

Games for Stroke rehabilitation

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ABSTRACT

Strokes are a leading cause of death and disability and have been described as a “worldwide epidemic” [5]. Strokes cause disability, partial paralysis and leave up to 85% of their victims with some form of motor impairment. Stroke rehabilitation starts as soon as possible and involves repetitive movement which people find repetitive and boring. A study [1] has found that as few as 31% of people complete their exercises as recommended. Adding to this the high cost of one on one therapy and transport to see specialists, stroke rehabilitation is a major problem. Games have been trialed for stroke rehabilitation to increase patient motivation and reduce costs. This literature review aims to find out to what extent games have therapeutic value and further, what characteristics make a good game for stroke rehabilitation. We find that in order for a game to be successful it must be based on solid therapeutic principles as well as game design principles including “challenge” and “meaningful feedback”. Different hardware and software can be used as long as it follows game design principles to encourage patients to perform therapeutic exercises. Games must also take into account the low morale of recent stroke victims and avoid discouraging beginners.

Author Keywords

Stroke; Rehabilitation; Video Games; Literature Review; Wii; Patient Motivation;

INTRODUCTION

Strokes are a leading cause of disability, there are thought to be about 6.4 million stroke victims living in the United States alone [1] and it has been described as a worldwide epidemic [5]. Strokes often cause long term damage to motor control including hemiparesis which is impaired motor function on one side of the body. 85% cent of stroke survivors will suffer some form of motor impairment, with up to 75% experiencing on going impairment [1][6]. Many authors [1], [5], [6] have found that the brain is able to rewrite or remodel itself around the damage. This remodeling is bought upon by repeated movements.

Authors divide stroke treatment into two distinct fazes. Most recovery will happen within the first few weeks and

months after a stroke in the sub-acute period [2], [3], [5], [6]. Patients can also make some improvements months or years after the stroke [2] [3] [5]. Some studies however [4], [6] focused on sub-acute rehabilitation. Most studies however, have focused on the chronic period because it is easier to acquire participants [2], [3]. It is also thought that video games can motivate patients to perform their on-going exercises [1], [2], [3], [5].

Therapy involves making repeated movements with the affected limbs, hundreds of times a day. Patients often complain that the movements are boring and that they get tired of them [1], [3]. A study [1] has found that as few as 31% of people complete their exercises as recommended. It is thought that by using concepts from video games, we can engage patients and motivate them to complete their treatments [1], [3], [5].

Traditional treatment for strokes involves intensive one-on-one therapy with an occupational therapist [2], [5]. Patients require a therapist because they are often unable or not motivated enough to complete the correct exercises alone. This is a costly approach as specialist time is valuable. The cost of stroke rehabilitation is increasing; Harley has found that American stroke rehabilitation costs have increased by 20% over the last two years [3].

In order to complete their therapy, patients must frequently travel to see a specialist. Several studies [2], [6] find that transportation of chronic patients to special rehabilitation centers is a significant cost. This cost and time spent travelling can dissuade some long term patients from completing all of their therapy sessions. Burke suggests that Games could reduce the cost of travel by allowing patients to complete their exercises from home with specialist visits [2].

Literature discusses ways to make video games effective for stroke rehabilitation. Two important factors are identified which determine whether a game will be suitable for treatment of stroke victims in either faze of rehabilitation. The two factors are; promoting movements which provide therapeutic value, and, motivating the patient to perform these therapeutic activities [1], [2], [3], [5]. To further elaborate these points, Harley recommends that it is essential that video games are based on proven rehabilitation principles [3]. Alankus recommends that Games balance the two goals of meeting user’s motivational needs and providing effective rehabilitation [1]. This review will discuss the ways in which previous studies have approached these two critical goals and what

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benefits appropriate video games can provide in stroke rehabilitation.

The Hypothesis of this literature review is that video games can be beneficial for stroke rehabilitation. In a large review of studies using virtual reality for stroke treatment, Laver found that virtual reality therapy is beneficial [5]. The review found statistically significant improvements for arm movement and activities of daily living when compared with conventional therapy [5]. Further to this, we will explore what makes a game more successful at motivating the patient than previous approaches.

Providing Therapeutic Value

The authors discuss three main points relative to developing games which provide therapeutic value. First, games must be designed with occupational therapy principals in mind, thus, games must encourage movements which provide therapeutic value to the users [2]. Second, Games must be able to measure the patient's movements correctly and determine whether the correct movements are being completed [3], [4]. This ensures that only therapeutic movements are being rewarded [2] and allows therapists to monitor progress [4]. Thirdly, Authors [2], [3], [4] noted that stroke victims have varying range of impairment resulting from stroke as well as skill level, thus it is important that games be customized to meet the individual patients therapeutic needs. This section will discuss ways in which studies have achieved these three important requirements.

In order to help with rehabilitation, the game must encourage the user to exercise the effected limb in a way that will strengthen the brains control over that limb [2], [3]. Burke mentions that some commercial games may already have some therapeutic merit for stroke rehabilitation because of the fact that they encourage limb movement at all [2]. Furthermore rehabilitation can be improved by paying close attention to the movements which will be encouraged. Laver's study concludes that existing approaches to using video games and virtual reality do provide therapeutic value when compared to conventional therapy [5].

Several authors [2], [1], [3], [4] discussed the importance of using proven rehabilitation techniques in the video games that they used. Some authors [3], [2] Worked directly with an occupation therapist to design the games. Alankus' study also played videos of the movements recommended by an occupational therapist before commencing the game [1]. This lead to the participant being increasingly conscious of why they are playing the game and reduced an incentive to cheat or succeed in the game without performing the therapeutic movements [1]. Adomovitch noted that it is particularly important to make accurate measurements of the patient's movement to ensure that the patient's movements do in fact have therapeutic value. [4]

As Adomovitch noted, it is essential that video games use hardware which is capable of rewarding only therapeutic movements [4]. Two general approaches were recognized in the literature. The first approach is to use customized or specialist equipment such as VR helmets, video capture with markers and CyberGlove. This approach was explored by several authors [2], [4], [3]. The second approach which was explored in this study was to repurpose commercial hardware such as the Xbox connect, or the Wii mote [1], [2], [6].

Exploring the specialized hardware approach, Burke discussed the use of video capture with a marker to track the users movement, movement is typically measured in only one plane so measuring some therapeutic movements can be difficult with this approach [2]. For hand rehabilitation, Adomovitch' study used a CyberGlove, the CyberGlove provides very accurate measurement of the user's finger movements and was highly suitable for stroke victims with affected hands. Some drawbacks are that the CyberGlove is quite expensive cannot provide haptic feedback [4]. As Harley found, a drawback of specialized equipment is that it is expensive and may require expert supervision [3].

The second approach is to use off the shelf solutions such as webcams and gaming consoles. Burke discussed using gaming consoles such as Wii and Xbox Connect as a platform; advantages the study identified include cost and easy setup without requiring an expert [2]. Several authors [1], [2], [3] speculate about a system which could truly be used at home with no supervision based on the Wii. Harley and Alankus [1], [3] used the Wii mote strapped to the arm of a patient for arm rehabilitation. Harley found that the Wii was able to ensure that movements closely matched rehabilitation exercises and thus ensured that the game was beneficial [3]. Taking the idea of using the Wii further, Saposnik completed a blinded clinical trial using the Wii as a gaming platform. The study found that the Wii slightly outperformed recreational therapy in a short term trial [6]. Saposnik cautioned however, that because the Wii only tracks the controller's movements, it may be possible to cheat and succeed at the game using trunk or body movements with little therapeutic value. The authors suggest more sensors or supervision as possible solutions [6]. This is a drawback which current off the shelf solutions suffer from, they may not be able to measure therapeutic movements with the same accuracy [1], [6].

Stroke victims suffer from a wide range and severity of symptoms; therefore, it is important to customize games to the individual patient [4]. Several authors [2], [3], [4] developed games which could be customized for each individual patient. Burke created user profiles which could be calibrated once for each patient and then be used to match the patient's skill level as the patient progresses [2]. Alankus' study elaborated further, proposing that the ability for the patient to modify video games themselves may give

them a feeling of control and encourage goal setting in their rehabilitation [1]. Individual patient's requirements can even make standardized games unusable; Harley noted that many stroke victims cannot grasp the Wii mote as originally intended and instead used an arm strap to mount the Wii mote [3].

Another key advantage of games identified by authors [1], [2], [3], [4], [6] was the ability for a patient or therapist to track the patient's progress automatically as time progressed. Several groups software [2], [3] allowed the results to be uploaded to the internet for an occupational therapist to review. Adomovitch also experimented with telerehabilitation (remote viewing and coaching of the patient by an occupational therapist) by allowing therapists to view a model of the patient's movements and provide feedback in real time. Adomovitch concluded that telerehabilitation is beneficial for motivation in some but not all cases [6]. Some authors [1], [6] also experimented with allowing users to see their own progress. Alankus found that their participants motivation came at first from the game and then from seeing her own real world progress [1].

Factors in Patient Motivation

The second important challenge in making a game for stroke rehabilitation is encouraging patients to play it. Two important goals must be achieved; Firstly, the game must be easily accessible to beginners, easy accessibility was identified as important by several authors [1] [2] [3]. Secondly, The Game must be fun to play and encourage long term participation and motivation [2], [3]. Burke Identified the two factors which a game must possess in order to motivate patients to keep playing, they are "meaningful play" and "challenge" [2]. These requirements of a game will be further elaborated.

"Meaningful play" means that the user feels that their actions in the game have meaningful consequences. Burkes study expressed that meaningful play can be achieved by giving the player meaningful feedback, they experimented with reward systems such as high scores or increased powers [2]. Other authors [3], [4] have also commented on the importance of feedback. It is believed that feedback can be separated into two categories; short term immediate feedback and long term feedback or progress.

Short term feedback can take many forms including knocking over pins, earning points or scoring a goal [1], [3]. Harley Agrees that providing feedback is important, this study used special effects similar to a pinball game to provide rich and engaging short term feedback when the user knocked over pegs [3]. Adomovitch also noted the importance of rich visual feedback in his non game VR rehabilitation application. Although he was not focused on making the simulation fun, he found that players were much more engaged because of the rich feedback which their

actions generated. Burke found aural feedback to be especially engaging when running the study.

The second category of feedback which should be provided to support meaningful play is long term feedback. Long term feedback can include high scores, level progression or a multitude of long term goals which can be set and accomplished by the participant [3]. By providing meaningful feedback over the long term, the authors [1], [3] noted that we can encourage repeated play and progress. Alankus also found that their participant persistently requested increased feedback from the games. Their participant wished that the game would "make me feel good" by making progress more visible [1]

By providing meaningful play we allow a player to engage with the game, It is the aspect of challenge which motivates the user to continue coming back to play again. A challenging game is one which is achievable but not too easy, it has been found to motivate users [2]. Several authors [1],[2],[3], [4] note the importance of balancing challenge in video games; too much and players will be frustrated, too little and they will be bored. Authors handled balancing challenge in different ways; Harleys game, Peggle, involves knocking over pegs to set high scores, it is based on chance at first but then as the user progresses, more and more skill is required to do beat high scores, similar to the game pin ball [3]. Burke created a game which automatically gets harder as the user does better in order to maintain a challenging game. While most participants enjoyed the challenge being set correctly, burke cautions that increasing challenge without first giving meaningful rewards can frustrate the user [2]. Thus successful video games for stroke rehabilitation should combine challenge with meaningful play.

While it is important that a game be challenging, it is also important that a game be easily accessible to beginners. Harley and burke [2][3] identified that a game must be easily enjoyable for beginner stroke survivors who often have low motivation as they find themselves unable to do what they once could. While it is important that the game is easily understandable for beginners, Alankus' study found that games themed on pre stroke activities which are no longer possible can damage motivation. Their participant disliked pong because it reminded her of table tennis which she can no longer enjoy because of her stroke [1]

Various methods of balancing easy accessibility for beginners and challenge for intermediate players were used. Burke [2] used user profiles to ensure that challenge was set appropriately for each user. Harley ensured that the game has an element of chance so that beginners could get rewarding feedback without necessarily playing skillfully [3]. By taking these steps, new players could adopt the game quickly without feeling discouraged [2], [3].

Summary

We have identified the primary factors and approaches which authors identified as being important for the success of video games in stroke rehabilitation. In a broad sense a successful video game must first have therapeutic value and second be able to acquire and maintain patient motivation. By tackling these two problems, video games can reduce the cost and improve patient outcomes for victims of stroke. We found from Lavers' review [5] that existing approaches have been successful overall compared to traditional therapy.

By basing the game on proven rehabilitation principles, or involving an occupational therapist in the development, authors were able to create games which had therapeutic value. Authors also explored the appropriate hardware for encouraging the correct movements; the Wii was contrasted with specialist hardware such as the CyberGlove. We found that the software must be tailored to meet the individual patient's needs.

The second critical factor was increasing motivation; we explored the three factors which are critical for patient motivation. Meaningful play means giving the player meaningful choices and rewarding feedback, challenge must be kept at an appropriate level to be motivating, and games must be easily accessible to beginners who may be easily discouraged.

By following these methods patient outcomes can be improved, the studies all showed signs of progress beyond what would be expected otherwise. It is important to note that we should not only compare video game therapy with conventional therapy, but also take into account the motivation and costs which can be a very important factor in the real world.

FUTURE WORK

In Laver's review, it was found that there was much variability between the effectiveness of studies [5]. And they were unable to determine which factors contributed most to success. Laver also pointed out that when doing clinical trials, Studies could not be blinded, that is, we cannot rule out the placebo effect because all patients knew that they were receiving video game therapy [5]. While there have been many promising pilot or case studies [1] [2] [3] [4], and large studies on whether or not virtual reality has therapeutic value in clinical settings[5], there have been no large studies on the long term effectiveness of video games for improving patient motivation.

The biggest gaps are in the construction, adoption and commercialization of technology. Video gaming technology

has shown its promise, what now needs to happen is a commercially available or widely distributed video gaming platform. Research which may take us towards this end would include larger scale trials in hospitals, releasing user customizable games for patients to try themselves or further refinement until a commercial quality product is available.

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