Analysis of Motivation in Virtual Reality Stroke Rehabilitation

Paula Epure and Michael B. Holte(✉)

Department of Architecture, Design and Media Technology,
Aalborg University Esbjerg, Niels Bohrs Vej 8, 6700 Esbjerg, Denmark
pepure12@student.aau.dk, mbh@create.aau.dk

Abstract. This paper investigates the post-stroke adult population and their motivation to use virtual reality rehabilitation in the rehabilitation process. The study was conducted on 10 patients, part of a rehabilitation program at NeuroRehab, Sydvestjysk Sygehus, Grindsted, Denmark. The sample of patients was divided into a control group and an experimental group, where the experimental group practiced additionally 30 min of training using a virtual reality rehabilitation system. The system consists of: a head mounted display – Oculus Rift, a motion sensor controller – Leap Motion, a desktop computer and a custom built task simulator game. To study the patients' motivation, a questionnaire based on the Intrinsic Motivation Inventory, play performance measurements, and video recordings were utilised. It is concluded that the patients who utilised the virtual rehabilitation system indicated slightly increased motivation compared to the control group.

Keywords: Motivation · Stroke · Virtual reality rehabilitation

1 Introduction

Stroke has been declared the leading cause of disability and death around the world. The majority of the surviving population experience chronic motor deficits and reduced quality of life [1]. To generate neuro-plastic change and functional motor recovery of patients' impairments, extensive amounts of practice are required, as neurophysiological data shows [2]. However, previous data indicates that patients generally perform a rather limited number of repetitive movements in conventional therapy, which is problematic for the recovery process [3]. Moreover, the efficiency of conventional rehabilitation is limited by a considerable amount of factors such as: logistical, financial, environmental and individual barriers [4]. Consequently, extensive research is focused on improving the conventional rehabilitation. A novel direction towards optimisation is the use of Virtual Reality (VR). VR can be described as a human-computer interface which invokes real-time simulations of a certain activity or environment, enabling user interaction through multiple sensory modalities [5]. VR therapy can offer a range of advantages: complete control over the stimuli (including consistency and variation of complexity), reliable records of patients' performance, a safe learning environment, individualised treatment, and increased motivation by introducing "gaming" in the rehabilitation process [6].

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The aim of this study is to explore the patients' motivation in utilising VR as part of their rehabilitation process, and thereby verify the hypothesis: *the post-stroke adult population indicates superior motivation when utilising VR therapies as part of their rehabilitation program.* To verify the hypothesis an explanatory sequential design method is utilised, in which game scores, questionnaire results and video recordings are gathered for an experimental group and a control group. The experimental group utilised a VR system consisting of: a motion sensor, a head mounted display (HMD), a computer desktop and a custom built VR task simulator game.

2 Background

This section presents a summary of conventional rehabilitation describing the consequences of stroke and the common treatment applied. Subsequently, VR therapy is introduced and its possible improvements for conventional rehabilitation. Lastly, the notion of motivation is described from therapists' perspective, as well as the gaming perspective.

2.1 Conventional Rehabilitation

Generally, the post-stroke population experiences deficits which may lead to persistent or permanent functional limitations, involving paralysis, abnormal control of movements, loss of coordination, loss of range of motion, abnormal posture, spasticity, memory deficits, spatial neglect, aphasia, dyspraxia and more. These impairments are an impediment towards performing activities of daily living (ADLs: eating, dressing, waling, etc.) and Instrumental ADLs (IADLs: cooking, laundering, shopping, etc.). Hence, the post-stroke population has no capacity for living independently and being self-sufficient. On a physical level, the motor impairment following stroke starts with complete paralysis in one side of the body, usually the opposite side of the brain where the stroke occurred (hemiplegia). Subsequently, severe physical weakness is experienced in the same side as hemiplegia (hemiparesis) [1]. Motor impairment is experienced by 55% to 75% of stroke sufferers and is usually associated with reduced quality of life [2]. These patients need to re-learn basic movements in order to regain their independence. While recovery is possible, most patients will remain with permanent limitations and impairments [3].

Conventional clinical practice for stroke rehabilitation depends on clinical studies and evidence from basic science of the high potential for brain remodelling as a result of neuroplasticity after neurological injury [2, 4]. Neuroplasticity or neural plasticity represents the mechanism utilised by the brain to encode experiences and learn new behaviours. Moreover, it is also the mechanism utilised for re-learning lost behaviour in the case of a damaged brain. For neuroplasticity to occur the training has to be challenging, repetitive, task-specific, motivating, salient and intensive [4]. Currently, the resources available through conventional rehabilitation are not able to fulfil the requirements for enhancing post-injury neuroplasticity. The limitations of standard rehabilitation are: time-consuming, labour and resource intensive, dependent on patient compliance, limited geographical availability, modest and delayed effects in some patients, initially underappreciated benefits by stroke survivors, and it requires cost/insurance coverage after the initial phase of treatment. Although, through conventional rehabilitation patients can benefit of partial recovery, neuroplasticity should be more stimulated. Therefore, research is conducted to indicate the possibility of introducing Virtual Reality in conventional therapy [5].

2.2 Virtual Reality Therapy

Virtual Reality can be defined as a computer-based technology which enhance user interaction with a multisensory stimulated environment and provides real-time feedback on user performance. Currently, most of the VR systems are primarily audio-visual experiences utilising either a computer screen or a HMD to immerse the user in a virtual environment. Additional sound information is provided through speakers or headphones. Furthermore, advanced VR systems are using haptic feedback technology, which has the advantage of stimulating the sense of touch by applying forces, vibrations or motions as tactile information. VR has been introduced in various fields (military training, architecture, sports, art, medicine, etc.). For stroke rehabilitation, VR has the possibility of applying relevant concepts such as: high repetition, high intensity, and task-oriented training of the paretic side [5]. The benefits that VR can offer for stroke rehabilitation are extensive: specificity and adaptability to each patient and disease, ability to provide patient engagement, tele-rehabilitation and remote date-access, precise assessment and safety [6]. However, for this study the focus is on repetition and motivation.

As previously stated, repetition is crucial for neuroplasticity to occur, therefore patient compliance and motivation has a highly important role in the rehabilitation process. A functional outcome of the therapy depends primordially on active cooperation of the patient. Motivation can be increased by applying a serious game format to the training sessions [6]. The benefits of increased motivation are not only towards a more active participation but also towards longer and more lasting training sessions. Therefore, greater physically and cognitively recovery can be achieved if specialists will acknowledge and implement more motivational factors in the rehabilitation process [7]. However, currently, only a few prototype systems for this population exist, and the games are rather simplistic and often neglected in terms of effectiveness and suitability for the rehabilitation process.

2.3 Motivation

There is a common belief, among specialists in rehabilitation, that motivation of patients has a determinant role in the outcome of rehabilitation. However, the understanding of the term *motivation* varies from one physiotherapist to another [8]. Rehabilitation literature indicates no consensus regarding the nature and determinants of motivation, as specialists often disagree over the meaning of “motivation”. There is a common belief that motivated patients have higher performances in rehabilitation exercises, and are expected to recover faster and more successfully compared to unmotivated patients. Specialists in rehabilitation are constantly aware of patients’ motivation and try to improve it based on personal beliefs [9]. Maclean et al. [9]

conducted a study in which they interviewed 32 professionals regarding patients' motivation. When listing the determinants factors of the rehabilitation outcome, all the professionals mentioned the term motivation, even though the interviewer never introduced the topic. The results of the experiment indicated different factors that affect motivation: personality traits, clinical factors (age, stroke severity, cognitive function and depression), family, culture, rehabilitation environment, and therapists' behaviour. The results exposed that there are three major techniques to improve patients' motivation: setting relevant rehabilitation goals, providing information about rehabilitation, and accessing and using the patient's cultural norm [9].

Ryan et al. [10] investigated motivation for computer game-play and its effects on well-being by applying the Self-Determination Theory (SDT) developed by Lanyi et al. [11]. They hypothesised that the reason behind increased motivation in gaming is that players experience autonomy, competence and relatedness while playing. Consequently, a satisfactory experience causes motivation to play, while a frustrating experience results in a deficit in persistence. SDT focuses on factors that are facilitating or undermining motivation, both extrinsic and intrinsic. According to SDT, the core type of motivation for play and sports is the intrinsic motivation. This is applicable for when playing games also, as, like sport, players do not acquire extra-game rewards or approval – most players play to be involved in gaming activities and sometimes they face disapproval. Therefore, the motivation to play games is intrinsically satisfying because players are seeking "fun". Hence, this paper focuses on intrinsic motivation.

There are several factors that can support or undermine motivation such as: autonomy, competence, presence and intuitive controls [10]. Autonomy relates to willingness or a sense of volition when performing a task. Autonomy in games can be enhanced by: provision for choice, use of rewards as informational feedback and non-controlling instructions. Competence refers to a need for challenge and experiencing efficiency. Factors that enhance competence are: opportunities to acquire new skills, optimal level of challenge, and receiving positive feedback. Perceived competence is one of the most important satisfactory factors in games, as it enhances the players' experience of feeling accomplished and in control [12]. Another factor to be considered in game motivation is presence, which refers to the experience that one is within the game world. Presence is widely associated with the concept of flow [13] which is an intrinsic motivation theory. To enhance presence, game designers attempt (s) to create a realistic and authentic VE with a focus on compelling storylines and graphic environments. Lastly, another variable of interest is intuitive controls which can determine the level of players' satisfaction. Intuitive controls are defined as game controls that are easily understandable and do not interfere with the sense of presence [12]. Based on this theory, there is a need to apply the same motivational factor for rehabilitation game as they are in entertaining games.

Although motivation has been discussed in several studies in the field of virtual reality for rehabilitation, there is a need to measure it and acknowledge its importance within the field.

3 Methods

This section presents the target group and ethical consideration involved in the experiment conducted. Next, the system development and functionality is explained. Lastly, the data gathering and treatment methods are introduced.

3.1 Target Group and Ethical Considerations

The experiment was conducted at NeuroRehab Centre, Sydvestjysk Sygehus, Grindsted, Denmark on a sample of 10 test subjects. The sample was formed by three women and seven men with a recently stroke occurrence (no longer than 2 months). The test subjects were split in two groups: a control group where no extra treatment was applied, and an experimental group utilising a VR system for 30 min.

For a balanced randomisation of the two groups, a pre-test was applied. Each test subject performed a Box and Block [14] test for motor skills evaluation purpose. To gain validity and replicability of the experiment, different factors were considered when allocating the patients, such as: pre-test score of the Box and Block test, stroke location, gender and age. The patient information can be seen in Table 1.

Table 1. 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

Due to the medical sensitivity of the study, vigorous ethical considerations were discussed and applied regarding: informed consent, deception, debriefing, confidentiality and protection from physical and psychological harm. The therapists and the patients were fully informed about the experiment and asked to sign a consent form. The test subjects agreed to be video recorded, accepting that the recordings will only be used for research purpose. All the patients were supervised by their therapist during the experiment to avoid any physical and/or psychological harm. The patients had the right to quit the experiment at any time, and their names and personal data remained confidential (only their initials are used as reference).

3.2 System Development and Functionality

The proposed system constitutes: a hand-tracking device (Leap Motion) motion sensitive to different movements and gestures, a HMD (Oculus Rift) simulating the Virtual Environment (VE), a desktop computer (PC) and a custom build task simulator game – Virtual Reality Kitchen (VRK). The tracking device is placed on the headset for higher accuracy and realism. The positional tracking camera for the headset is placed approximately 70 cm in front of the patient at a height of 130 cm. The room used for the experiment contained solely artificial light for a more accurate functionality of the tracking device and camera.

VRK is a task simulator game that replicates training exercises from Activity of Daily Living (ADL), which are conventionally applied in rehabilitating stroke patients. VRK is a PC-game, controlled with Leap Motion using the headset as a display. The game has been designed to replicate tasks for upper extremities and trunk rehabilitation with a focus on: reaching, grabbing, leaning, pinching and grasping.

The VRK contains two tasks: *coffee making* and *grocery sorting*, and a *calibration scene*. The coffee making scene implies eight actions such as: *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*. A maximum amount of 60 points is rewarded for completion, in which 10 points are given as time bonus if completed in less than 3 min. The grocery sorting scene implies sorting and placing of 17 items in one of three possible locations: freezer in the left side, fridge in the right side and four shelves on the wall in front of the patient. Each correctly placed item is awarded with 10 points, consequently a maximum amount of 170 points. The maximum achievable total score including the 10 point bonus is 180 points. The calibration scene is specifically designed to define an individual's playing space based on the patients' abilities. To ensure an appropriate level of difficulty for the tasks, all the possible interactions are occurring in the calibrated space. The requirements for calibration are reaching as far as possible to the left side, right side, and top.

The VE is replicating a fully furnished kitchen with custom created objects designed in Blender (a free source 3D modelling software). The system was developed in Unreal Engine 4 (a suite of tools utilised for design and game development). This software was chosen for its important feature – the Blue Print – a visual scripting system utilised for quick design and development. The language used for the scripts is C++.

3.3 Test Procedure and Data Gathering

For this study an explanatory sequential design method is utilised. The experiment was conducted at NeuroRehab, Sydvestjysk Sygehus, Grindsted, Denmark, over period of four weeks. The experimental group had 3 weekly interactions with the system of 30 min duration in addition to their conventional rehabilitation in accordance with National Clinical Guidelines for Rehabilitation [7]. For each test session, in-game scores were registered and video were recorded for each patient in the experimental group, while the control group followed their conventional rehabilitation treatment. To measure the patients' motivation, a questionnaire was applied at the end of the last test session for both the control and the experimental group. Consequently, the data gathered consisted of quantitative data: in-game scores and questionnaire answers (Likets scale), and qualitative data: video recordings.

The analysis of the in-game scores and the motivational indicators of the questionnaire will indicate if there is a correlation between motivation and performance. The applied 7-point Likert scale questionnaire consists of 16 items adopted from the Intrinsic Motivation Inventory – a multidimensional measurement tool for assessing participants' subjective experience regarding a certain activity in laboratory experiments [15]. The questionnaire's scale is used to assess participants' *interest/enjoyment, perceived competence, effort/importance, pressure/tension* and *value/usefulness*. These five sub-scale represented different factors influencing motivation. The items were selected, adapted and translated to Danish (the native language of the participants). The wording of the items is identical except the activity. However, there is a difference between questionnaires based on which group it was applied to. The experimental group has phrases such as "playing" and "using system", while the control group has phrases such as "physical training" and "exercising". For grading the items a colour scheme was designed with seven circles coloured from red to green, where red signifies 1 point, yellow: 4 points, and green: 7 points. The points signify: 1: not true at all, 4:

Table 2. Results of the motivation questionnaire.

IMI	Control group patients					Experimental group patients				
Item	P	L	S	PO	R	PV	J	M	F	B
Q1	6	6	–	6	–	3	–	7	6	6
Q2	7	2	–	6	–	7	–	6	7	7
Q3	6	7	–	7	–	7	–	6	7	7
Q4	6	5	–	6	–	5	–	7	6	7
Q5	7	7	–	7	–	5	–	6	7	7
Q6	6	6	–	3	–	6	–	7	5	7
Q7	4	7	–	6	–	4	–	6	6	7
Q8	7	6	–	7	–	6	–	6	7	7
Q9	5	2	–	6	–	4	–	6	5	7
Q10	6	4	–	6	–	4	–	7	7	7
Q11	7	6	–	7	–	5	–	6	7	7
Q12	2	6	–	6	–	7	–	6	6	7
Q13	7	7	–	7	–	4	–	6	6	7
Q14	7	7	–	7	–	6	–	4	7	7
Q15	5	7	–	7	–	7	–	6	5	7
Q16	5	5	–	6	–	4	–	7	7	7
Total	93	90	–	100	–	84	–	99	101	111
Mean	5.8	5.6	–	6.2	–	5.2	–	6.1	6.3	6.9
Mean	5.8					6.1				

somewhat true, and 7: very true. The purpose of the colour scheme is to simplify the grading by offering additional visual cues, as the participants suffer of cognitive impairment. Finally, video recordings were analysed and partially transcribed with focus on actions and speech that are relevant for the concept of motivation. To this end, the patients' reactions and attitude towards the system were analysed based on motivational factors used in questionnaire.

4 Results

This section presents the results from the Intrinsic Motivation Inventory questionnaire applied to both groups (Table 2), the results from the in-game scores showing the patients performance in the experimental group (Table 3), and extracted themes from the video analysis (Table 4).

Table 3. In-game scores for the experimental group.

Patient	Week	Day	Score 1st scene	Score 2nd scene	Total score	Mean SD
PV	1	1	10	10	20	
PV	2	1	10	20	30	45
PV	2	2	10	50	60	23.8
PV	3	1	10	60	70	
M	1	1	60	170	230	
M	1	2	60	160	220	
M	2	1	60	150	210	223,3
M	2	2	60	160	220	8.16
M	2	3	60	170	230	
M	3	1	60	170	230	
F	1	1	50	140	190	
F	1	2	50	140	190	
F	2	1	50	160	210	205
F	2	2	60	160	220	12.24
F	2	3	50	160	210	
F	3	1	60	150	210	
B	1	1	50	170	230	
B	1	2	60	120	180	
B	2	1	60	170	230	220
B	2	2	60	170	230	22.36
B	2	3	60	170	230	

Table 4. Observations from video recordings.

Patient	Overall reactions - motivational factors				
	Enjoyment	Competence	Effort	Tension	Importance
PV	Negative, frustrated	Not perceived, defeated	Very high	Very high	Useless, very low
M	Positive, joy, fun	Not mentioned	Very high	High	High
F	Positive, joy, fun	Average perceived	High	Medium	Medium
B	Positive, excitement, happiness	Highly perceived	High	Medium	Very high

5 Discussion

This section discusses the results by comparing questionnaire results and in-game scores in-between patients.

The highest obtainable average score for the questionnaire is 7, as it is based on a 7-point Likert scale. The highest average score registered is 6.9 by B in the experimental group. However, the lowest average obtained by PV 5.2 is also in the experimental group. A total average score was calculated and it indicates that the experimental group score (6.1) is slightly superior to the control group score (5.8). Hence, it can be assumed that the motivation of patients from the experimental group was slightly higher compared to the control group. However, during the experiment three patients decided to stop participating in the experiment: two from the control group were discharged faster than expected, and one from the experimental group quitted because his condition was too poor to exercise with the VRK.

Maclean et al. [9] suggest that relevant rehabilitation goals, providing information regarding rehabilitation and using the patient's cultural norm were primordial factors for increasing motivation. The VRK succeeded to deliver relevant rehabilitation, as the tasks were following ADL training exercises. However, the VRK did not provide information regarding rehabilitation which might have led to decreased motivation. The patient's cultural norm is a factor included in VRK, as all the objects and the environment were designed to appeal the elderly Danish population. Patient B reacted positively to the environment, sustaining that she could easily identify all the objects, which were familiar to her. This might have influenced her attitude towards the VRK, as she truly believed the game was suitable for her. On contrary, the video recordings show that one of the patients, PV, could not identify any of the objects present in the VE, due to his cognitive impairments. This might have influence his decision to quit the experiment.

Ryan et al. [10] sustain that to increase motivation in gaming players should experience autonomy, competence and relatedness while playing. In the VRK competence was achieved by implementing the calibration scene which allowed the players to establish an appropriate level of difficulty for their tasks. Therefore, each time they calibrated the game they could observe the improvement by comparing the dimension of the playing space. Because the differences were sometimes low and hard to observe, some of the therapist were always discussing and comparing their movement range. Autonomy was also implemented in the system through the usage of the HMD Oculus Rift, which allows the user to visually separate from the real world. Even though the therapists were supervising the test sessions and the patients were not alone, wearing the HMD gave the patients a sense of independence. E.g., after patient F finished playing the game in one of the test session, he reported that he "came back from the virtual world". This indicates a sense of presence that he experienced and it correlated with the flow theory [12]. The relatedness of the tasks for the patients is debatable. Although the tasks were extracted from the ADL model utilised for conventional rehabilitation, some of the patients felt more related than others. During the experiment some of the men stated that they were not particular interested in kitchen activities. PV who chose to quit the experiment, sustained that he could not recognise nor relate to the environment at all. Moreover, he could not see the purpose of the VR training, as he was not familiar with the tasks or objects in the VE. However, the only woman from the experimental group, B, felt highly related to the environment. It can be assumed that the tasks and the VE were genre related. However, they were adapted based on ADL, and are conventionally part of a rehabilitation program.

According to Ryan et al. [10], a satisfactory experience increases motivation to play, while frustration results in decreased persistence. This can be seen in Table 3, as PV obtained a very low in-game score, which led to lowering his persistence from one test session to another, thus quitting the experiment. As a result, he had the lowest score registered for the questionnaire with an average of 5.2. Although considering that the highest possible achievable score is 7, and that his experience was rather negative, the obtained score is relatively high. On contrary, the patients who obtained the highest scores were motivated to continue playing as many times as possible. Both M and F tested the system six times (Table 3). M achieved the highest in-game scores and the lowest SD, although he scored average (6.1) in the questionnaire on motivation. This might be due to the fact that M was not able to communicate enough during the testing sessions. Besides the feedback received from in-game scores, the patients received verbal and sometimes physical feedback from their therapists. For M the lack of responsiveness caused by his condition might have influenced his overall perception of the system.

Based on the video recordings it was discovered that the patients had an overall positive reaction to the VRK and experienced excitement during the test sessions. However, B had an outstanding reaction by being constantly highly immersed in the game. She was laughing continuously and cursing when the system was not reacting as she wanted to. On contrary, M was very quiet during his interactions with the system. It was observed that M was highly immersed in the game and aspired to gain the maximum score every time. F verbalised his reactions, however, his immersion and motivation were perceived to be lower compared to B and M. Contrary, PV experienced negative reactions towards the game. In general, the encountered differences in how the patients perceived the system correlate well with the findings of Maclean et al. [9]: personality traits, clinical factors (age, stroke severity, cognitive function and depression), family, culture, rehabilitation environment, and therapists' behaviour.

6 Conclusion

The hypothesis of this study: *the post-stroke adult population indicates superior motivation when utilising VR therapies as part of their rehabilitation program*, proved to be true. Based on the discussion above it can be concluded that the patients in the experimental group presented slightly higher motivation when utilising VRK, as part of their rehabilitation process in comparison to the control group. Furthermore, the three factors from the STD: autonomy, competence and relatedness were important in determining the level of motivation of patients. However, other factors, such as: personality traits, clinical factors, family, culture, rehabilitation environment and therapists' behaviour seem to be factors of influence.

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