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HandCARE4: A Game-Based Rehabilitation System for Patients with Stroke

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Abstract: Stroke is a relatively common acute cerebrovascular disease. It is very harmful to health. Failure to treat it in time may cause paralysis or even death. However, the development of medicine in recent years has been able to help most stroke patients avoid death. But how to solve the movement disorders caused by stroke is still a global problem. At present, regular long-term repetitive exercises can effectively help stroke patients recover their limb function. Because the traditional rehabilitation treatment cycle is too long, and the treatment process is very boring. It leads to there are only about one-third of patients can persist in rehabilitation after discharge [1]. In other words, the vast majority of stroke patients are likely to be accompanied by movement disorders throughout their lives. In this project, we have developed a robotic device for the rehabilitation of hand function for patient with stroke. The system was based on a VR-game rehabilitation method to solve stroke patients' current problems in traditional rehabilitation exercises. The HandCARE-based operating platform can theoretically ensure that the rehabilitation process is effective. This article will focus on the VR-Game part of the project.

Keywords: Rehabilitation; Stroke; VR; Game-based therapy.

1. Introduction

The reason for a stroke is that insufficient blood flow to the brain leads to brain cells' death, leading to a series of severe consequences[2]. Based on current medical conditions, timely and effective treatment can guarantee patients' lives to the greatest extent. But still, there are about 75% of patients will have varying degrees of movement disorders, especially the dysfunction of hand [1]. Traditional intensive and standardised rehabilitation treatment can still help them relieve movement disorders to the greatest extent for these patients. However, this conventional rehabilitation treatment is boring, resulting in only about one-third of patients being able to persist in rehabilitation training after discharge. So even if medicine can save their lives, if they can't continue in rehabilitation exercises, then physical movement disorders or other stroke sequelae will stay with them for life. Based on the current situation, traditional rehabilitation training can help them relieve movement disorders, but how to motivate patients to persist in rehabilitation training is a problem.

Many industry participants are not hyping the concept but want to penetrate these technologies for the past few years. For example, in the medical field, VR/AR technology has been accepted and applied to rehabilitation training, stress relief, and surgery. So the feasibility of VR in the medical field has been confirmed. However, this is an entirely new field, so the results obtained by testing user satisfaction are not ideal, and more in-depth research on supporting systems is needed [3]. In addition, the elderly group accounts for a massive part of stroke patients. However, there is still evidence that the elderly are not less enthusiastic about games than young people, so we want to change traditional rehabilitation training's status quo from the VR games' perspective.

There is a problem in developing a game. That is, at this stage, there are more and more media and channels for people to feel information, and the sensory stimulation that information brings to people is getting stronger. Therefore, it is difficult to arouse the interest of participants through ordinary and simple traditional methods, let alone motivate patients to take some extremely boring rehabilitation training. Therefore, enhancing the sensory experience may be a key to arouse the interest of participants. One of the most valuable aspects of VR/game is It can create a truly immersive experience, allowing participants to enjoy the atmosphere created by VR without the real world.

2. Related work

2.1 Motion Rehab AVE 3D [4]

This is a system used to help patients with mild strokes in rehabilitation. The game developed by Unity is built into the system, and the Kinect motion sensor is used to monitor the patient's motion information in real time. The user can control the game character to make corresponding activities through the sensor. In terms of user interface, the system supports VR devices such as Oculus Rift. It can monitor the six activities of people in three-dimensional space in real time, including flexion, abduction, shoulder adduction, horizontal shoulder adduction and abduction, elbow/wrist extension, knee/ hip flexion and abduction [4]. That is to say, the user is using

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the device for rehabilitation exercise At the time, the system can obtain their sports information. The purpose of this project is to help patients relieve several key movement disorders of the limbs. HandCARE is to help patients ease hand movements.

Although the focus is different, there are still many lessons to be learned. For example, in the test of this project, they quantitatively analysed the user's activity level and the angle of limb extension. This helps them to make adjustments for different patients. We also have corresponding settings in HandCARE. The strength of each finger is divided into ten levels, which can be adjusted according to the needs of users. But these must be adjusted through quantitative analysis with the project.

2.2 A VR-based user interface for the upper limb rehabilitation [5]

This project's principle is similar to Motion Rehab AVE 3D, but it is to enhance the patient's experience in the upper limb rehabilitation process. The system is basing on the Unity engine and Kinect. Using the developed interface can improve the patient's rehabilitation ability through playing games. The most attractive place for this project is that they use ergonomic analysis and QFD methods to analyse patients' needs. The rate of human error can be reduced through these two analysis methods, and safety and comfort can be enhanced. And during the test, the project team paid attention to the interaction between rehabilitation exercises and patients. And for this, an independent test interface is designed to determine the patient's injury level in the process of using the device for rehabilitation exercise. Based on the test results, the difficulty of the game is adjusted appropriately to meet the needs of different patients. This is what the HandCARE project currently needs. We need to explore a complete set of test methods to help us obtain other patients' parameters. Because the human hand is a very delicate system, it is different from the limbs. The human palm has more than 15 different joints [6]. And the wrist joint is also composed of three main joints. Therefore, it is not easy to obtain the palm parameters of other users quantitatively. Thus, the measurement methods mentioned in this document will help us build our test system to prevent users from being hurt in the process of using this equipment.

3. Rsearch Methods

HandCARE is in collaboration with Imperial College (UK). But in a sense, HandCARE3 is a device from ten years ago, it cannot meet the current target requirements-relieve the tedious process of rehabilitation training, so we decided to develop a new generation of HandCARE4 based on HandCARE3. We will try to combine rehabilitation training and large-scale video games on this platform, not limited to simple jigsaw puzzles or other simple games because this kind of game cannot motivate patients to exercise continuously, and it is easy to feel tired and bored. So the first task is to improve the user experience, which includes a new immersive experience and a highly customised video game.

3.1 Interface Part

The game part of this project is based on the Unity game engine. This game engine provides a complete set of software solutions that can be used to create 2D and 3D content and support most platforms on the market, including mobile phones, tablets, pc, and AR And VR equipment. Supporting multiple VR platforms is an important reason why we chose Unity as a game development engine. In this way, potential users can purchase different equipment according to their economic situation. Second, creating a game with essential visual elements from an empty scene is difficult for non-game developers. Fortunately, in 2018, Unity released the 3D game development kit. Using a game kit to create games does not require deep learning programming language. This massive toolset put together by Unity staff. It is easier for artists and non-programmers to use the Unity engine to create games. As long as the user has basic programming knowledge and a game design proposal, they don't need to learn the Unity coding ecosystem. In other words, Unity provides us with a customised game toolkit, which can be deeply customised according to the needs of the project. And we have certain permissions to modify the toolkit's content, which perfectly meets our project requirements. Coupled with Unity's support for the VR platform, we can complete almost all visual effects on one platform.

3.2 Game Logic

The entire game is based on a storyline. The protagonist Ellen is forced to land in an unfamiliar environment due to damage to the spacecraft. She needs to complete a series of tasks in this scene and defeat the ultimate enemy. During the game, players need to perform corresponding operations according to the task prompts. There are two types of notification boards. One is the direct notification, which guides the user on how to control the movement of the mission through gestures. The second is indirect prompts, where players will complete tasks based on limited information.

Regarding the interaction between the player and the game, the Game kit provides various presets for users to use. It contains some interactive props. For example, there are some pressure pad triggers and MovingPlatform in the prefab document. We used these props to create simple game logic, such as connecting the pressure pad trigger with the door. When the player triggers the Pressure pad, the door will automatically open. The combination of interactive modules completes the main part of the game experience.

3.3 Game Control

In terms of game operation, we use gestures, which are customised for different hand movement disorders. That is to say, these gestures are designed according to the patient's situation, and the motor's traction force on the finger can also be adjusted so that the patient can make some game operations on the HandCARE platform. Also, this game will support the VR platform, and the game experience that VR brings to players is incomparable to ordinary games. For example, in Steam, SUPERHOT VR is a simple picture, and the model does not have any textures and textures, but because of the game experience, this game also earned developers $260 in a short time [7]. So, through this example, we can see the ability of VR games to catch users' eyes. This gave us a reason to develop a VR game for HandCARE.

3.4 User Study/ UX

Considering that our user group will be mainly elderly people, we have added a series of guides to the game, such as voice prompts and gesture prompts. We used the principle of frame-by-frame animation to add a gesture prompt to the game. Users can intuitively make corresponding operations by viewing the prompts. For example, in the game, the player wants to manipulate the character to

shoot through gestures. At this time, the user needs to use the index finger and thumb. This process completes the operations in the game and helps the user complete finger rehabilitation training. So, it is conceivable that if the game can arouse users' interest, they may unconsciously complete rehabilitation training.

Regarding how to improve the user experience of the boot interface, we used the green keying commonly used in the film industry in the project. In front of the green background, real people take pictures of gesture activities, and then through a series of processing, these pictures are made into frame-by-frame animation and imported into the game. And with simple text messages and voice prompts to help users quickly adapt to the game's operating model.

3.5 UDP protocol

The data transmission part is in charge of my partner Sam. Here I will briefly introduce the reason why we chose UDP from the perspective of user experience. It's easy to access data packet. UDP transmits data faster than TCP and consumes fewer system resources. Although UDP's transmission stability is worse than that of TCP, it is easy to lose packets during data transmission. But for the HandCARE project, the data that needs to be transmitted is extremely limited, so UDP is relatively stable and efficient in the process of transmitting a small amount of data [8]. Users need to use HandCARE to control the game. UDP can effectively reduce the delay of game operations and significantly improve the user experience.

4. Discussion

Many projects related to VR stroke rehabilitation are base on games, but they all overlooked a problem; that is, the user may dislike it. For example, in a project of Shanghai Jiaotong University, users need to operate the game by using rehabilitation equipment [2]. This kind of game looks simple, but rehabilitation treatment requires long-term persistence, so users will quickly feel that the game is boring. So it does not solve the shortcomings of traditional therapy. HandCARE4 is developed on a high-quality video game. Compared with conventional games, it has a beautiful game- environment and exciting interactions. For young people, they may find fun easily. But there is a problem. As mentioned, many times in the article, elderly patients account for the vast majority of stroke patients. Although some theoretical foundations can support that the elderly are not less enthusiastic about games than young people, it is still a risky attempt to build a rehabilitation system basing on the video game. Because of the differences in personalities, the types of games that people like are different, directly affecting their gaming experience. Maybe when users are curious about this game, they can drive them to use HandCARE to control characters to complete tasks and complete their rehabilitation activities. These digital games provide them with content they haven't touched before with a user-friendly interface. [9].

5. Conclusion and Future work

Due to COVID-19, we cannot invite volunteers to conduct small-scale tests at this stage. When conditions permit, I hope to invite some elderly patients to complete a short-term test on our rehabilitation system. HandCARE has a theoretical basis for relieving movement disorders caused by stroke. So the purpose of our test is whether the HandCARE4 game can motivate users to continue playing. In other words, whether the HandCARE4 game can solve the tiresome traditional rehabilitation treatment, this is a question that must be verified. The second important thing is to investigate the acceptance of play-based rehabilitation equipment for elderly stroke patients. I still hope to get these data through my survey and testing to complete this project. Besides, it will take the manpower and time to complete a video game. So, at this stage, the completeness of the game I can provide for this project is far from enough. Therefore, the game can only help me with some functional tests. So in the future, the game will be completed regarding the results of user surveys.

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