Games for Physical Rehabilitation

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ABSTRACT

Games can be used to motivate people, who need to perform repetitive exercises as part of physical rehabilitation. People with stroke, cerebral palsy and muscle atrophy have limited motor movements. Different research papers suggest different gaming systems that can be used for therapy, which not only motivates these patients but also improves the effectiveness of therapy. The games discussed in this report are virtual reality based games and gesture based games. The virtual reality based games use Nintendo Wii remotes to track movements whereas gesture based games use Kinect or other image processing systems to track movements.

The main challenges faced while replacing traditional occupational therapy with game therapy are to do with design of the system. The system needs to ensure it meets the patient needs, abilities and rehabilitation requirements. These challenges can be minimised by customizing the games to incorporate user specific exercises advised in the therapy. There were also other challenges involved in evaluation of case studies performed. These were minimised by using a wide range of evaluation techniques that assess both quantitative and qualitative data. The gaming systems were used in the case studies and the results showed a significant difference between occupational therapy and game therapy. However, further research needs to done to replace the traditional therapy with the new game rehabilitation techniques.

INTRODUCTION

Stroke is considered the leading cause of physical impairments of five million people in the United States and 250,000 people in the United Kingdom [1][2]. In addition, there are many people living with motor disabilities such as cerebral palsy and muscle atrophy, who are unable to perform daily basic tasks [3]. Stroke and wrist injuries cause limitation in the range of wrist movements and can only be improved by rehabilitation exercises that target at flexion and extension motions [4]. However, stroke patients are receiving very little therapy due to the economic pressure on the health care system [5]. Virtual reality presents multidimensional environments to users that enable a feel of real events [6]. Although doctors suggest that limitations experienced by these people due to their disability can be minimised by repetitive exercises, studies shows that only 31% of these people perform exercises as recommended [3]. This can be due to inadequate therapy sessions at clinic and lack of motivation at home. To solve this problem, games had been designed to help physical therapy and studies were conducted to analyse the outcome of usage of these games. This report discusses in detail about the challenges faced while using gaming therapy, the approaches used to minimise these challenges, the methods implemented evaluate gaming therapy and the results obtained. It also mentions the future work that will be performed to further improve gaming systems.

CHALLENGES

The following are the challenges faced in the research papers. They are mainly to do with the design of the gaming system and studies conducted on participants. The challenges faced in terms of design described below are meeting patient needs and requirements (including system affordability) and rehabilitation standards to facilitate improvements. The challenges with studies are sample size, study duration and sample variation.

Design

The design should not only focus on the patients' needs but also on the rehabilitation needs. According to [1], there were initial studies that focused on enabling game-based therapy through custom devices but these devices are difficult to use in home environment or school settings. The users are quite different to the traditional game players as they would interact with gaming world with limited motion. Another limitation of these was that they detected motion only in one direction. This is not much useful as stroke results in decreased flexion and extension of wrist [4]. Furthermore, the user needed to have sufficient movement in their arms to be able to start using the device, which defeats the purpose of improving the restricted movements through games.

The available devices also lack haptic (touch) feedback and ability to use multiple players [6]. It is important to enable a safe environment while aiming at the patients' requirements and personal abilities [2]. According to [3], sensors used in motion based games can cause discomfort and lead to force feedback. The colours of the markers used in vision based games may be too close to skin or clothing colour and as a result can cause conflicts [2]. [1] realised that the standard motion assessments using virtual reality games may not fully capture the patient improvements. Rather than precise motion related measurements, they analyse overall measurements such as energy expenditure and task classification.

In addition, the input devices used in many studies are expensive or custom-made, which makes them harder for home-based use [1]. It is out of reach for people with motor

disabilities to afford those high cost devices as they may be unemployed. According to [6], virtual reality systems designed for rehabilitation purpose are not commercially available. Stroke patients are not receiving sufficient therapy due to economic pressures on health care system [5].

Studies

According to [1], the limitation in their study is focusing on a single participant. Stroke survivors are very diverse with different backgrounds and disability levels. The study did not address speech, language, or memory disabilities caused by stroke. For the pilot studies conduction in [gesture-vision], there was no significant observed difference between traditional physical therapy and gesture therapy. The reasons for this were size of the group was small, sensitivity of scales used for data analysis was not high enough and scales were not designed to evaluate motivation.

[1] chose a participant who was seventeen years post stroke. As research suggests that most motor recovery occurs in the early stages, this was not an appropriate choice. The studies conducted in [1], [2], [3] and [5] did not last very long. Duration of a study plays a major role as the time provided may not be sufficient for significant improvements a patient can achieve. However, there is always a question on whether longer study periods improve motor functionality.

APPROACHES

The following are the approaches used to minimize the challenges faced. Different papers use different approaches to deal with the challenges. The approaches vary depending on the gaming systems being used and target users.

Design

According to [1], the approach used to enable home based therapy is to design systems by addressing target users appropriately. And to address the challenges mentioned earlier, it is important to observe the usage of these gaming systems by therapists and patients at clinic and home. This enables us to develop an understanding of the needs of home based users and this can be achieved by conducting studies. [4] talks about using a two directional game that specifically concentrates on flexion and extension motions. This game would engage the users in a variety of games by helping them improve a range of wrist movements.

[6] addresses the challenges by using commercially available virtual reality gaming system, Nintendo Wii. This is system enables rehabilitation using its motion sensors to measure user's motions and maps them into virtual reality. Its remote can be easily held by the user. The system uses haptic feedback to help the user. [2] addresses the challenges by PC-based low cost webcams that offer an affordable therapy. It uses image processing algorithms for motion detection and creating game like tasks for home rehabilitation. It uses colour markers to avoid any discomfort or inconvenience to the patient. [3] uses Kinect based system for physical therapy in a school setting avoiding gaming controller. [1] enables assessments by watching the game log replays to analyse repetitions performed. It takes in participant feedback for noticed improvements rather than relying on the game log data.

[2] and [3] address the problem of affordability by using gesture based gaming systems, which are affordable and commercially available. They use standard PC and webcam or Microsoft Kinect based system. [4] approaches the challenges by building a cost effective, portable system that can provide feedback to therapist and also facilitate multiple users. [5] minimises the therapy expenses by developing a technology that allows the patients to exercise and improve motor movements on their own without regular monitoring of therapist.

Studies

[1] minimised the challenge of not being able to notice significant difference between traditional therapy and game therapy by using various measures to analyse the data. It has analysed both qualitative and quantitative measures. The quantitative data was collected using game logs. Range of motion, motion precision, and motion smoothness was measured using these logs. For qualitative analysis, participant was interviewed to gather information about acquired abilities and newly discovered abilities.

[6] approached studies related challenges by using therapists to assess the improvements in the motor movements so that differences can be easily detected and compared. The standard assessments procedures used helped in determining differences better than gaming data.

METHODOLOGIES AND FINDINGS

[1] conducted a six week study using a 62 year old female who is seventeen years post stroke. She was in the hospital for three months after her stroke and doctors told her that she may not improve further in the future. Before the study, she had limited movement in her arm and she rested her elbow on her body. The gaming system was developed so that the participant could play games at home independently on her own and therapist could monitor the process. Information was collected from the participant about her likes and dislikes to customise the motion based video game. The participant played Helicopter, Pong, and Baseball Catch. These games were selected by the occupational therapist because the movements required to play them are equivalent to the exercises the participant is supposed to perform. The therapist also adjusted the suitable difficulty level and speed of the games.

The participant was provided with two Wii remotes, a Web camera and a laptop with preloaded game software. The Wii remotes were used to measure the arm tilt and they were attached to her body using arm straps. The participant was trained to use the system at home without anyone's

help. The participant played games for 75 minutes a day. The participant attended weekly meeting, where the weekly data was collected and she was interviewed. The game settings were modified based on the assessments by therapist. The participant also underwent motion assessed sessions, which are standard therapy sessions. These sessions were conducted at the beginning, in the middle and towards the end of the study.

Over the six week period, the participant reported that the ability to use her affected arm has improved. The quantitative data from the game logs supports the qualitative improvements collected from interviews. After the study the participant had a larger rotation range on the shoulder. She was able to complete few tasks that she could not at the beginning of the study. There was a gradual increase in the range of motion.

[3] conducted a study with two participants, Peter, age 17 and Sherry, age 16 who were diagnosed with cerebral palsy and muscle atrophy respectively. They both have insufficient muscle endurance. This study tested the Kinect based rehabilitation system (Kinerehab) at a special education school. Kinect was connected to notebook computer preinstalled with rehabilitation software. Audio and video feedback was used to encourage students to engage in rehabilitation.

The study was divided into two phases with two sessions a day. The baseline phase is a standard therapy phase with no assistive technology. Rehabilitation program content was instructed to the participants and was performed on the wheel chair. It was repeated several times depending on the participant's suitability. Performance inaccuracies were not interfered the number of correct movements was manually counted. The Kinerehab system was used in the intervention phase. Both the participants performed exercises by sitting on the wheel chair six feet away from Kinect module. The cues on the screen were used to complete programs. There was no interference of the therapist for performance inaccuracies and the program was repeated thrice. Kinerehab uses gesture recognition to count the number of correct movements.

The difference in the number of movements in the baseline and intervention phases in both the participants was observed to be significant. The movements in the intervention phase were higher than the baseline movements. The participants were highly motivated and interested in the system. They were willing to use it after the experiment and suggested allowing multiple users to participate in the rehabilitation simultaneously.

[6] conducted a 4 week study on a 13 year old attending a summer program at a developmental disabilities school. The patient had poor motor planning, poor ability to complete tasks and poor ability to stay focussed. He was chosen because he had hand skills to manage Wii remotes. The gaming movements can be done in both sitting and standing positions. The games were selected based on patient interest and therapeutic goals. A therapist was always guarding behind to ensure participant stability. All games promoted upper proximity control.

The patient participated in 11 sessions. The duration, repetition and difficulty of games were selected based on his ability and observation of performance. Over the 4 weeks period, he moved from single player games to 2- and 3-player games. The postural control of the patient improved and mobility increased. The weight distribution became more symmetrical. The patient has significantly improved after training with the gaming system.

[5] talks about two pilot studies conducted with gesture therapy in Mexico City. In the first study, a stroke patient interacted with gesture therapy. The patient attended 6 sessions of 20 to 45 minutes each. The system promoted stretching, relaxation, flexion and extension of wrist and fingers contraction. The difficulty of the exercises was increased with increase in the number of sessions. After 6 sessions, patient showed an improvement in flexion, extension and relaxation. The patient also increased the use of affected arm.

The second pilot study was a comparative study consisting of 11 patients divided into two groups. 5 patients received gesture therapy and 6 received traditional occupational therapy. The functionality of the affected arm was evaluation before and after the study for both the groups. Both the groups showed significant improvements after the study. Although the group that used gesture therapy were motivated to perform the exercises more than the other group, the difference in motor functionality between the groups was not particularly significant.

CONCLUSION

Research shows that affected limbs of people with motor disabilities can show improvement with repetitive exercises. People with stroke, cerebral palsy and muscle atrophy are known to improve movements in their affected limbs if they receive proper occupational therapy and perform all the exercises as advised. However, many people discontinue therapy due to lack of motivation and insufficient therapy sessions. This report discussed how this problem can be addressed by using virtual based and gesture based games to increase motivation among patients. The report also discussed about the problems involved in using game therapy, the approaches that can be used to minimise the problems. It further discusses the implementation methods and outcomes of using gaming systems by describing case studies. Although, the studies carried out show a positive outcome, further research needs to be conducted with a large number of diverse individuals to rely on games for physical therapy.

FUTURE WORK

The future work of [1] involves designing the system to enable independent therapy so that the therapists' burden is minimised. Independent therapy sessions will benefit people without therapy access. Also, future work should involve letting the user set their own goals and ideas, which facilitates communication between therapists and patients. Better feedback systems should be developed so they can be guide in designing games that address personal situations. Furthermore, feedback systems should focus on presenting an overall picture of improvement to the participant by focussing on the positives aspects to encourage motivation. Improve game therapeutic motions to allow full motion range and incorporate games that use every day movements.

[2] wants to improve the colours of markers it uses as they create conflicts if the colours are too close skin and clothing. Future works for vision based systems involve improving the robustness of the system by evaluating varying lighting conditions. Further improvements would be the usage of two webcams to facilitate three dimensional tracking. [3] wants to conduct studies using a wide range of participants to further evaluate the system and results. [5] wants to create a home based system that provides remote interaction with therapist and medical team for future work. It also wants to extend the system for full arm tracking to obtain more accurate movement measurement. It wants to increase the range of therapy solutions.

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