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Development of a Virtual Reality Leg-Cycling Training System for Stroke Patients

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Abstract—**People with neurological damage may develop physical impairments such as hemiplegia, and interlimb coordination deficits are common among stroke patients. Leg-cycling exercise is an alternative and symmetrical bilateral leg movement. However, stroke patients are generally reluctant to attend leg-cycling trainings.**

Virtual reality (VR) is a new and promising computer-based technology to promote leg-cycling training among stroke patients. A new force-detect leg-cycling training system which combined with a virtual community environment has been developed by our research team. Two healthy subjects were recruited to attend the preliminary case study. The results showed that the two healthy users could successfully operate the VR leg-cycling training system and control the direction of the virtual car in the virtual environment. In the next stage, patients with interlimb coordination deficits should be recruited in the training courses so as to verify the rehabilitative effect of the VR leg-cycling system.

Keywords— virtual reality, leg-cycling, stroke, rehabilitation

I. Introduction

PATIENS with stroke frequently develop lower-extremity discoordination, which, together with the loss of mobility, are two main symptoms of hemiplegic stroke patients, with approximately 85% of them develop impaired mobility three months after the stroke [1]. Cycling exercise is a common intervention to improve muscle strength and functional mobility of stroke patients since the kinematic patterns of cycling are similar to that of walking. Therefore, stroke patients can work out their affected legs in cycling exercise.

However, subjects with stroke often perform the cycling exercise exclusively by their unaffected legs. In other words, their affected legs are often passively driven by the unaffected ones. In addition, stroke patients are usually reluctant to attend the traditional, monotonous leg-cycling training courses. Therefore, it is necessary to develop new intervention tools to improve lower extremity coordination among stroke patients in a rehabilitation program. Virtual reality (VR) based technologies are one of the novel tools with great potential for rehabilitation application [2-4]. VR involves the use of advanced technologies to produce a simulated (i.e., virtual) environment which is comparable to the real world [5]. VR has also been shown to be a suitable tool for cognitive rehabilitation because it allows a more comprehensive, ecologically valid, and controlled environment [6-7].

The application of VR in leg-cycling training is so far limited. The virtual community environment program has been developed by our research team, along with a new force measurement cycling device to evaluate the force output from both affected and unaffected legs of hemiplegic patients during cycling exercise. Therefore, the purpose of our study is to investigate the applicability of the VR based leg-cycling training.

II. Methods

Two load cells (FAD-100; Transcell Technology, Inc., IL, USA) were mounted on each pedal of the leg-cycling training system to detect the force output from right leg and left leg respectively. The load cells signals were connected to a digital oscilloscope for real-time display, which were digitized at 4 kHz with a computer program constructed in the Labview platform (National Instruments Corp., Austin, TX, USA). A shaft encoder (MES-30-360P; Microtech Laboratory Inc., Kanagawa, Japan) was attached to the shaft of the cycling system to measure the crank angle continuously. Through the shaft encoder, we could receive information concerning the velocity of the cycling system so as to control the speed of the virtual environment. Users should control the direction of the virtual car in the virtual community environment, which has been developed by our research team (Fig. 1). When users generate equal forces to move each pedal, the virtual car goes straight; and when users generate more force in moving the left pedal, the virtual car turns right (Fig.2), and vice versa.

In the preliminary case study, we recruited two healthy subjects to evaluate the usability of VR leg-cycling training system. They had to conduct several tasks, including right- and left-turn trials. The Virtools (Dassault Systèmes; Vélizy-Villacoublay, France) applied in our system can automatically calculate the finish time, deviation frequencies and deviation time of any particular trial. A "deviation" is defined when one side of the virtual car crosses over the boundary of the pathway. The "deviation frequencies" is the total amount of time the virtual car crosses over the pathway boundary and the "deviation time" is the time duration of the virtual car outside the boundary of the pathway.

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Fig. 1. A participant was operating the VR leg-cycling training system.

Fig. 2. The virtual car performed a right-turn.

III. RESULTS

The two healthy subjects could control the direction of the virtual car successfully in the virtual community environment. When the participants moved the pedals on the VR-cycling training system with equal forces, the virtual car went straight in the virtual environment. When more force was added in moving the left pedal, the virtual car turned right. In addition, participants could change their stepping frequency to control the speed of the virtual environment. The performance of each subject is shown in TABLE 1.

TABLE I. THE PERFORMANCE OF THE TWO SUBJECTS

Item	Participant A	Participant B
Finish time (sec)	270	202
deviation frequencies (times)	15	12
Total deviation time (sec)	90	26
Average deviation time (sec/time)	6	3

IV. DISCUSSION AND CONCLUSION

Traditional rehabilitation for stroke patients can improve their mobility and general locomotors function. VR rehabilitation, a novel technology, has been implemented in a wide range of training courses and has been shown to significantly improve motor learning/control processes among neurologically impaired patients. In our study we have developed a VR-cycling training system which can detect the asymmetric force outputs from users. From the preliminary case study, it has been shown that healthy subjects could successfully operate the virtual car of the VR leg-cycling training system. However, to take individual differences into account, future test should involve more subjects. In the next stage, we will recruit people with lower-extremity discoordination to participate in the VR-cycling training. This way we will be able to collect more data on the correlation between the asymmetric force outputs and virtual community environment from this group.

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