Developing a Digital Game for Domestic Stroke Patients' Upper Extremity Rehabilitation – Design and Usability Assessment

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Abstract. Digital games have been proven effective in upper extremity rehabilitation for stroke patients in addition to arousing higher motivation and feelings of pleasure. A well designed upper extremity rehabilitation digital game should intentionally meet the purpose of rehabilitation. Therefore, it is desirable to dmestically develop digital upper extremity rehabilitation games for the local hospitals as well as individual users. We are proposing this research to develop such digital games for rehabilitation and their feasibility assessment. A questionnaire was designed to evaluate the usability and feasibility associated with using this game. The results of this study can be summarized as follows: (1) the set of upper extremity rehabilitation game was named as upper extremity rehabilitation gardening game (UERG game). It is special designed for domestic stroke patients. (2) This UERG game uses Kinect's skeletal tracking features and motion sensor to interaction with patients. (3) design features are as following: game contents include three difficult levels according to different upper limb motor function recovery stages; to record user's motor performance; to provide feedback information (for example: to record the completed the task time and to detect whether the user has compensatory action, etc.). (4) A total of 10 patients to assess this set of games. The results showed that 90 % of patients reported that using UERG game in treatment increased their treatment motivation.; 70 % of them reported that this games is very interactive; 80 % patients considered this game is conducive to recovery their upper extremity functions; 80 % patients considered the feedback information provided help them to

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understand their performance in each session after training; 60 % patients indicated the game interfaces were easy to operate and learning; 90 % of patients reported that this game is enjoyment and satisfied with this game for rehabilitation. They are willing to continue to use.

Keywords: Upper extremity rehabilitation · Stroke · Digital gaming design · Usability assessment

1 Introduction

Many daily living tasks are performed with the upper limbs. Upper limb motor deficit is one of the main symptoms of stroke patients, and up to 85 % of stroke patients experience hemiparesis immediately after stroke (Saposnik et al., 2010). Therefore, rehabilitation treatment of the upper limbs is very important for stroke patients.

Upper extremity rehabilitation equipment (UERE) is usually used for training the proximal upper extremity movement functions (Lee et al., 2010). They are essential tools in the occupational therapy (OT) practice. Most existing clinical UERP provides no feedback to the patients in Taiwan. Patients may find that repeating the same activity can be boring and monotonous and thus develop a negative attitude toward the therapy process. In order to increase the mental satisfaction and physical vitality of rehabilitation therapy, some therapists have using off-the-shelf video game systems in rehabilitation. Digital games have been proven effective in upper extremity rehabilitation for stroke patients in addition to arousing higher motivation and feelings of pleasure. However, only a few OT departments in Taiwan's hospitals have tried to adopt digital games in their OT programs. The main reasons may be summarized as following: a) the devices are expensive; b) the gaming interfaces are not in Chinese, hence easily causing operation errors and inconveniences; c) the gaming interfaces are complicated for patients to independently operate the games without help from the therapists; d) the games contents are design for normal person to leisure, not for Stroke patient. Their individual strengths and weaknesses may affect treatment effectiveness and safety for the patient. Therefore, digital games for stroke patient must be designed with users in mind. Such products that truly fit the users can increase user acceptance (Jacobs, 2008).

It is desirable to domestically develop digital upper extremity rehabilitation games for the local hospitals as well as individual users. The purpose of this study was to develop a digital game system for rehabilitation and to assess their feasibility. It is hoped that the results of this study could be used to improve existing UERE to meet the practical needs of practitioners providing treatment and quality care.

2 Methods

This study included three parts: 1) to conduct literature review and expert interviews to identify types of daily living activities that meet treatment purposes and then determine the priority of each task for patients' resumption to independent living; 2) to design a

digital game for upper extremity rehabilitation, based on the selected daily living activities and the results of our previous research on improvement of game design; 3) a questionnaire was designed to evaluate the usability and feasibility associated with using this game. Further elaboration of the parts follows.

2.1 Expert Interviews to Identify the Game Contents for Rehabilitation

This part includes two items to identify the game contents for rehabilitation: 1) to interview the clinical occupational therapists, and 2) to reference previous research results.

Three clinical occupational therapists were interviewed. They proposed two most important suggestions for the system design: 1) Reaching-to-Grasp is one of the most important daily living activities. Also, note that, when patients do Reaching-to-Grasp activity, the compensatory movements easy occurred. Therefore, therapists suggested that an attention function of the Compensatory Movements design is needed in the digital gaming design for rehabilitation. 2) Rehabilitation-based game contents (such as usage situation and tasks)should conform to the actual task in life. It would make patients more familiar with the task of daily life.

Our previous study was to survey the therapeutic effectiveness, usage problems and needs of the commercial digital videogames (Wii and XaviX) applied in rehabilitation, then summarize a guideline for improvement design of the digital UERP. Design guidelines can be synthesized as follows, where items a to d are about software design, and items e to i about hardware (Chen et al., 2014): (a) To increase the response time of the games. (b) To increase difficulty levels of the games in order to better suit the various patients with different abilities of upper extremity functions. (c) To expand the sensor's sensing scope. (d) To be able to record movement data, such as: reaction time, operating time. (e) To improve the ways to fix the controller on the user's hand. (f) To fit the controllers size for different hand dimensions of the patients. (g) To provide better correspondence between the game and real-life movements. (h) To provide controllers for body control training, such as chest strap and belt. (i) To simplify the controller's operation. A systematic design process was then followed to create the digital UERP.

Considering these interviewed results and authors previous research results, we proposed a set of digital gaming.

2.2 A Digital Game Design for Upper Extremity Rehabilitation

According to the foregoing results, a digital game system for upper extremity rehabilitation was designed. It is especially designed for the patients with upper limb defect. In order to make the system context meet with the actual task in life, this study references some studies (Relf 1973, 2005; Relf and Dorn, 1995; Soderback et al., 2004) and clinical occupational therapists reported apply gardening tasks in rehabilitation can

stable mood, establish self-confidence, and increase patients' therapy motivation. Therefore, this game system design was named as 'upper extremity rehabilitation gardening game (UERG game).'

UERG game is designed to use Kinect's motion sensors and skeletal tracking function, and to combine with the gardening activities (Fig. 1). Functions and contents of this system has been repeatedly discussed and revised with occupational therapy experts, digital media experts and product design experts. The design characteristics are described as following:

(a) Three difficulty levels of the games (Fig. 2): easy, medium, and difficult.

In easy level, the game includes three tasks: to dial the soil (Fig. 3), to pick up the seeds to sow, and to water the potting. These tasks are main training patient (Brunnstrom recovery stages of upper extremity in III-IV stages)(Sawner & LaVigne, 1992) to do reaching-to-grasp activity and expend forward movement. When patients operate smoothly and the posture correct, the seed would grow into seedlings in fresh green (this color means the seed is healthy growing). On the contrary, if the user's operation is on and off, or the posture not correct (e.g. the Compensatory Movements occur or body barycenter offset), the color of the seedlings will present in tan (this color refers to the seedling is not healthy).

For medium level, the game includes three tasks: weeding (Fig. 4), deinsectization, and photosynthesis. These tasks are main training patient (Brunnstrom recovery stages of upper extremity in IV-V stages) to do reaching-to-grasp activity, expend forward movement, abduction movement and adduction movement. The seedlings color also the same the foregoing situation.

For difficulty level, the game includes three tasks: to block the wind for little tree, to block the lightening, and receive sunlight (Fig. 5). These tasks are main training patient (Brunnstrom recovery stages of upper extremity in V-VI stages) to do compositionality movement, fine movement, balance and coordination movement by both hands. The little tree color also the same the foregoing situation.

(b) Navigation function: In order to avoid the patients get lost in the process of operating, this system provides navigation function to guide patients operating menu and each task. At the login screen (Fig. 6), patient can chose the voice guider speaks in Chinese or Taiwanese. Before task execution, patients could watch a animation with 3D virtual character to understand how to operate the task (Fig. 7).

(c) Feedback: to present operating time in one task, encourage slogans (Fig. 8) and the Compensatory Movement warnings (Fig. 9). Patients are asked to correct his/her posture, when the graphic warnings appear in screen. Once the posture is corrected, the graphic warnings will clear off, then the game starts.

(d) Recording movement data (Fig. 10): a single action of moving speed, spend time in complete one task, the time and date of user login the game, posture error times (e.g. the Compensatory Movements or body barycenter offset), and moving track of the each action. These data would help patients and therapists to know recovery progress situation in each therapy session.

Fig. 1. Usage situation

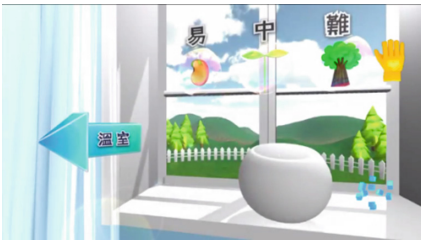

Fig. 2. Three difficulty levels of the games

Fig. 3. Easy level: to dial the soil

Fig. 4. Medium level: weeding

Fig. 5. Difficulty level: receive sunlight

Fig. 6. The login screen

Fig. 7. Navigation

Fig. 8. Encourage slogans-good job!

Fig. 9. The compensatory movement warnings.

名字	分數	時間	代償數	任務一時間	任務二時間	任務三時間	關卡名稱
單一使用資料							
test	1650	415	5	157	57	201	FlowerTree
test	1790	461	4	153	112	196	FlowerTree
test	3020	190	1	124	26	40	SmallPlant
test	18760	316	6	84	81	151	BigTree
全部資料							
test	1650	415	5	157	57	201	FlowerTree
test	1790	461	4	153	112	196	FlowerTree
test	3020	190	1	124	26	40	SmallPlant
test	18760	316	6	84	81	151	BigTree
YI HSUAN	1820	221	0	130	23	68	SmallPlant
YI HSUAN	2240	412	3	120	74	218	FlowerTree

Fig. 10. Recording movement data

2.3 The Usability and Feasibility Assessment

In order to confirm whether the UERG game design is feasible used in clinical, we applied participatory design in this part. The occupational therapists and Stroke patients were invited to actual use this system, and proposed their suggestions. The stroke patients were asked to complete a total of 5 training sessions in 2 weeks, scheduled at three 20-minute sessions per week (excluding set-up time). After 5 training sessions, each patient also completed the questionnaire.

Stroke patients were recruited from an outpatient occupational therapy department of Chung Shan Medical University Hospital in Taiwan. Inclusion criteria were as follows: (a) hemiparesis with upper extremity dysfunction following a single unilateral stroke, (b) a history of first-time stroke (3-24 months post stroke), (c) a need for upper extremity rehabilitation to convalescent levels of Brunnstrom stages III to V, (d) ability to communicate, and to understand and follow instructions, and (e) ability to maintain sitting and standing balance unsupported for two minutes under supervision (score ≧3 on the Berg Balance Scale). Exclusion criteria were as follows: (a) engagement in any other rehabilitation studies during the study and (b) serious aphasia or cognitive impairment. Each patient gave informed consent. This study was approved by the Human Research Ethics Board of a local hospital.

A questionnaire is designed based on the technology acceptance model (TAM) multi-item and related literature (Tsai et al., 2012; Davis et al., 1986). The Technology Acceptance Model is an information systems theory that models how users come to accept and use a technology. This questionnaire contains two parts: 1) the basic subjects information and 2) the TAM included five major variables, such as Perceived Usefulness, Perceived Ease of Use, Attitude toward using, attitude to use, and perceived usefulness. According to these factors and the game features, the questionnaire was completed. Each item were listed on a 7-point Likert-type scale with 1 signifying "strongly disagree" and 7 being "strongly agree".

For the occupational therapists, they were invited to use the UERG game and propose suggestions.

2.4 Data Analysis

The collected data were analysed with an SPSS statistical package. For each question on the questionnaire, the mean and standard deviation were calculated.

3 Results

A total of ten stroke patients were recruited, four males and six females, with an average age of 52.9 years (SD: 14.7). For their upper extremity convalescent levels of Brunnstrom stages (proximal), five patients were in IV stage, and five patients in V stage. For their upper extremity convalescent levels of Brunnstrom stages (distal), two patients in III stage, three patients in IV, and five patients in V stage. All subjects were never use digital games for upper limb rehabilitation.

Stroke patients agreed the game is feasible and acceptable (mean 5.4). 90 % of patients reported that using UERG game in treatment increased their treatment motivation (mean 5.3); 70 % of patients reported that this games has high interactivity, they still want to use it in their rehabilitation (5.7); 80 % of patients considered that UERG game is conducive to recovery their upper extremity functions (mean 5.0); 80 % of patients considered that the recorded movement data can help to understand their performance of each session after training (mean 5.0); 60 % of patients indicated that the interfaces were easy to operate and learning (mean 5.1); 90 % of patients reported that this game is enjoyment and satisfied with this game for rehabilitation, and are willing to continue to use (mean 5.6). Overall, Stroke patients showed positive attitudes toward the UERG game in rehabilitation.

Three clinical occupational therapists proposed two suggestions as following: 1) the Compensatory Movement warnings is too sensitive to break off the game. They suggest that the motion sensor sitting should expand the area. 2) about the game's induction system, it is suggested that adjust the sensor high sensitivity and synchronization of action.

4 Conclusion

This study develops a upper extremity rehabilitation gardening game and to assess their feasibility. The results of this study can be summarized as follows: 1) the UERG game is special designed for patients with upper limb deficits. 2) This UERG game uses Kinect's skeletal tracking features and motion sensor to interaction with patients. 3) design features of UERG game include the following: game contents include three difficult levels according to different upper limb motor function recovery stages; to record user's motor performance; to provide feedback information (for example: to record the completed the task time and to detect whether the user has compensatory action, etc.). 4) A total of 10 patients to assess this set of games. The results showed that 90 % of patients reported that using UERG game in treatment increased their treatment motivation.; 70 % of patients reported that this games is more interactivity, they still want to use it in their rehabilitation; 80 % of patients considered that this game

is conducive to recovery their upper extremity functions; 80 % of patients considered that the feedback information provided can help to understand their performance of each session after training; 60 % of patients indicate that the game interfaces were easy to operate and learning; 90 % of patients reported that this game is enjoyment and satisfied with this game for rehabilitation, and are willing to continue to use.

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