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Short Report

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Research of the effectiveness of virtual environments in post-stroke rehabilitation

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Abstract. In the 21st century, with the usage of multimedia devices several areas are widening where, on the basis of distance learning and e-learning, special activities can be performed. The after-care of stroke patients was studied in a home-environment-based therapy system, through the StrokeBack1 framework. In our study we examined to what extent can the immersion and VE technologies be used as rehabilitation devices for stroke patients. We also examined — with the help of clinical and control groups — that to which extent is the virtual therapy expected to be applicable on a long term with the addition of multimedia devices. In addition, we examined the acceptance, willingness, and cooperation skills of the test subjects.

Keywords. Virtual environment; e-learning; stroke rehabilitation; efficiency measurement

Introduction

Within 'StrokeBack', which is a newly started project partly funded by the EU, the goal is to improve the speed and quality of stroke recovery (Ortmann, Langendörfer, Sik Lányi, 2012), by the development of a telemedicine system which supports ambulant rehabilitation at home settings for stroke patients with minimal human intervention.

Changes in clinical practice cause that most patients are discharged from hospital within a very short time, so the research and development mostly concentrate on home-based rehabilitation. This approach has various advantages; for example new skills are automatically transferred into daily life, improving motivation and morale. In addition, home-based therapy is less expensive, more motivating and, – because of the familiar environment – more comfortable too.

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¹ University of Pannonia, Faculty of Information Technology Department of Electrical Engineering and Information Systems Virtual realities and imaging technologies laboratory The researcher and developer team at the University of Pannonia's role in the 'StrokeBack' project is to create games which can be used during the home rehabilitation process by the patients, or replacing clinical rehabilitation and speeding up the process of recovery.

State-of-the-art

Every year more than 700,000 people suffer stroke in the United States, making it the third most common cause of death, especially for elderly peo-

¹ StrokeBack Project – http://www.strokeback.eu

ple per year. According to the World Health Organization's data 15 million people suffer stroke worldwide in a year. Although survival rate is improving, 5 million die and another 5 million remain permanently disabled yearly. Our societies are facing a growing number of people aged 75 and above, many of whom will experience impairment or disability, due to stroke. This older population will rise from 7.5% of the European population in 2003 to 14.4% in 2040, i.e., almost doubles. Effective rehabilitation is critical to reduce the burden of disability not only on the individuals and their families, but also on society.

Many applications have been developed all over the world for stroke rehabilitation (Sik Lányi, 2006). One of the most interesting of these researches is the VividGroup's Gesture Xtreme System (Kizony, Katz, Weingarden, Weiss, 2002; Kizony, Katz, Weiss, 2004). It's a unique approach to VR, which might have important applications for the rehabilitation of children and adults with physical and/or cognitive impairment.

Telemedically controlled systems, using low-cost, web-based audiovisual telemedicine units have been tested as well (Broeren, Georgsson, Rydmark, Stibrant Sunnerhagen, 2002). Connor et al. in San Francisco used a haptic guided, error-free learning unit with an active force feedback joystick and computer for rehabilitation of cognitive impairments caused by stroke (Connor, Wing, Humphreys, Bracewell, Harvey, 2002).

The project called "Virtual Reality for Brain Injury Rehabilitation", developed at Lund University in Sweden, investigated usability issues of VR technology for people with brain injury; examined the issue of transfer and training; developed different applications of VR for training in daily tasks, such as kitchen work, using an automatic teller machine, finding one's way in a complex environment, using virtual vending and automatic service machines (Davies, Löfgren, Wallergård, Lindén, Boschian, Minör, Sonesson, Johansson, 2002; Wallergård, Cepciansky, Lindén, Davies, Boschian, Minör, Sonesson, Johansson, 2002).

In 2006 Lövquist and Dreifaldt presented an application based on an immersive workbench and a haptic device, designed to motivate stroke patients in their rehabilitation of their arm. The patients see this as a complement to the rehabilitation techniques used today and it gives them alternative exercises that are encouraging, challenging and fun to help them ease their recovery (Lövquist, Dreifaldt, 2006).

Questionnaires and focus group interviews were led in Sweden. The researchers addressed the question of usefulness of virtual reality based rehabilitation equipment in practical therapy, by letting experienced therapists explore one such equipment for six months in their regular practice under natural circumstances. The conclusion was that such equipment has benefits beyond real life training, that variation in content and difficulty levels is a key quality for wide suitability and that the combination of challenging cognitive activities, which encourage motor training, was considered particularly useful (Pareto, Broeren, Goude, Rydmark, 2008).

According to Burke, the VR games were indeed usable and playable by people with stroke. Further, the games seemed to stimulate a high level of interest and enjoyment by the participants (Burke, McNeill, Charles, Morrow, Crosbie, McDonough, 2010).

Older people and new technologies are principal research and development areas (Emiliani, Stephanidis, 2005). Improving the quality of life for elderly people is an emerging issue within our information society. Most of the stroke patients are in the older generations – their physical and emotional needs must be supported. (Holzinger, Ziefle, Röcker, 2010).

The recovery of the voluntary motor control is improved by many repetitions of functional exercises including fine finger and whole arm movements. By using serious games, patients are

more motivated and willing to do more exercises. Moreover, these games mean not only recovery of sensory motor control, but improvement in logic and thinking abilities.

VR based games

Rehabilitation of stroke patients aided with games has a reason for existence.

In the StrokeBack project games are single player games, which the patient can play by himself/herself. After installing and setting up the software, the patient can use it alone; the therapist won't need to assist. This can be very convenient, because the user can play at any time, and won't need to wait for the appointment with the therapist. It is expected that the patients will play more with the games, than they would do exercises.

Five games are under alpha testing: Wordy Labyrinth, Memory, Labyrinth, Word Puzzle and Free Kick. Out of the other two games, Break the Bricks, is already under beta-tests (Dömők, Szűcs, László, Sik Lányi, 2012). These games are not only aiming movement rehabilitation, but they can also improve mental condition with their easy logical puzzles.

Navigation in the games, controlling with events

The patient can navigate in the games' menu and start a selected game with dedicated hand movements, which are not used in the games. During the games, the patient can control the gameplay with specific rehabilitation exercises. The game is shown on the screen, and the icons for "pause", "help" and "quit the game" are shown on the interaction board. The patient can also stop the game with a dedicated stop movement.

The validations of the moves are very important, not only because it is harmful to learn a wrong movement. This is why not only the simple movement event is handled, but the features of the movements are connected to the different, predefined events.

This way the therapists can define sets of rehabilitation exercises which can be used and which fit for each game, so one game can be controlled with more different training movements. This is very good, because there is no need to make a new game for every exercise, and one exercise can be practiced with more games too, to make the patient more motivated and satisfied.

From another point of view, with these universal events, the therapist can set up the games to the patients capabilities. Because the real movement and the movement event is separated if the patient has lower range of motion, the movement tracking and validating device could be set up to a "lower level", which evaluate more inaccurate movements as "good" ones.

Feedback

The foundation of a good gameplay is the player feedback. When the players' input is matched with a response — whether it tells the player that they have hit or missed, failed or succeeded, or come close or far — the player remains involved in the exchange. The player is left disillusioned and uninterested if no feedback is given. This is why the feedback is crucial to any game. The satisfying player feedback can turn even the smallest success in a game feel fulfilling, and can even keep players excited about something out of their control.

Feedback in the games can be provided in many forms. It is mainly connected to performance of the player and the accuracy of the rehabilitation exercise.

Performance feedback

A simple but informative feedback for the player is the reached score in the game. In our games, the score, the player achieved on a level is calculated from the time of completing the level, from the rate of accurate and inaccurate movements (determined by the "good" and "bad" markings in

the movement events) and from specific parameters that each game has (for example in the Labyrinth the number the player hits a wall can be a parameter).

Another important feedback is the amount of time the player needed to finish a level. This is principally not important because of the speed, but because the patient needs to play at least for 5-7 minutes to practice a given exercise efficiently. If the player finishes a level too fast, then a harder level or a game with longer levels is needed for effective therapy.

It is important to mention, that these scores will not only be shown to the patient, but they are stored in the database of the game and sent to the therapist as a feedback about the patient's performance.

Measuring the efficiency

The developer games are the most efficient if the patient enters into the spirit of the game. On the basis of the level of immersion the application gives different game experiences to the patients. The efficiency of the therapy — its expected efficiency based on indirect measurements — can be predicted. For this can the games' user test be used, during which we examined — with volunteer stroke patients and therapists in clinical environment — that on which level could the users acquire the usage of the games. We also surveyed, with questionnaires, that on which extent did the game experience remain, and in what measure did the players find the games, serving a very serious rehabilitation method, a 'playful' one.

Testing

The tests have been carried out in two stages.

The first tests were carried out with a volunteer control group aged between 18-65, who were healthy and had no previous (professional) computer skills in this specific field. This group consisted of 35 persons. The first clinical test was carried out in the rehabilitation centre of Brandenburg Klinik. During the clinical test the games were tested by stroke patients older than 18. This group consisted of 10 persons, who were all stroke patients. Men were between 40 and 67 years old, women between 35 and 36 years old. The average age of men is 52 years, and the women's 35.5 years. The average age in the whole group was 48 years. The results of the two test series (the results of the tests for 'healthy' test subjects, and the results of tests for stroke patients) were compared after evaluation. Based on the answers we investigated whether the usage of the games were manageable and useable. The test subjects were asked about their subjective feelings of the games, and in the end of the tests, the test subjects were asked to form their own opinions concerning the games.

According to the answers on the questionnaire these developer games are applicable in the rehabilitation. On the basis of answers, concerning the usability and the difficulty of acquiring the games' usage, we found out that the usage does not serve any difficulties. 70% of the patients who filled the questionnaire have answered the questions. Among them, according to total calculation and averages 57,14% thought the usage of the game was easy, on a scale from 1 to 5 they classified them on the most positive 5th category ; 28.57% classified them in the 4th category; and 14.28% classified them in the 3rd, medium category.

The level of immersion determined whether the patients could show a better time in the completion of the games after fulfilling the levels from time-to-time repetition; whether they could beguile a longer time in the game, and rate the game less tedious. According to their freely expressed opinions, they were waiting the next difficulty levels of the games, they were curious about the next hardenings of the game levels; so the game experience, the feelings of competition and challenge fully remained, only one feedback contained such objection, which referred to the specific disease as an interfering factor of playing the games. These responses indicate, that the

computer game remains a computer game for the patient, where the primary goal is the physical rehabilitation, but during the testing they became the devices of relaxation for the patients.

This sequential exchange indirectly shows that the players — if they really enter to the spirit of the formed environment of the developer game — they will more efficiently use the game as a therapeutic tool. Based on the feedbacks the level of adoption exceeds our expectations. This is prior because if a new technology, no matter how efficient or focused it is, its usage will not show any results, if the target group cannot accommodate the new technology.

Conclusion

This paper described a number of games designed for the stroke rehabilitation. The main focus is on user interface and relevance feedback in the games, which were tested and with the help of them the efficiency and the level of immersion were measured. The games are adoptable for other type of rehabilitation processes. The clinical tests proved that the games are useful and user friendly rehabilitation tools. The growing level of presence in the time of gaming increased the patients' activity, and it was a good foundation for using these serious games as a specific rehabilitation tool.

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