Improvement Design of the Clinical Upper Extremity Rehabilitation Product for Stroke Patients

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Abstract. The purpose of this study was to survey the usage problems and needs of the traditional UERE and commercial digital videogames applied in rehabilitation, and summarize a guideline for improvement design of the digital UERP. According to the guideline, this study was to design a Hand-rehab product design with treatment needs, and evaluate its acceptability with a questionnaire. The hardware design features includes: (1) the shapes and sizes of the operation objects can be chosen by the users to fit their own hand dimensions, (2) weight of the object can also be adjusted accordingly. The software design features are: (3) it displays visual and verbal cues, game scores, and operation times to the patients in each stage, notifying whether or not their action succeeded, (4) it allows adjustments of the reaction time to movements and the scope of sensing area of the objects. (5) The scope size of sensing area of the object can be adjusted. A total of 52 post-stroke patients were invited to assess the acceptability of Hand-rehab product. For the acceptability, most patients, after a trial with this product, reported had a positive and high satisfaction (mean 6.7, SD 0.6) with Hand-rehab product for rehabilitation.

Keywords: Physical disabilities occupational therapy · Upper extremity equipment · Rehabilitation product design

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1 Introduction

Upper limb motor deficit is one of the main symptoms of stroke patients. Between 55 % and 75 % of survivors continue to experience motor deficits associated with diminished quality of life (Saposnik et al. 2010). Many daily living tasks are performed with the upper limbs; therefore, rehabilitation treatment of the upper limbs is very important for stroke patients. Upper extremity rehabilitation equipment (UERE) are essential tools in the occupational therapy (OT) practice and are frequently used in most of Taiwan's OT clinics. Their individual strengths and weaknesses may affect treatment effectiveness and safety for the patient (Huang et al. 2013). Therefore, UERE must be designed with users in mind.

The most fundamental principle in motor learning is that the degree of performance improvement is dependent on the amount of practice (Krakauer 2006). Practice at its simplest, which is just performing the same movement repeatedly (Krakauer 2006; Sabari 1991), may be the most effective way to improve performance during the training session itself (Krakauer 2006). Patients at each session of therapy take about 15–20 min in repeated use of the equipment, which are common in Taiwan because a therapist usually has to take care of two to three patients at a session. A therapist has to try to motivate patients, for example, by embedding meaningful occupations with the UERE. The outcomes of OT would be best when the tasks employed for patients are meaningful to patients. Many UERE are employed for the purpose of preparing the body for future integrated work. For example, many clinicians begin OT for patients with stroke with a UERE and range of motion therapy prior to engaging the patient and move on to functional reaching tasks. These prior or preparatory activities are part of the treatment process. However, a skilled therapist knows that these tasks are not the end goal of therapy. These tasks are required components and are often only the short-term goals. These short-term goals contribute to longer-term goals like being able to independently do upper-body dressing. Therefore, the functions of the traditional UERE are needed to remain and redesign for user needs (Huang et al. 2013).

A key challenge for a clinician is to motivate a patient through/during the more routine preparatory activities in anticipation of future meaningful occupations. The meaning component in OT is how a therapist utilizes an individual success with the UERE and clearly ties these successes to future purposeful activities. Most existing clinical UERP provides no feedback to the patients. Patients may find that repeating the same activity can be boring and monotonous and thus develop a negative attitude toward the therapy process (Chen et al. 2015). 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. A better designed piece of equipment with variable options to choose and fun to use may also be helpful for therapists to plan the therapy activities with interaction and feedback. These therapy activities may raise clients' motivation to participate in the activities. With the increase of clients' motivation, both patients' levels of participation in therapy activities and the therapeutic effectiveness might also increase as a result.

Our study was to survey the usage problems and needs of the traditional UERE and commercial digital videogames applied in rehabilitation, then summarize a guideline

for improvement design of the digital UERP. According to the guideline, this study was to design a digital UERP with treatment needs, and evaluate its acceptability with a questionnaire. In this study, we choice one pieces of equipment commonly used for OT in Taiwan hospitals - Stacking cones (Table 1-A) as improvement design case.

2 Methods

The study includes three parts: (1) a questionnaire was developed to survey the usage problems and improvement needs of the existing UERE and commercial digital videogames used in Taiwan hospitals. (2) According to the results of the usage problems and improvement needs, summarize a guideline for improvement design of the UERP. (3) Redesigning the Stacking cones. (4) Evaluating the acceptability of the Stacking cones.

2.1 The Usage Problems and Improvement Needs of the Existing UERE

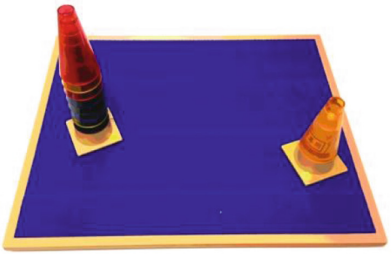
Subjects. The target sample of this study was therapists working in OT departments of hospitals at the time of survey. One hundred and thirteen hospitals having OT units with three or more full-time therapists were selected and surveyed.

Procedures. The researchers mailed the questionnaires to one therapist at each selected hospital with an OT department, and then he or she gave the questionnaires to other occupational therapists to fill in. The questionnaire description included the purpose of the study, the definition of the surveyed items, a description of the fill-in questionnaire and the deadline for returning the questionnaire to the researchers. The therapists were asked to check the appropriate items according to their personal experiences and opinions. The questionnaire was written in Chinese. It consisted mainly of four parts: therapist personal profile, questions about usage problems, improvement needs of the eight different types of UERE and suggestions for new designs for UERE.

Each therapist was asked two kinds of questions about the equipment: (1) usage problems and (2) improvement needs. The usage problems and adding new design for UERE items were listed on a 5-point Likert-type scale with 1 signifying “strongly disagree” and 5 being “strongly agree”. A multiple-choice checklist concerning features needed for improvement in the new design was also provided. Furthermore, the therapists were also asked to provide additional information not mentioned in the questionnaire.

Results. For the Stacking cones, a total of 184 valid questionnaires were received. The usage problems of Stacking cones were easily damaged (mean 3.6, SD 1.1), Uninteresting (mean 3.0, SD 0.9), Base unstable (mean 3.1, SD 1.1) and Height not adjustable (mean 2.2, SD 0.8). For the improvement needs, a higher value signifies a more urgent need for improvement. The Stacking cones, the top two features with the

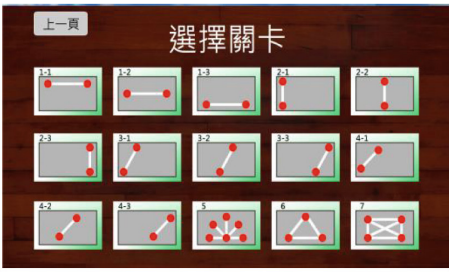
Table 1. Design features of the Hand-rehab product



A. The Stacking cones commonly used for OT in Taiwan hospitals.

B. The touch screen is used to display the tasks of Hand-rehab product.

C. The shapes and sizes of the operation objects.



D. The menu of the tasks in Hand-rehab product.

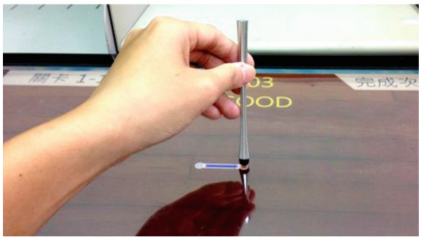
E. Weight of the object can also be adjusted.

F. It displays visual and verbal cues, game scores, and operation times to the patients.

(*Continued*)

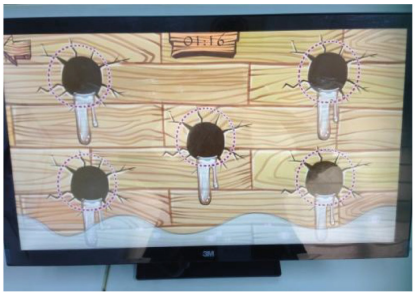
G. It allows adjustments of the reaction time to movements and the scope of sensing area of the objects.

H. The scope of sensing area of the object is about 60 mm in diameter.



I. The scope of sensing area of the object is about 36 mm in diameter.

J. The scope of sensing area of the object is about 2 mm in diameter.



K. The menu of the tasks with scenario in Hand-rehab product.

L. A new series of the tasks - Block holes.

highest percentages were the following: (1) interchangeable components (57 %) and (2) durable material (51 %).

2.2 The Usage Problems and Improvement Needs of the Commercial Digital Videogames

Subjects. 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 $\geqq 3$ 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.

Procedures. This part was a single-blind clinical trial. First, clinical therapists reviewed their patients with the inclusion criteria and asked about their willingness to participate in this trial. Subjects who accepted were asked to sign an informed consent form. All subjects were sequentially allocated into three groups (the XaviX®Port group, the Nintendo Wii group, or conventional group) by the researcher according to the order of recruitment (i.e. patient one goes into group A, patient two into group B, patient three into group C, patient four into group A, and so on). The functional ability of each subject's affected upper extremity was assessed by one of the assessors in two stages: (1) prior to the interventions, and (2) immediately after completing all the training sessions. All subjects were asked to complete a total of 20 training sessions over eight weeks, scheduled at three 30-minute sessions per week (excluding set-up time). In addition to the training sessions in this study, all subjects also received at least one hour of occupational therapy and physical therapy, respectively. After the post-training assessment, each patient also completed the improvement needs, motivation and enjoyment questionnaire.

Results. A total of 24 consecutively screened stroke patients completed all the training sessions. Each group had 8 patients. For the improvement needs of the Nintendo Wii and XaviX®Port games were: (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. Regarding motivation and enjoyment, patients in the Nintendo Wii and

XaviX®Port groups reported that using video games in treatment increased their treatment motivation. Enjoyment was significantly greater in the Nintendo Wii and XaviX®Port groups than in the conventional group ($F2, 21 = 18.55$, $p < 0.001$).

2.3 A Guideline for Improvement Design of the Stacking Cones

In terms of the improvement needs of existing UERE and the commercial digital videogames, we can synthesize a design guideline for Stacking cones as follows: (a) To provide interchangeable components. (b) To use durable material. (c) To increase the response time of the games. (d) To increase difficulty levels of the games in order to better suit the various patients with different abilities of upper extremity functions. (e) To provide better correspondence between the game and real-life movements. (f) To be able to record movement data, such as: reaction time, operating time.

2.4 Evaluating the Acceptability of the Stacking Cones

The acceptability of using the digital UERP in rehabilitation was assessed with a questionnaire by stroke patients after a trial with this product. Inclusion criteria were the following: (a) Hemiparetic with upper extremity dysfunction following a single unilateral stroke, (b) the required upper extremity rehabilitation convalescent levels were Brunnstrom stage III to IV, i.e., having basic upper extremity synergies to perform joint movement voluntarily, (c) ability to communicate and follow instructions. Each patient was asked to use the product 15 min, then to fill in a questionnaire. The items of the questionnaire were drafted according to the Technology Acceptance Model (TAM). The items were scored on a 7-point Likert-type scale, with 1 signifying "strongly disagree" and 7 being "strongly agree".

3 Results

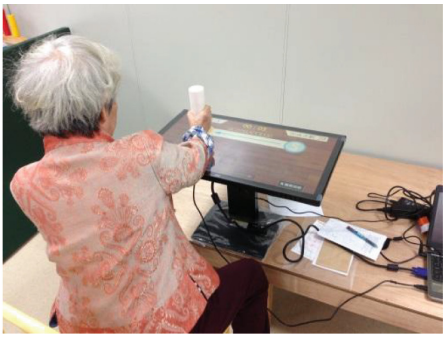
The Stacking Cones Redesign. Based on these preliminary results, a design proposal for a digital UERP with treatment needs in mind was proposed, named as Hand-rehab product. The Hand-rehab product has a touch screen to display the game contents and it incorporates objects from daily live in its operation.

The hardware design features includes (Table 1): (1) the shapes and sizes of the operation objects can be chosen by the users to fit their own hand dimensions (Table 1-C), (2) weight of the object can also be adjusted accordingly (Table 1-E). The software design features are: (3) it displays visual and verbal cues, game scores, and operation times to the patients in each stage, notifying whether or not their action succeeded (Table 1-F), (4) it allows adjustments of the reaction time to movements and the scope of sensing area of the objects (Table 1-G). (5) The scope size of sensing area of the object can be adjusted (Table 1-H-J).

The Acceptability of Hand-Rehab Product. A total of 52 post-stroke patients (34 males and 18 females) were admitted from the occupational therapy department of Chung Shan Medical University Hospital. The mean age of the patients was 54.1 years (SD 14.4). 28 (54 %) patients ever used computer, and 24 patients (46 %) never used computer. 17 patients (33 %) ever used touchscreen, and 35 patients never used. 9 patients ever used digital games for rehabilitation, but 43 patients never used.

For the acceptability, most patients, after a trial with this product, reported had a positive and high satisfaction (mean 6.7, SD 0.6) with hand-rehab product for rehabilitation (Table 2).

Table 2. Stroke patients used the Hand-rehab product



4 Conclusion

This study proposed the initial design of the Hand-rehab product. It is still debatable whether treatment with video gaming systems can effectively facilitate upper extremity functions, and this area still needs more research.

Two suggestions are proposed for future studies: (1) it will be better if the views of those therapists who use Hand-rehab product were also further surveyed. (2) In order to make this product more suitable to use in rehabilitation, it would be necessary to survey the therapeutic effectiveness of the Hand-rehab product.

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References

Chen, M.H., Huang, L.L., Lee, C.F., Hsieh, C.L., Lin, Y.C., Liu, H., Chen, M.I., Lu, W.S.: A controlled pilot trial of two commercial video games for rehabilitation of arm function after stroke. Clin. Rehabil. **29**(7), 674–682 (2015)

Huang, L.L., Lee, C.F., Hsieh, C.L., Chen, M.H.: Upper extremity rehabilitation equipment for stroke patients in Taiwan: usage problems and improvement needs. Occup. Ther. Int. **20**, 205–214 (2013)

Krakauer, J.: Motor learning: its relevance to stroke recovery and neurorehabilitation. Curr. Opin. Neurol. **19**, 84–90 (2006)

Sabari, J.: Motor learning concepts applied to activity based intervention with adults with hemiplegia. Am. J. Occup. Ther. **45**, 523–530 (1991)

Saposnik, G., Teasell, R., Mamdani, M., Hall, J., McIlroy, W., Cheung, D., Thorpe, K.E., Cohen, L.G., Bayley, M.: Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: a pilot randomized clinical trial and proof of principle. Stroke **41**(7), 1477–1484 (2010). The Stroke Outcome Research Canada Working Group