Man In India, 96 (6) : 1853-1862

DESIGN OF 3D IMMESIVE LEARNING ENVIRONMENT TO ENHANCED HAND SKILL AFTER STROKE

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This paper basically introduces the design of 3D model as user interface which intends to improvise the hand stroke rehabilitation system. A 3D immersive learning environment was developed based on needs analysis for rehabilitating hand function in stroke patients. Those environments developed by using Autodesk 3D MAYA software, Adobe Photoshop, Unity 3D and supported by wireless cyber glove. This new developed system is aimed to improve the functional recovery hand stroke patients by stimulating their cognitive and motor based on Fitts & Postner (1967) theory. The system used cyber glove as input device for user interaction with a virtual environment. The target level is designed in each task to increase patient motivation and individualize exercise difficulty to a patient's current state. The 3D cybertherapy system cosists of multiple environments involves with activities of daily living (ADL) routines. Nine (9) left hemiplegic stroke patients involved in this study. The evaluation showed that each participant had significant improvement in the measured parameter. The system is believed to help in improving the cognitive and hand rehabilitation aspects of hand stroke patients.

Keywords: Hand stroke rehabilitation, 3D model, Virtual Reality Technology

INTRODUCTION

Stroke is a health issue that continues to be discussed as it contributes to the high number of disability and death globally (King *et al.,* 2011). Majority of the victims experienced physical and cognitive capability (Brunner *et al.,* 2014). The cognitive dysfunctions such as memory, attention, language, etc will effect the victims' quality of life. Within the survivor, sixty percent of stroke patients suffer from hand dysfunction (Jia *et al.,* 2007). The hand is the upper body part which always paralyzed among these patients. Obviously, hand plays a various important roles in human daily activities (Park *et al.,* 2011; Connelly *et al.,* 2010). As a result, patients are unobstructed to involve active in their daily routine without others assisting in order to eat, drink, dressing and etc. Thus, the most challenging part is to provide training for re-learning skills of paralyzed hand according to the needs of stroke patients, especially in elderly.

Previous researches show that intensive and repetitive exercises able to enhance the hand function in a shorter period of time (Merians *et al.,* 2006). Due to the short period of patients staying in the ward/hospital and received training in recovering the paralyzed upper limb are very limited, stroke patients should undergo rehabilitation by attending the program which had been set at the outpatient

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rehabilitation centers. However, the study found those patients always reluctant to go to any rehabilitation center (Jack *et al.,* 2001). Consequently the development of a paralyzed limb function to be slow to recover.

Conventional therapy for upper limb recovery is tediously done where a therapist will assist a stroke patient individually during training session. This situation led the training provider to bear with higher costs. Training which being done covers stretching, multiple ranges of hand movement, daily living activities and other training needed by the patient. However the training provided cause patients to feel bored, fatigue, loss of motivation and thus did not achieve what was expected (Tsoupikova *et al,* 2013). Therefore, a variety of research being done now focusing on training strategies to provide therapy that can increase interest and motivation to restores the multi-functional skills of stroke patients' limbs (Fluet & Deutsch, 2013 ; Broeren *et al.*, 2002).

Currently, cybertherapy technology has been increasingly used in stroke rehabilitation, which gives an opportunity for the stroke patients to feel the experience in a cyber-world and can provide training task within consistent. Cybertherapy describes a computer-generated scenario objects (virtual world) that can simulate real life environment. The interaction was designed in three dimensions (3D), comprising of a direct visual, sensory and auditory feedback. The potential benefit of using cybertherapy would be the ability to increase the duration, frequency and intensity of therapy (Turolla *et al.*, 2013). The combinations of 3D computer graphics and specific input devices such as Head Mounted Display (HMD) and sensing gloves allows users immerse in the virtual learning environment. The immersive learning environment gives opportunity to the user an intuitive manipulation of objects in the virtual scenario that mimic the real world. Furthermore, the clinical research provides evidence that cybertherapy can provide more engaging, motivating and adaptable environments than conventional therapy in various cases (Tsoupikova *et al.,* 2013).

Saposnik and others (2010) discussed the importance of virtual reality and game element in therapy and how these are able to provide an environment in which individuals have the opportunity to forget about their surroundings and situation and focus directly on a task in the simulated environment. Several other investigators have developed a hand rehabilitation system, but for the most part they are complex and expensive. The Rutgers Hand Master II has been used in combination with a Cyberglove to improve hand function in patients with stroke (Boian *et al.,* 2002). The system uses a palm-mounted pneumatic pistons integrate to virtual environment to train finger flexion and extension. However, this Finger Trainer was designed to perform passive finger movement only. Thus, the goal of this study was to design and develop the 3D Cybertherapy system (3D CTS) to be used in therapeutic training of hand after stroke in active movement and low cost.

The collaboration of medical professionals and technologies expert plays a major role to define strategies to stimulate the cognitive and improve their functional ability. One of the essential paralysis of the body are the hands (Park *et al.,* 2011; Connelly *et al.,* 2010). As concerned, hand plays an important role in implementing the daily activities of human life, which is used to hold hands, pinching, grasping, throwing, and many other activities. Therefore, without the ability to function well with hand can seriously affect the psychology aspects of the patient in a negative manner. Due to this fact, there is a desperate need of the teaching methods and effective rehabilitation tool to relearn skills that are lost due to stroke among the patients. Many studies conducted previously have found that the use of virtual reality technology will help to educate stroke patients to go through hand rehabilitation effectively and efficiently (Tsoupikova *et al.,* 2013). In the study, virtual reality technology is used as a simulation in which its criteria: interactivity, repetitive, fun, engaging and functional diversity are likely to provide significant contribution to the learning situation for stroke patients at different levels of severity.

THE INVESTIGATION OF THE STROKE PATIENTS' NEEDS

A survey is done to investigate the problems occurred among stroke patients in the hospital in southern region in Malaysia by using conventional hand rehabilitation therapy. This survey is done by interviewing the stroke patients and also their therapists. This method is considered as the needs analysis which is responsible in shaping the development of a new system which addresses in improving the stroke patients' cognitive aspect and also the hands rehabilitation. Both patients and therapists are believed to be the core voices in investigating the specific needs since they are the focal actors in the hand rehabilitation session and this fact allows them to provide the best answer. All the information gathered from this needs analysis will be use as a guide in designing the rehabilitation system.

DESIGN OF THE SYSTEM

The collaboration of therapists and technologies expert plays a major role to define strategies to stimulate the cognitive and improve the hand function functional ability. The system was designed carefully as to meet the stroke patient special needs. Therapists provided comments based on their daily work with patients and they were actively involved in environmental design and exercise development. The entire 3D virtual environment created based on the first stage of needs analysis conducted within the stroke group and the therapist. The system design was relied on substantial input from therapists from the rehabilitation unit to identify stroke-specific hand rehabilitation tasks and related functional activities.

Our immersive learning system was created through a combination of several software packages which is for 3D modelling development, used Adobe Maya and the Unity 3D implements the virtual environment which consists of different task

Figure 1 : The 3D Cybertherapy system. The user is wearing a cyberglove connected to the computer

Figure 2 : Series of exercise in 3D Cybertherapy

environment. The central aimed of the system was to provide a virtual training for finger flexion or extension focusing in daily life routine. Thus, the 3D Cybertherapy System was design consists of different task environment to be chosen by the stroke patients for hand training specifically in home environment as shown in figure 2. The patients might feel that they're in their own house while doing the series of exercise. These features would likely increase patient motivation and engagement.

In order to provide the real time feedback for finger movement, cyberglove is used to interact with virtual environment (figure 1). The bend sensor will track the movement of each finger. Thus the system offers feedbacks to respond appropriately to the patients' actions in which make it appears to be real and interactive. The result of every access that the patients made will be recorded in a database. This situation will help the patients to monitor their progress and this will definitely help to motivate them to keep on using the system in order to improve themselves and their confident will be greatly increased. As the cyberglove is lightweight and permits a large workspace, it affords great flexibility for treatment. The user can sit, stand, or even move about while wearing the device. Hence, it would be suitable for home use.

The patient receives feedback on his/her performance in real time during the exercise. Additional performance feedback is provided numerically by the graphical user interface on the left side of each task to provide feedback about the finger flexion/extension in real time. The color of indicator bar will change from yellow to green if the user successfully completed the task. At the end of the task, additional congratulation images appearing in order to keep the patient motivated. Importantly, the difficulty of each task can be modified to match the capabilities of the user. In this manner, the user can be optimally challenged in order to maximize the therapeutic benefits.

Meanwhile, the user can turn to get a 360° view of the surrounding area of virtual environment. In many exercises, the user attempts to perform reach-touch, grasp and release of the presented object in different environments around the house (figure 2). A set of virtual everyday objects, such as a comb, foods or a soap requiring different amounts of digit extension in order to sufficiently open the hand for grasp were created and can be accessed to provide a different object for each task. The objective of these exercises was to improve finger range of motion in active movement.

The used of Visual C program is to transmit the joint angle data to the computer for used in updating the virtual hand in the 3D virtual environment scene. Additionally, the program specifies which objects are appear in the scenes and the dimensions of these objects. It computes the desired joint angles needed to shape the hand to grasp, based on the dimensions of the objects and transmits these desired angles to the system. This system will allow several patients to interact in virtual space with activities designed to enhance upper limb and skilled hand function.

The user allowed to access every task after successfully complete each stages. It is to ensure that they pass the easier task before going through the hardest grasping activity. Graphical feedback of assistance and range of motion of the device enables the therapist to gauge progress and make adjustments during a therapy session. Training task difficulty can thus be controlled by therapist. The users are required to touch and grasp a specific object in order to provide rooms for them to use their hands excessively within the 3D virtual environment. The tasks in general are the simple daily life activity which is illustrated in figure 3 and figure 4.

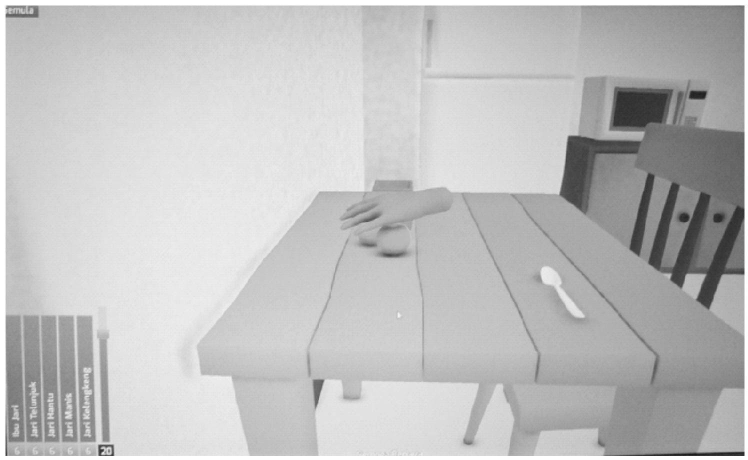

Figure 3 : Grasping the fruits on the table

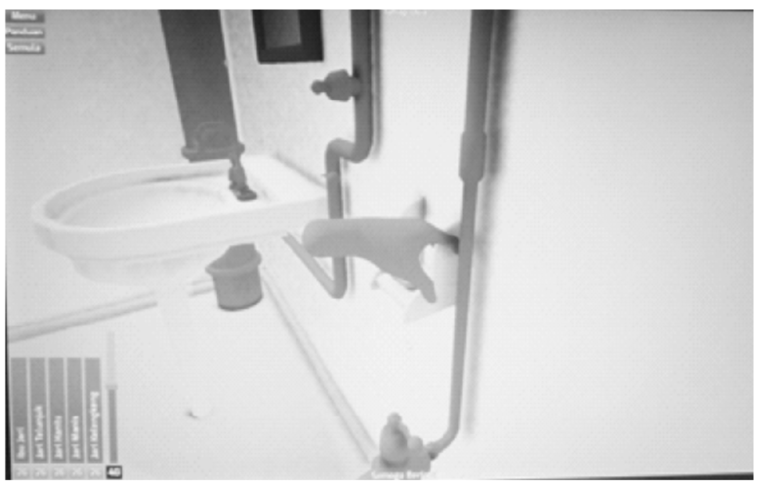

Figure 4 : Pick up a soap in the bathroom

After they go through the excessive practice of simple reaching tasks like in the previous picture, the patients will be presented with more difficult tasks; however, the tasks are still within the real-life contexts. The task difficulty were based on the amount of finger flexion/extension. Basically, the tasks are developed based on the life tasks which require lots of hands movement in reaching specific objects.

MEASURING THE DEVELOPED SYSTEM EFFECTIVENESS

The goal of each task focuses on improving active finger range of motion in the context of a functional grasp-release movement. In training, the participant is seated in front of a large screen of the laptop (17 inch monitor) to give a clearer visual of brief instruction displayed automatically in each scene (figure 1). This is to provide the information about the operating procedure of the system. The data glove was calibrated for each subject to ensure accuracy of the data collected. The welcoming screen displayed the multiple tasks to be selected by the user or assisted by the therapist (figure 2). The menu is followed to the task difficulty. The guidance from the therapist is needed, so that the patient will choose the suitable task according to the level of their hand impairment

In evaluating the system effectiveness, the method used is the tracking data method in which it involves with an experiment. This kind of evaluation deals with the data generated in the computer whenever the patients access to the system. The time history will tell that within that particular time duration, how much the patients have improved in cognitive and hand rehabilitation aspects. Observations are done for both tests as to support the data from the computer system. The researcher's field notes will be used as evidences in backing the findings from the tracking data.

THE STUDY

The system developed above has been tested on a stroke patient during a twelve week study. A total of 9 elderly participants aged range from 49 to 70 years with a specific inclusion volunteered to take part in this session. The participants had sustained left hemiplegia after stroke stroke for 6 month to 3 year prior to study. Most of the patients enrolled had already received previous rehabilitation intervention in the outpatient unit. The Occupational Therapist (OT) in one of the outpatient rehabilitation Unit was recommended the participant involved in this study. Only the patients with diagnosed Cerebrovascular accident (CVA) included in this study. The following conditions were considered as exclusion criteria; Mini Mental State Examination (MMSE) score < 20, severe verbal ability and poor upper arm movement. Those criteria were decided for the feasible screening within a defined population of stroke survivors. We explained to all participants the experiment schedule and answer their questions and then request their informed consent to the experiment. They are volunteering to participate after giving a brief information about the system while attending their rehabilitation session.

The participants were trained three times a week in a six week period. They practiced for about an hour session. The therapist assisted the participant in wearing the cyberglove completely. Each user done and calibrated the dataglove and was instructed in the hand rehabilitation movement, and given up to 5 minutes to practice and become accustomed to working in the virtual environment. After done, the therapist explained the 3D cybertherapy system task and they are guided through a series of the exercises. For the study, improvement in the finger range of motion during the training procedure was observed and recorded individually in time series.

The participants are required to give an opinion about the cybertherapy system after they completed the task in order to make improvements in the system.

1.6. RESULT

For this session only 4 participants have completed the 18 session using 3D Cybertherapy system. Below is the result obtained after four stroke patients undergone treatment for 6 weeks. Figure 5 and 6 shows the improvement in the patients' thumb and finger performance over the six week intervention. All the four subjects show improvement measures as recorded by the therapist. All the participants shows a positive improvement in finger movement over six week intervention period. Figure 5 shows a great improvement of changes in thumb range of motion for all the participants. As participants practice grasp and release repetitions, they can control and maintain their grip and pinch strengths better as well as faster articulate their arms and fingers. The positive improvements in finger range of motion had shown in figure 6. There were more than 50% changes in the angle of flexion each participant during six week intervention. We noticed that participant stayed highly engaged in the virtual learning environment during the training session. Therefore they were able to do more movements over the later training sessions. Overall, the developed system has been stable. In response to our question regarding the learning environment, most of the participants gave encouraging words. PT1 said that the system is very useful and user friendly (easy to access). The most exciting when they can see the virtual hand move synchronously with the data glove.

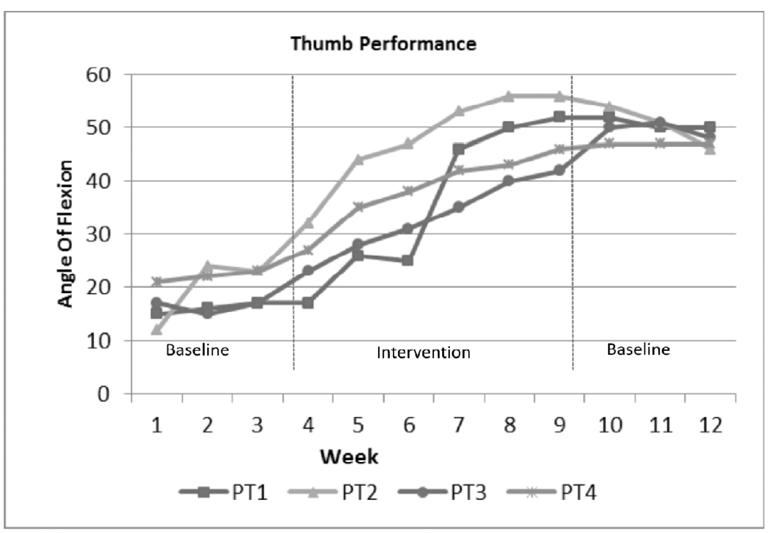

Figure 5 : Thumb performance

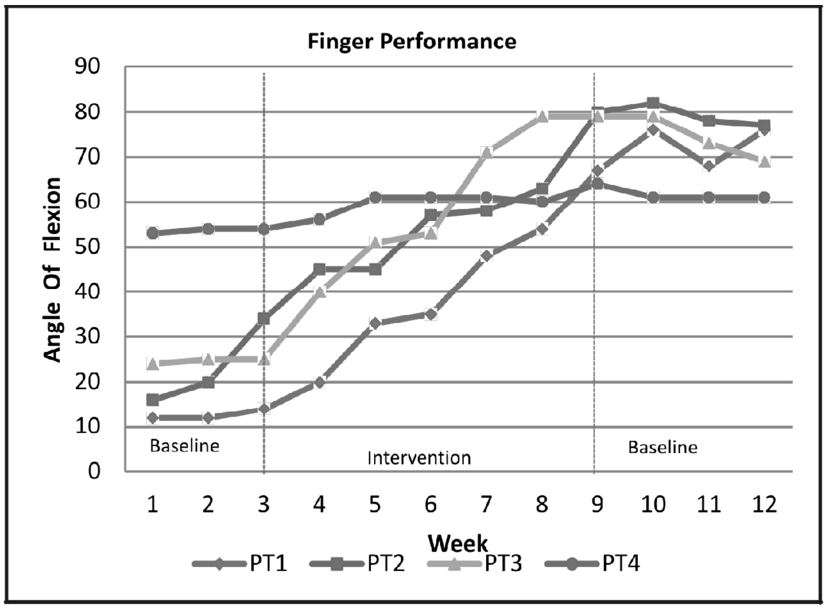

Figure 6 : Finger performance

CONCLUSIONS

This study demonstrated that we have been able to develop a complete 3D cybertherapy system, which incorporate an input device to accommodate patients with different level of hand impairment and based on handstroke needs. Overall, the responses to our system were positive. Cybertherapy technology was found to have potential as an assessment and training device in stroke rehabilitation. It has been shown that the use of cybertherapy in rehabilitation affords the opportunity for individuals to practice movements in several different environments and provides unlimited options for object size, type, and location. It also has the capability of creating an interactive, motivating environment in which practice intensity and feedback can be manipulated to create individualized treatments (Conelly et al, 2010). Moreover, by using computer assisted rehabilitation, it can be easier to implement specific rehabilitation exercises, increase intensity, repetitive, and skill based . The system would help meet the needs of the rising number of stroke patients with impaired hand function.

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