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Development of Mirror Therapy Using Non-Immersive Virtual Reality

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Abstract. Mirror therapy (MT) is a method to train upper limb after Stroke or Parkinson incident. The combination of MT with virtual reality (VR) has given more immersion experience into the illusion, while MT needs participant concentration to truly sensate the illusion as real. The purpose of this research is to design and develop first prototype of VR-MT as physical therapy equipment for enhancing motor performance in upper limb after Stroke or Parkinson. Upper limb motion in VR-MT is captured by Microsoft Kinect. We involve five healthy participants as VR-MT tester to execute a therapy task by controlling virtual limb to hit apples or avoid bombs in virtual environment (VE) for 10 minutes. After the treatment of therapy task, participants do simple assessment by answering a questionnaire. The result of statistical analysis of the questionnaire can be concluded that four elements including controllability, natural operation, sense of delay,and spatial difference are important key to control the movement of virtual limb correctly in VR-MT.

Keywords-*virtual limb, missing limb, immersion, operability, concentration, natural operation, sense of delay, spatial difference, Microsoft Kinect*

1. Introduction

Muscular weakness of the upper limb is a main obstacle in stroke or parkinson physical therapy because of limited functional performance [1, 2]. Current stroke or parkinson therapy for treatment of upper limb including bilateral and unilateral movement training [3], robotic movement assistant [4], and constraint induced movement [5] are based on physical activities, whereas these therapy have a restriction use because of severe hemiparesis and lack of sensor deficits. The other problems are costly and requiring a large workforce to apply these therapy in home use [6].

Researchers found that information which collected by motor imagery of brain processing could enhance motor performance after stroke or parkinson incident [7, 8]. This evidence has created an innovation in stroke and parkinson therapy called mirror therapy (MT) by using mirror images of limb to treat phantom limb pain. The treatment of MT uses a simple box allowing a patient with concision to see a reflection of normal limb in the visual plane of the missing limb. A patient sits in front of a mirror placed vertically in the midsagittal plane and feels the sensation as if he can move his affected limb. To get deeper sensation of MT, a patient must concentrate to truly perceive the illusion as real. Tricking brain processing to raise illusion for forcing missing limb to move like a normal limb is a key in MT. Human is easy to catch information in the form of visualization rather than auditory. Virtual reality (VR) offers more complete immersion into the illusion [9]. VR allows patients to see single-handed tasks with the missing limb, whereas it is impossible to apply with a mirror.

[10] uses VR to treat a patient with chronic pain in Okayama University Hospital. Input of this system uses wearable devices including data gloves to measure the movement of fingers for grasping operation and a magnetic sensor to obtain spatial movement of forearm. The forearm on the affected side appears on the virtual environment (VE) and the movement and rotation of the real forearm on the affected side can be precisely reproduced. [11] implements VR-MT to train upper limb for health promotion of patient post-stroke. Virtual limb operation is controlled by combination of camera and OpenCV. Because of length of image processing, the degree of delay is high and less natural operation. In this proposed research, we develop a VR-MT system using non-immersive VE by eliminating the use of wearable devices, limiting sense of delay, and creating natural operation. Microsoft Kinect is used as tools to detect motion capture and hand grasping when interacting with objects in VE. Based on [12, 13], VE is designed to present complex multisensory information to the user in providing entertainment, a safe, and motivating to achieve special purpose. The use of visual and auditory cueing [14, 15] has been applied in our designed VE to positively influence motor function in healthy people and in persons with stroke or parkinson not only in real-world settings.

2. Method

2.1. Research design

This research uses a cross sectional design. Participants who are involved consist of five healthy volunteers. The Hospital Ethics Committee at dr.SoebandiJember approved this work. All participants provided written informed consent prior to participation.

2.2. VR-MT System

The VR-MT system has been developed using a non-immersive VE based on evidence in real-word, computer, monitor, desktop speakers, and Microsoft Kinect as upper limb motion capture.

2.3. Game design

The VR-MT system is created by Unity 5.4 with a first person perspective views as shown in Fig. 1 and 2. To improve perception of self-motion and immersion, the choice of field of view in VE is 80°. The choice of color contrast and texture in VE are selected high to give a striking differences between objects in VE including line, tree, avatar, apples, bombs. The objects in our VE are scaled to real-word proportions to present more immersion. The goal of design process is to create an adequate scenery mirroring view. The choice of avatar is taken from default examples of Microsoft Kinect Unity SDK. Scripts are written in C# to customize and have control over the VE during the trial. The monitor display is placed on a table, whereas Microsoft Kinect is placed on top of monitor display. A participant takes a seat in front of Microsoft Kinect at the distance of 1.5-2 meters from it for capturing upper limb motion.

Figure 1. VR-MT simulation where a participant has pain on left hand.

Figure 2. VR-MT simulation where a participant has pain on right hand.

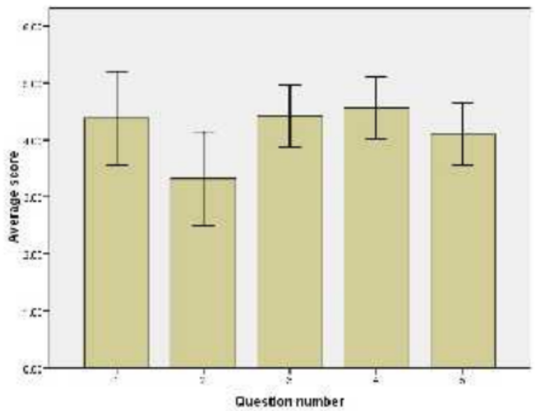

Figure 3. Statistical analysis of questions of the questionnaire

2.4. Participant

The simulation of VR-MT involves five healthy participants (average age 23.8; range 21-26 years). All participants can do right and left handed.

2.5. Data collection and Data analysis

Data are collected from questionnaire to obtain information about controllability, concentration, natural operation, sense of delay, and movement tracking during therapy task. Questionnaire are evaluated by score range 0-5. A high score means greater impact to the VR-MT system. A participant executes of the therapy task using VR-MT for ten minutes to catch apples or avoid bombs using his virtual limb. A participant simply moves his missing limb on the table to control virtual limb movement. After the execution of therapy task, a participant must answer the questionnaire as follows:

- How much could a participant control correctly virtual limb movement as seen on monitor?
- How much could a participant pay attention to monitor as long as executing therapy task?
- How much could a participant take action naturally the virtual limb?
- How much did the delay of movement affect to take action and move a direction of virtual limb as participant intended?
- How much did spatial difference affect to take action of virtual limb?

Analysis of the upper limb motion is evaluated by calculating ratio of hitting apples or avoiding bombs in the whole therapy task using VR-MT.

3. Result

Questionnaire which has been answered by participants after therapy task consist of three variables of VR-MT immersion experiences , namely question number 1, 2, and 3 associate to controllability, user focus or concentration, and natural operation. While question number 4 shows that sense of delay between virtual limb and missing limb and tracking of movement. The last question number 5 want to know whether fluctuation of virtual limb influence to operate during rest the real missing limb. Average score and standard deviation for the question number 1-5 are shown in Figure. 3.

As shown in Figure. 3, average scores for question number 1, 3, 4 and 5 are above 3.0. The statistical result of mean indicates that the development of VR-MT system gives the participants a sense of deep immersion (moving faster or slower, smooth operation, and control) in VE [16, 17] whereas concentration in non-immersive VE needs more attention to focus during therapy task. Result from questionnaire shows that spatial difference between the movement of virtual limb and missing limb are not perceived in which this does not influence when controlling the virtual limb in using developed VR-MT system. Other information can be obtained from questionnaire is that a participant can move virtual limb to a direction as his/her intended. This can lead to restore to the correct forward model related to motor.

A patient with muscular weakness of the upper limb usually has a scare to touch an object by the hand because of pain. To overcome this problem, the development system uses Microsoft Kinect as motion capture controlling virtual hand movement in VE. As a result, the development system does not bring a scare by touching painftul hand (missing limb) with a measurement equipment. Result of the ratio of number of times that caught an apple or avoided a bomb during therapy task for ten minutes is shown in Table 1.

Tabel 1. Evaluating Performance of Virtual Upper Limb of VR-MT in Therapy Task

Participants	Apples	Bombs	Ratio (%)
1	35	2	82.5
2	39	2	92.5
3	33	1	80
4	34	3	77.5
5	36	2	85

As seen in Table 1 shows that the ratio of participants when they use VR-MT to control virtual limb movement to hit apples or avoid bombs is above 77%. This indicates that all participants positively perform therapy task and control the virtual limb well.

4. Conclusion

The developed VR-MT system has been proven to make improvement for muscular weakness of the upper limb for people post-stroke or post-parkinson as a target patient. The developed VR-MT presents more complete immersion into the illusion, whereas it is more better than conventional MT that requires strict focus and concentration to truly perceive the illusion as real. The adoption of Micosoft Kinect can provide non-contacting motion measurement to eliminate a fear by participants when using their painful hand to touch an object. From the statistical analysis result shows that controllability, natural operation, sense of delay, and spatial difference are four important elements for control of virtual limb in VE. Ratio of participants when they perform therapy task and control virtual limb increase over 77%. It indicates that the debeloped VR-MT system is easy for participants to perform therapy task by their self for enhancing motor performance of upper limb after post-stroke or post-parkinson.

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