

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This study aims to investigate how a virtual reality training system (VRTS) influence the patient-therapist interaction compared to conventional training within a stroke rehabilitation program. The VRTS consists of a HMD (Oculus Rift DK2), a motion sensor for hand tracking (Leap Motion) and a personal computer to run a Virtual Environment (VE). This was developed specifically for stroke patients with a team of therapists from Sydvestjysk Sygehus Neurological Rehabilitation Grindsted, Denmark, and contains both physical and cognitive tasks. The tasks were created around Activities of Daily Living tasks (ADL). To do so, a conventional training program was studied, consisting of ADL training in a kitchen.

2 Related Work

Patient-therapist interaction has been a focus of research for many years, and can be divided into three different interaction models [2]. All three models focus on the needs of the patient, and that each patient is an individual with personal values and background:

1. *Client-centred practice* focuses on patient autonomy; the responsibility is shared between patient and therapist. The goal is to create a caring and empowering environment where the patient is in control of the direction of their rehabilitation.
2. *Patient-centred care* focuses on the patients' perspective on rehabilitation. The therapist informs the patient regarding their condition and discusses the rehabilitation options, in order for the patient to understand their condition and the value of rehabilitation.
3. *Patient-focused care* focuses on the philosophy of care, including the physical, emotional, social, and spiritual needs of the patient. Here the patient-therapist relationship is equal, and striving to give information and a simplification of choices for the patient.

The following section provides details on patient-therapist interaction and their relationship in conventional rehabilitation.

2.1 Patient-Therapist Interaction in Conventional Rehabilitation

A systematic observation was conducted by Talvitie [3] to study the communication between patients and therapists, which indicated the therapist to be more verbally active than the patient. The therapist spoke the most of the time under the study to communicate instructions and corrections, whereas the patient only made short comments and asked few questions regarding their performance. This can be related to the therapist's need to communicate a specific task under training. This is usually done with a mix of verbal instructions and explanations, combined with physically demonstrating the specific task and physically aiding the patient under movement. Therapists with experience in the field of motivation tend to use verbal encouragement and tactile cues combined with constant hand communication and physical aid more often than therapists with less experience [4].

Lettinga et al. [5] discovered that physical aid and verbal guidance prevent the patients from making mistakes, hence, they are not able to evaluate their own performance or learn from it. This can be argued to be applicable for all stroke patients; however, cognitive impairments, as neglect, can affect the patients' self-awareness, and therefore, they need to rely on the therapists' aid and guidance [5].

There exists an inconsistence in how patients are informed about their diagnosis, due to the patients' own knowledge and experience of the rehabilitation. Usually, the therapists do not consider these factors; therefore, they do not convey the information [6]. The Therapists tend to focus on a symptom oriented approach instead of considering the individuals' background and knowledge, leading to a disconnection in the new established relationship between patient and therapist in the early stage of conventional rehabilitation [7]. However, Slingsby [8] describes a new approach to the rehabilitation, a relationship-centred model, developed in three parts:

1. *Patient motivation:* considered to be related to the rehabilitation outcome and can be increased by effective patient-therapist interaction.
2. *Personal relationships:* determined to be the primary factor in the rehabilitation process, as the relationship between the therapist and patient "it is the key to successful stroke rehabilitation", as stated by Slingsby [9].
3. *Professional behaviour:* can be defined as the therapists' ability to adapt their behaviour and way of communicating according to the patients. This is described as a tool to foster personal relationships with the patient and the patient's family [9].

2.2 Advantages and Disadvantages of VR Rehabilitation

Recently, Virtual Reality has undergone a significant development. As a result, custom created displays and commercial HMDs are currently becoming more available. Moreover, due to the advance of technology, both hardware and software, VEs are becoming more immersive and interactive. Rizzo and Kim [10] developed a SWOT analysis on VR rehabilitation, analysing the potential future of VR rehabilitation. The SWOT analysis consists of Strengths, Weaknesses, Opportunities and Threats related to VR rehabilitation. Their findings can be seen in Table 1.

The strengths of VR rehabilitation include real-time feedback for the patients while interacting with the VE; Enhancement of motivation through gaming factors and self-guiding exploration; along with adaptability through interface modifications. For a commercial level, the strengths are its low-cost duplication and distribution, error-free learning and safe test and training environment.

The weaknesses of VR rehabilitation include the interface. 3D user interfaces need further development to design a more efficient and easy to understand way of interacting with the VE. Another weakness is the possibility of motion sickness; this can be induced when the VE runs in low frame rate both in static and dynamic environments, combined with low resolution on the display. Furthermore, the wires influence in a negative way the user experience, as they become a distraction when used in dynamic environments.

The opportunities of VR rehabilitation is highly related to the increased focus on VR. The commercial HMDs: Oculus Rift, HTC Vive and PlayStationVR were released

Table 1. SWOT analysis on VR rehabilitation [10].

Strengths	**Weaknesses**
• Enhanced ecological validity • Stimulus control and consistency • Real-time performance feedback • Cuing stimuli to support "error-free learning" • Self-guided exploration and independent practice • Interface modification contingent on user's impairments • Complete naturalistic performance record • Safe testing and training environment • Gaming factors to enhance motivation • Low-cost environment that can be duplicated and distributed	• The interface challenge 1: interaction methods • The interface challenge 2: wires and displays • Immature engineering process • Platform compatibility • Front-end flexibility • Back-end data extraction, management, analysis, visualisation • Side effects
Opportunities	**Threats**
• Emerging tech 1: processing power and graphics/video integration • Emerging tech 2: devices and wires • Emerging tech 3: real-time data analysis and intelligence • Gaming-industry drivers • VR rehabilitation with widespread intuitive • appeal to the public • Academic and professional acceptance • Close-knit VR rehabilitation scientific and clinical community • Integration of VR with physiological monitoring and brain imaging • Telerehabilitation	• Too few cost/benefit proofs could impact VR rehabilitation adoption • Aftereffects lawsuit potential • Ethical challenges • The perception that VR will eliminate the need for the clinician • Limited awareness/unrealistic expectations

to the public in 2016, and innovators around the world are currently developing and investigating ways to make HMDs wireless and improve the resolution. Furthermore, the companies behind the HMDs are developing commercial drivers and hardware in order to achieve higher realism and accessibility. The most important opportunity is to minimise the cost of rehabilitation processes. This technology is appealing to the public and is brining excitement and enjoyment among patients. There is a universal academic and professional acceptance that this is the future of rehabilitation, and that it can strengthen the relationship between the clinicians and patients.

The main threats that VR Rehabilitation is facing are that there is no tangible low cost/benefit proof due to its novelty. People may have unrealistic expectations of VR since the awareness is still limited, and some clinicians have the perception that the system will replace them.

2.3 Patient-Therapist Interaction in VR Rehabilitation

There are no studies at present time on patient-therapist interaction within the field of Virtual Reality due to the novelty of VR. Many works focus on the physical or cognitive improvement or physiological measurements in order to validate the clinical efficiency of VR Rehabilitation rather than the effect of VR on the patient-therapist interaction. Hence, the contribution of this study is to investigate the patient-therapist Interaction in VR rehabilitation.

3 Methods

This section introduces the system development and its functionality. Next, the target group and ethical considerations will be introduced. Finally, the test procedure and data treatment are presented.

3.1 System Development and Functionality

The virtual reality system consists of:

- *Hardware:* Leap Motion – a tracking device which is motion sensitive to different gestures and movements, Oculus Rift Development Kit 2 – a head mounted display headset displaying the VE, and a desktop computer (PC).
- *Software:* a custom-built task simulator – Virtual Reality Kitchen (VRK).

The Leap Motion is mounted on the Oculus Rift to give higher accuracy and realism. The tracking camera from Oculus Rift was positioned 70 cm in front of the patient and at 130 cm height. Artificial lighting supported good functionality of the devices.

VRK simulates training exercise from ADL that are usually part of the stroke rehabilitation at NeuroRehab Centre at Sydvestjysk Sygehus, Grindsted, Denmark. The task simulator game is a PC-based game displayed on both Oculus Rift and a monitor display, and controlled with Leap Motion. The in-game tasks involve physical exercises for recovery of motor functions in the upper extremities and the trunk. The movements include: *reaching, grabbing, leaning, pinching* and *grasping*.

There are two tasks in the VRK: *coffee making* and *grocery sorting*. Additionally, a *calibration scene* was developed. In the *coffee making* scene the patients are required to complete eight actions in order to get a score of 60 points. These actions are: *opening tab, lifting coffee machine lid, filling the glass with water, pouring the water then the coffee in the machine, placing the jug in the machine, closing the lid* and *pressing the on/off button*. The scoring is divided so 10 points is given for the five actions and an additional 10 points if the tasks were completed in less than 3 min. In the *grocery sorting* task, the participants are required to sort and place 17 items in one of the three possible locations: *freezer* (left side), *fridge* (right side) or on *fours shelves* (frontal). 10 points are given for every correct placement with a total possible score of 170 points. The maximum achievable total score was 180 points. The aim of the calibration scene is to define a training space based on individual capabilities and limitations. The interactive objects are only placed in the training space to achieve an appropriate individual level of difficulty per task. To calibrate the game, the participants were required to reach as far as possible in three directions: left, right and top.

To develop the VE, a free source 3D modelling software, Blender was utilised. The objects were designed to resemble an entirely furnished kitchen. For actions and interaction, the system was developed in Unreal Engine 4 – a suite of tools for design and system development purpose. Unreal Engine 4 provides an important feature (the Blue Print) which is a visual scripting system enhancing simple design and development. The programming language used for the scripts is C++.

3.2 Target Group

A sample of 10 participants and 5 physiotherapists involved in a rehabilitation program at NeuroRehab Centre, Sydvestjysk Sygehus, Grindsted, Denmark were included in the experiment. The patients consist of 3 women and 7 men who suffered a stroke no longer than two months before the experiment. The therapists were 3 women and 2 men. Patients were divided in two groups: a control group, where conventional rehabilitation treatment was applied; and an experimental group, where subjects utilised the VRK system instead of their conventional rehabilitation. All the patients were pre-tested using a Box and Blocks scale, which determined their physical motor condition. Randomisation of the participants was effectuated based on different factors such as: Box and Blocks score, stroke location, paraplegic side, gender and age, see Table 2.

Table 2. Patient information (BB: Box and Blocks, R: Right arm, L: Left arm).

Nr.	Name	Age	Gender (M/F)	Stroke location	Paraplegic side	BB score (R/L max: 150)	Group (E/C)
1	P	58	M	Left side	Right	R20:L22	C
2	PV	77	M	Right side	Left	R19:L6	E
3	L	74	M	Left side	Right	R15:L49	C
4	J	74	M	Cerebellum	Right	R15:L23	E
5	S	70	F	Left side	Right	R45:L63	C
6	M	61	M	Both sides	Right	R46:L50	E
7	PO	80	M	Right side	Left	R44:L39	C
8	F	85	M	Right side	Left	R50:L18	E
9	R	62	F	Frontal lobe	Both	R46:L46	C
10	B	60	F	Left side	Right	R40:L45	E

3.3 Ethical Considerations

Ethical considerations were discussed and applied regarding informed consent, deception, debriefing, confidentiality and protection from physical and psychological harm. Considering that the nature of the study was rather sensitive, the therapists and the patients were completely instructed in all the aspects of the experiment and asked to sign a consent form. The aim of the form was to acknowledge their understanding of the study and to allow the researchers to video record the sessions. The sessions were entirely conducted with physiotherapists to avoid any harm. Furthermore, a researcher was partially observant of the experiment to ensure a good functionality of the system. All the parties involved had the right to stop the experiment at any time. Their names and personal data were utilised only for the purpose of research.

3.4 Test Procedure, Data Gathering and Treatment

To test how a virtual reality training system (VRTS) influences the patient-therapist interaction compared to conventional training within a stroke rehabilitation program, a qualitative research method was applied. The experiment was conducted at NeuroRehab, Grindsted, Denmark. The duration of the experiment was four weeks, where the experimental group had 3 weekly interactions with the system of 30 min duration in accordance with National Clinical Guidelines for Rehabilitation [11], while the control group followed their conventional rehabilitation treatment. A semi-structured interview was conducted with each participant from both groups. Additionally, each test session was video recorded to observe the physical and verbal interaction between the patient and the therapist and possible conversations.

The qualitative data was extracted through semi-structured interviews and video recordings of interviews and test sessions. The semi-structured interview consists of five questions as follows:

1. How important is the role of the therapist in your rehabilitation process?
2. If the system was plug-and-play, how would you feel if you would have to use it by yourself without your therapist?
3. Do you trust your therapist with providing you the right guidance for your rehabilitation process?
4. Is your therapist motivating you through the process of rehabilitation?
5. Is the VR system changing the interaction between you and your therapist?

The questions were adapted for each group and the therapists; however, the meaning of the questions was identical for each participant. The questions were translated into Danish (the participants' native language), and the interviews were also conducted in Danish. All of the interviews were video recorded and transcribed and the transcriptions were translated into English, read and categorised in different themes such as: physical aid, verbal guidance and patient confusion, and the themes were compared between groups. The video recordings were utilised to support the results from the semi-structured interviews, hence, each session was transcribed and translated into English, and patterns were established and compared between groups.

4 Results

This section will present the results obtained from the test following the procedure presented in Sect. 3.4.

4.1 Semi-structured Interviews

The primary findings from the semi-structured interviews of the therapist and patients are presented in Table 3.

Table 3. The primary findings of the semi-structured interviews.

Question	Therapists' answers
1	*Therapist without VR experience:* the therapist role is paramount, it is us who have the knowledge and works with it every day, so I think it is important to guide and give good advices
2	*Therapist with VR experience:* For the patients who it fits and where there is motivation, I can see VR as a great tool. You can train specific goals as a patient to which is motivating
3	*Therapist without VR experience:* Yes, the patients trust me. I know it is not always realistic but then you have to find a middle ground
4	*Therapist with VR experience:* I think motivation is an important part, and to give the right feedback to the patient. It is very motivating when they use the HMD
5	*Therapist with VR experience:* Yes, it is changing the interaction with the patient, a bit; he is disappearing into another world. However, this is also the challenge; how much should you aid and guide the patient and how little *Therapist without VR experience:* Yes, it does, it has done that in this case. We have come to know him better and he has come to know us, and we know how much we can push him
Question	Patients' answers
1	*PV:* It cannot be described, the therapists are crucial; if I did not have them, then I would be lost. They came to me with the solution of moving to another rehabilitation center, but I said no way! I want to stay here until I am at the level where I can go home. Not before. And they accepted that
2	*F:* In the morning after the coffee, I sat down with one of the occupational therapist balls and practiced a bit, and then I went over and did knee flexion. So, I could absolutely use it without my therapist; I do not just sit and watch TV
3	*PV:* I Completely trust my therapist 100% *JB:* I have to trust my therapist; I do not know better. So, for me it is simple
4	*JB:* I assume that. It requires motivation to deal with some cases. It is often her last push that keeps me going, when we think it is a waste of time
5	*PV:* Not at all. Now it is this thing we concentrate on and then we go on to something else. It is like any other training tool

4.2 Patterns in Patient-Therapist Interaction

Patterns were discovered and labelled according to the themes mentioned above: *Therapist with Prior Knowledge of VR Rehabilitation*

- The therapist physically aids the patients while interacting with the system.
- Aids the placement of the patient's left hand (support hand) to the table in order to use the right hand to control the system.

- Asks the patient to move back in order to get a better sitting position.
- Compliments the patient for his performance.
- Tries to verbally guide and motivate the patients.
- Motivates the patients by explaining he is doing a good job and physically showing with his hands which areas are active under the movements.
- Uses physical aid in order for the patient to understand the in-game grabbing.
- Motivates the patient as he fails to place objects and gets confused.

Therapist without Prior Knowledge of VR Rehabilitation

- Therapist's body interferes with the infrared light from the Leap Motion and moves out of the area of video recording.
- Standing aside and does not provide guidance when patients are confused.
- Uses no physical aid and only observes the patient.
- Stands far away from the patient.
- Following the patient but not commenting on the patient's performance.
- Sits down next to the patient and motivates the patient while the system is restarting and the HMD is taken off the patient.

5 Discussion

This section discusses the presented results in order to draw a conclusion of the study.

Interference with Hardware. There is a clear difference in the way the therapists interact with their patient while they have the HMD on. The therapists with experience in VR rehabilitation sit next to their patient in order to aid the patient, e.g., as it was observed under the test of PV, while the less experienced have a tendency to stand or sit with some distance to the patient. This can be due to their limited knowledge of the VRTS, as they do not know how much they can aid the patient without interfering with the system. E.g., this was observed under the second test of B, where the therapist interferes with the Leap Motion, and as a result, moves further away from the patient, where she stands for most of the testing period. In contrast, the therapist with more experience shows no fear of interfering and aids the patient and moves his hand out of frame when it starts to be tracked instead of the patients. All the therapists answered under the semi-structured interview that they did not feel any influence of the VRTS on the interaction with the patients, even though contrary facts have been observed. It can be argued that the therapists are not aware of their changed behaviour with patients utilising the VRTS compared to conventional rehabilitation.

Patient Confusion. Patient confusion can be seen under all preliminary tests as the patients are new to the system. B uses the first test session to learn how to manipulate the in-game objects with the Leap Motion, as the grabbing need to be controlled and precise. E.g., when the therapist asks her to grab an object the answer is that the patient is too afraid to grab it. This fear and confusion diminished over the following weeks while B is interacting with the system. One of the patients, JB, a 74 years old with a stroke in his cerebellum, had difficulties in understanding how to interact with the system and grabbing using the Leap Motion. JB decided to quit the experiment after the first week of training, as he felt “defeated”. He could not understand why the in-game objects could fall out of his hand when the Leap Motion stopped tracking or when he did not look at the hand. Furthermore, he could not understand cognitively where different objects had to be placed, even with verbal guidance and physical aid from the therapist. A male patient, PV, who had the lowest score in the pre-test, also experience intensive struggling while using the system. He pushed objects without grasping the hand, as he did not have any tactile feedback and therefore could not understand when to grasp. An experienced therapist, who was supervising his testing sessions, verbally guided and physically aided the patient without any response. Therefore, the therapist used a physical box in order to simulate the grasping of the in-game object which aided the patient in completing the task.

Physical Aid. Again, the therapists can be divided into two groups: with and without VR rehabilitation experience. The therapists with VR rehabilitation experience aided the patients while testing, they manipulated with the patients’ paraplegic arm in order for the patients to either use it as support or to manipulate the in-game objects. The therapist who was supervising the first test of patient B used his own hand as a weight to hold the patients left hand on the table. The reason of the therapist actions was to support a good sitting position of the patient, when he was using right hand to manipulate the VE. The same therapist was accompanying PV in his test session, where he again used physical aid to assist the patient. PV was using his left hand for playing while the therapist was supporting the patients back, as PV had the tendency to push his body to the left side, due to neglect. The less experienced therapists did not utilise physical aid, as they were not in range of the patient and did not react when the patient needed aid. It was observed that the patients assisted by less experienced therapists learned the mechanics of the game faster than the patients with more experienced therapists. This is in correlation with the discovery made by Lettinga et al. physical aid can minimise the patients’ ability to learn from their mistakes.

Physical Guidance. Physical guidance is hard to achieve as the patient is using a HMD, and therefore cannot see the therapist’s body and hands. This results in a higher degree of verbal guidance from the experienced therapist and acts as a barrier for the therapist with less experience. The therapist who assisted PV in his test sessions used physical guidance after the HMD were taken off. Therefore, the patient received physical guidance regarding his position and the way of grabbing for the following session.

Verbal Guidance. All the therapists with VR rehabilitation experience intensively utilised verbal guidance, and assisted the patients under the entire testing sessions, whereas the therapists with less experience used no form of or little verbal guidance. This could be a result of their lack of knowledge of the in-game tasks or their fear of interfering with the system. The patients who received verbal guidance performed more proper movements compared to the one who did not. Consequently, those without verbal guidance performed improper movements while trying to reach the objects faster in any way possible, as no therapist prevented it. This can be especially seen in the test of PV and first test of B, where the therapist guides the patient in every move to readjust their sitting position when it is incorrect. Under the semi-structured interviews, all the patients expressed gratitude and trust towards the therapists and their guidance, and the therapists expressed trust in the patients to follow their guidance.

Motivation. Therapists with no VR experience did not motivate the patients while using the VRTS. However, they sustained in the interview that they used motivation in the rehabilitation and training of each patient. Again, this can be a result of their lack of experience with VR rehabilitation and fear of interfering, or insufficient introduction to the VRK. The more experienced therapists (e.g., JB's therapist) used motivation to convince the patient to participate in more sessions. Furthermore, the therapist supervising PV asked the patient to place a few more objects and complimented his performance in order to encourage him to continuing playing.

6 Conclusion

The purpose of this paper was to evaluate the difference in the interaction methods between patients and therapists when utilising a VRK compared to conventional rehabilitation. The testing sessions indicated a clear difference between the therapists and their way of interacting with the patients. The therapists with experience in VR rehabilitation approached the patients as in a conventional training session utilising verbal and physical guidance, including hand gestures and commands. Furthermore, they physically aided the patients throughout the test by supporting the paraplegic hand and arm [3], and motivated the patients by giving compliments, establishing a closer therapist-patient bond. Whereas, the therapists with less VR rehabilitation experience demonstrated a lack of therapist-patient interaction, as they did not use any of their regular methods to interact with the patients. Consequently, the system could be a barrier between patient and therapist, because of the fear of interfering with the system or a lack of training in VR rehabilitation. Therefore, it can be concluded that a VRK affects the interaction between patient and therapist. However, proper training in VR rehabilitation can eliminate many of the barriers so the VRK can be used as any other tool in rehabilitation without any influence on the interaction.

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