Applying Commercial Digital Games to Promote Upper Extremity Movement Functions for Stroke Patients

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***Abstract*—The objective of this study is to evaluate the effectiveness, usability and satisfaction of conventional devices, Nintendo Wii and XaviX, on upper extremity rehabilitation patients in Taiwan, and to summarize a guideline for improvement design of such devices. Twelve stroke patients were divided in three groups: (1) Conventional, (2) Wii, (3) XaviX groups. Eight senior occupational therapists were interviewed about the usage problems and additional needs related to the use of these devices. The results show that Wii and XaviX could be equivalent to conventional rehabilitation devices for improving upper extremity motor functions. All patients in this clinical trial were satisfied with using the digital gaming devices for rehabilitation. The suggestions for improvement design in game devices are as follows. For the software interface devices: (a) To increase difficulty and the response time levels of the games need adjustment, (b) To record movement data and game scores each time, some device for recording is needed, and (c) The games need a Chinese version of the software interface. For the hardware design: (a) The hand controller must be interchangeable for the users, (b) The controller should be adjustable to fit different hand dimensions of the patients, (c) The game and controller movements need to be designed to correspond to real-life activities, and (d) The controller's operation needs to be simplified. These proposed guidelines would be necessary in order to embody design improvements of the devices.**

Keywords- effectiveness; usability assessment; commercial digital game devices; stroke; upper extremity rehabilitation

I. INTRODUCTION

The current clinical upper extremity rehabilitation devices are mostly static and provide no feedback to the patients [1]. Patients easily feel bored while repeating the same activity, hence generating a negative attitude toward the therapy process [2][3][4]. In order to increase mental satisfaction and physical vitality in rehabilitation therapy, some therapists have tried to use the existing commercial digital game devices (CDGD)in rehabilitation and have found effective treatment outcomes in addition to enhancing the patient's treatment motivation [3][5][6].

There are already many studies focused on digital game devices in rehabilitation such as Wii [2][3][5][6][8], Playstation EyeToy [5][8] and Kinect [4]. For example, a study examined the feasibility and safety of the Wii gaming system and compared it with recreational therapy in facilitating motor function of the upper extremity [7]. The results showed that Wii gaming technology represents a safe, feasible, and potentially effective way to facilitate rehabilitation therapy and promote motor recovery after stroke. However, some of Wii's disadvantages were that stroke patients found the control of the handset buttons difficult and frustrating to use; however, this obligatory hand use improved gross motor dexterity. Stroke patients did not simply play Wii sports, rather the device was used as a rehabilitation tool with targeted and movement goals aimed at reinforcing appropriate and coordinated motor patterns [6].

These existing devices are originally designed for entertainment with normal people with healthy physical and action conditions, not intended for rehabilitation therapy purposes or for people with physical disabilities [5]. Further confirmation and evaluation is necessary to see if a digital game device can really meet the user's usability needs in addition to its rehabilitation effectiveness. Usability testing is a method used to determine how easy a device is to use and to identify issues that must be addressed in order to improve the design and functionality of the device [9]. However, the usability of such devices for rehabilitation remains relatively rare [5].

Nintendo Wii and XaviX have been tested in clinical rehabilitation in several hospitals in Taiwan. However, whether the superiority of Virtual Reality systems can facilitate conventional therapy currently in use remains to be determined [2][10][11]. Further development is required to ensure that these devices are easy for patients and therapists to set up in a clinic and/or home setting [5]. Therefore, this study aimed to evaluate the effectiveness, usability and satisfaction of using Wii and XaviX in rehabilitation for stroke patients and for the occupational therapists, and to summarize a guideline for improvement design of such devices.

In the following sections, the methods applied and results obtained will be described respectively, and then implication of the results will be discussed, followed by a brief section of conclusion and future work.

II. METHODS

A pilot and double-blind clinical trial was implemented to evaluate the effectiveness between conventional devices, Wii, and XaviX in rehabilitation. In addition, the usability and satisfaction of using Wii and XaviX in rehabilitation were also assessed by stroke patients and occupational therapists.

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A. effectiveness evaluation

1) Subjects. Stroke patients were recruited from the occupational therapy department of Chung Shan Medical University Hospital. Inclusion criteria were the following: (a) Hemiparetic with upper extremity dysfunction following a single unilateral stroke, (b) a history of first-time stroke (3-48 months post stroke, (c) 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, (d) ability to communicate, (e) able to understand and follow instructions. Exclusion criteria were the following: (a) engaged in any other rehabilitation program 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 Chung Shan Medical University Hospital.

2) Settings. Conventional equipment, Wii, and XaviX were used in this trial (Table I). Each group was assigned to use two games or equipment in the additional treatment. The games and equipment for the groups were selected by three occupational therapists, and were considered as similar in training effect on upper extremity movements. For Nintendo Wii, two games (boxing and bowling) of Wii Sport were selected to use in this trial. As for XaviX, two games (bowling and ladder climbing) were selected to use in this trial. Ladder climbing contains three levels (easy, normal and difficult). While playing bowling, the user needed to hold a soft bowling ball, fixed to the hand with a safety belt. In ladder climbing, the user needed to wear glove sensors in the palms of both hands [13]. Corresponding to the Wii games (Bowling and Boxing) and the XaviX games (Bowling and Ladder climbing), two conventional equipment were selected in this trial. They are the Curamotion exerciser and the Climbing board and bar.

3) Functional assessments. Four functional assessments were used as follow:

a) Fugl-Meyer Assessment of Physical Performance (FMA) [14]. It was used to evaluate the motor functions. The upper extremity motor test part with a possible highest score of 66 was adopted in the evaluation. The reliability of Fugl-Meyer Assessment is generally considered reliable [15].

b) Box and Block Test of Manual Dexterity (BBT). It was used to test gross manual dexterity of a patient's affected side [16]. In the test, the patient was asked to move as many cubes (of side length of 2.5 cm) as possible using only the thumb and index fingers during a timed 60s trial.

c) The Functional Independence Measure (FIM). This scale assesses physical and cognitive disability. The scale includes 18 items, of which 13 items are physical domains based on the Barthel Index and 5 items are cognition items. Each item is scored from 1 to 7 based on level of independence, where 1 represents total dependence and 7 indicates complete independence. This measurement was assessed and shown to have high reliability and validity [17][18][19].

d) Upper extremity range-of-motion (ROM). This is used to assess the passive and active range-of-motion on the affected side [20].

4) Duration of intervention. The training comprised 20 sessions during 2 months, with each session lasting 30 minutes (excluding set-up time). The effectiveness was evaluated before and after completing the 20 training sessions. In addition to these trainings (Wii, XaviX, and Conventional) in this study, all patients also received at least 1 hour of occupational therapy and 1 hour of physical therapy.

B. Usability and satisfaction evaluation.

An interviewer-administered questionnaire was designed to evaluate usability and satisfaction of using Nintendo Wii, and XaviX. The questionnaire included two parts:

1) Usability. Three open-ended questions about device set-up, game-playing, and performance feedback were asked to the patients for them to answer orally. By these questions, we expected to understand the context of use problems encountered by the patients.

2) Satisfaction. Three 5-point Likert type questions about satisfaction, motivation, and fun were then presented on a sheet of paper for the patients to answer. By this trial, we expected to understand the patients' satisfaction with using the digital gaming devices in clinics.

C. Usability evaluation by occupational therapists

Expert interview was conducted to survey the current situation of the use of digital game devices and evaluate the usability of such devices in upper extremity rehabilitation.

1) Locations. Two hospitals were selected in a preliminary investigation: Taipei Veterans General Hospital (TVGH) and Kaohsiung Veterans General Hospital (KVGH). Wii is used in KVGH and Xavix is used in TVGH.

2) Subjects. As a professional, the occupational therapist possesses expertise about therapy theory and also has abundant experiences, and these are useful for the evaluation of rehabilitation devices or the commercial products applied in rehabilitation. Selection criteria for the interviewed therapists were as follows: at least 5 years work experience in occupational therapy, and at least one year experience in adopting the digital game device intervention in rehabilitation treatment.

3) Contents of the interview. Semi-structured interviews were used, which mainly consisted of two parts: (a) Therapist personal profile - gender, age, hospital name, and work experience in years, and (b) Questions about the usability evaluation of the Wii and XaviX.

D. Observation of the usage of the CDGD in clinics.

During field observation, the researchers observed the process of devices being operated independently by the patients or with help of the therapist. From the point of view of ergonomic design, the researcher would also take notes of usability issues of the devices.

E. Data analysis.

The characteristics of the study groups were described as mean and SD. Differences in baseline characteristics between the three groups were analyzed by One-Way ANOVA. Each group was analyzed using paired-samples t-

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tests for pre- and post-therapy values. For each group, the effectiveness index of each functional assessment was calculated, that is, the post-test score minus the pre-test score, then divided by the maximum possible progress (possible highest score of the assessment minus pre-test score) [21]. To analyze the interview data from occupational therapists and stroke patients, the recording was firstly transcribed verbatim. Similar opinions were combined and all unique responses were independently itemized for further discussion.

III. RESULTS

A. Effectiveness evaluation of stroke patients

1) Characteristics of the stroke patients. Twelve consecutively screened stroke patients finally completed the trial, with a mean age of 50.42 years (SD=11.20). The characteristics of the patients in the three study groups are shown in Table II. There are no statistically significant differences between the three groups with regard to age, time from stroke onset, Brunnstrom stages of affected side, or FMA pre-treatment score.

2) Pre and post-gaming for all stroke patients. All groups showed statistically significant improvements on the FMA, BBT, FIM and 4 items of ROM assessment scales from pre-treatment to post-treatment (Table III).

3) Between-group differences in score changes for effectiveness index. The results show that effectiveness index of each group had improvements for arm functions in stroke patients on FMA, FIM and ROM, but there was no statistically significant improvement among the three groups (Table IV). For the FMA results, the Xavix group had a better effectiveness index score than the Conventional and Wii groups.

TABLE I. GAMES AND CONTROLLERS OF THREE GROUPS

Group	Devices		Console	Controller	Program
Convention	Climbing board and bar				Conventional therapy (60 min) + both the Climbing board and bar, and Curamotion exerciser (30 min. in total)
	Curamotion exerciser				
Wii	Bowling				Conventional therapy (60 min) + both the Bowling and Boxing games (30 min. in total)
	Boxing				
XaviX	Bowling				Conventional therapy (60 min) + both the Bowling and Ladder climbing games (30 min. in total)
	ladder climbing				

TABLE II. CHARACTERISTICS OF THE STROKE PATIENTS

characteristics	Convention	Wii	Xavix	p-value
number of subjects	4	4	4	
gender (male/ female)	4/0	4/0	3/1	
age (years) (mean, SD)	53.3 (13.3)	47.3 (13.9)	50.8 (8.1)	0.784
time from stroke onset to involve gaming (months) (mean, SD)	4.9 (1.7)	8.7 (3.7)	11.0 (12.9)	0.551
paretic side (left/ right)	2/2	1/3	3/1	
Brunnstrom stages (mean, SD)	4.0 (0.0)	4.8 (1.0)	4.0 (0.8)	3.0
(proximal/distal)	3.3 (1.0)	4.8 (1.0)	(1.8)	0.291 0.181
FMA (pre-gaming) (mean, SD)	28.8 (3.6)	49.8 (17.1)	36.5 (19.9)	0.201

TABLE III. PRE AND POST-GAMING FOR ALL STROKE PATIENTS

Assessments	Pre-gaming mean (SD)	Post-gaming mean (SD)	p-value
FMA (UE)	38.33 (16.54)	44.42 (16.52)	0.000*
BBT	15.83 (18.91)	20.50 (21.63)	0.054*
FIM	108.50 (14.99)	112.08 (13.31)	0.005*
ROM - shoulder flexion	114.25 (59.70)	136.25 (53.52)	0.148
shoulder hyperextension	34.17 (17.30)	39.58 (9.88)	0.090
shoulder adduction	83.33 (34.47)	107.92 (24.81)	0.002*
shoulder abduction	106.67 (47.31)	131.25 (48.58)	0.016*
shoulder internal rotation	42.92 (25.18)	47.75 (28.04)	0.263
shoulder external rotation	42.92 (29.58)	52.92 (32.92)	0.124
elbow flexion	111.67 (30.25)	125.00 (21.64)	0.112
forearm supination	35.00 (34.97)	52.92 (36.83)	0.010*
forearm pronation	45.00 (41.40)	52.08 (46.00)	0.068
wrist flexion	31.92 (35.09)	42.50 (33.06)	0.078
wrist extension	22.75 (26.18)	30.00 (27.63)	0.065
wrist ulnar deviation	12.08 (16.71)	15.42 (17.12)	0.087
wrist radial deviation	6.25 (8.56)	10.67 (10.17)	0.028*

*p value for pre-gaming versus post-gaming

TABLE IV. BETWEEN-GROUP DIFFERENCES IN CHANGE SCORES

Groups	Convention	Wii	Xavix	p-value
	EFFECTIVENESS INDEX, MEAN (SD)			
FMA (UE)	0.21 (0.50)	0.19 (0.15)	0.34 (0.46)	0.725
FIM	0.24 (0.13)	0.11 (0.15)	0.17 (0.21)	0.559
ROM - shoulder flexion	0.33 (0.58)	0.33 (0.47)	0.36 (0.43)	0.996
shoulder hyperextension	0.68 (0.22)	0.25 (0.50)	0.06 (0.13)	0.063
shoulder adduction	0.44 (0.23)	0.46 (0.53)	0.35 (0.27)	0.900
shoulder abduction	0.33 (0.42)	0.35 (0.40)	0.40 (0.41)	0.971
shoulder internal rotation	0.02 (0.16)	0.08 (0.03)	0.01 (0.08)	0.628
shoulder external rotation	0.06 (0.45)	0.58 (0.50)	0.27 (0.29)	0.262
elbow flexion	0.07 (1.17)	0.40 (0.49)	0.14 (0.34)	0.811
forearm supination	0.25 (0.17)	0.69 (0.47)	0.38 (0.48)	0.317
forearm pronation	0.47 (0.55)	0.50 (0.58)	0.25 (0.50)	0.780
wrist flexion	0.22 (0.27)	0.43 (0.42)	0.50 (1.00)	0.817
wrist extension	0.09 (0.20)	-0.78 (2.16)	0.34 (0.43)	0.456
wrist ulnar deviation	0.06 (0.07)	0.17 (0.33)	0.11 (0.22)	0.828
wrist radial deviation	0.27 (0.36)	0.90 (1.05)	0.19 (0.38)	0.313

B. Usability and satisfaction evaluation.

1) Characteristics of the interviewed occupational therapists. Eight therapists were selected and interviewed, three (one male [A] and two females [B, C]) were from KVGH and five (two males [D, E] and three females [F, G, H]) were from TVGH. They had an average age of 35.1 yrs (SD=6.3) and work experience of 10.8 years (SD=6.3).

2) Usability assessment by occupational therapists.

T1.Effectiveness. All eight therapists agreed that the Wii and XaviX are effective in upper extremity rehabilitation, and could enhance the patient's treatment motivation and pleasure. Therapist D commented that some of the game projects with their controllers can effectively strengthen the training of reaching and grasping movements and achieve better therapy effectiveness as compared to the traditional equipment. In addition, therapists mentioned that the existing conventional equipment are still important in rehabilitation and not possible to be fully replaced by digital gaming devices. The traditional equipment do not require the patient to react in time and restrict his/her movement speed, hence the patient can repeat the movement as many times as he/she wishes and at a speed at his/her own control. Therefore, the digital game devices can play a supporting role in

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rehabilitation treatment by providing diversification and interesting game projects for improvement of patient motivation toward the treatment.

T2. Ease of Use. Three therapists (A, B, C) considered that Wii is easy to set up, except some errors may occur when setting up the game software items. The usage problems are the following: (a) The current software interface is in Japanese and not easy to understand, hence it is prone to cause errors in the set-up process; (b) The required response time of the game is too fast and not easy to keep up with for the patients; (c) Some patients may have difficulty to hold the hand controller, hence the need for additional bandages to tie it on the hand; (d) For some patients, the games are too difficult.

For XaviX, five therapists agreed that the hardware is easy to set up, except the software interface operation may cause occasional mistakes. The usage problems are the following: (a) The current software interface is in Japanese and not easy to understand, hence it is prone to cause errors in the set-up process, especially for the games of visual perception and memory training, which are impossible to operate without literacy of the Japanese language; (b) The sensor is not sensitive enough, e.g., the action may obstruct the reflective film and interrupt the detection by the sensor; (c) The controller gloves have only one single size, thus, they do not necessarily fit to all patients; (d) Although the games are available in three levels of difficulty, the differences between the difficulties are too abrupt and hard to meet the patient's required degree of difficulty.

T3. Comfort. The results show that, for both Wii and XaviX, none of the eight therapists had received any complaints from the patients concerning discomfort in operating the controllers. However, therapist A commented that the controller of Wii often fell off from some patients' hands even with the safety ring held around the wrist. Therefore, he proposed that the controller be designed to be adjustable in size or to have a banding strap to help the patient to hold it with. Some patients cannot press the buttons on the controller to operate the menu due to incomplete recovery of the hand functions, hence they need to be assisted by the therapist for such operations before they can proceed with the game. Therefore, it is desirable to redesign the interaction mode between the controller and the game. For XaviX, therapist D suggested that this device provides a different set of controllers, which are suitable for different forms of motor training for the patients. For instance, the use of gloves, bowling balls, and other controllers can be useful for training the hand grip function.

T4. Acceptability. All eight therapists agreed that most patients can accept the use of Wii or XaviX for treatment. Therapist B explained that people interested in the game have a very high degree of acceptance of such devices. However, some elderly patients tend to prefer using the traditional rehabilitation equipment, because they feel that the traditional equipment are some physical objects that can be held and manipulated, hence giving a feeling of the effect of treatment. On the contrary, digital game devices give an impression of laxness and frivolity, and hence are inefficient and ineffective for those patients.

3) Usability assessment by stroke patients

S1. Device set-up. Two patients of the Wii group mentioned that they could set up the device and then operate the Remote to choose a game from the main menu to play by themselves. However, the other two patients needed the therapist to assist them to set up the device, and to operate the Remote to choose a game from the main menu for them to play. One patient of the XaviX group mentioned that he could set up the device and then operate the controller to choose a level of the game from the main menu to play by himself. The other three patients mentioned that they could only do some of the steps, i.e. to choose a level of the game from the main menu to play.

S2. Game-playing. Four patients that participated in the Wii group mentioned that they encountered only one usage problem: 'during the bowling game, they felt that it was difficult to press the control pad and to hold down the B button while using the device. Therefore, they usually had to use the unaffected hand to help. This difficulty is understandable, because their fingers, still under restoration, were weak and clumsy, hence they would need more time to operate the buttons. The four patients that participated in the XaviX group mentioned their respective usage problems as follows: (1) the safety belt of the bowling ball loosened easily, (2) the weight of the soft bowling ball was too light to feel: "I felt only the return swing of the hand. It didn't seem to be effective in training the strength of the upper extremity muscles." (3) Could not play well: "In the first two times I was not sure if my posture was correct, so I felt somewhat frustrated." (4) The bowling ball could not be gripped in the normal way: "My hand movement function still needs to be restored and the fingers curled, so the only way for me to play with the bowling ball was to hook the safety belt in my hand. In this way, the ball was unsteady when I swung my hand."

S3. Performance feedback. All eight patients agreed that they would pay attention to the scores of the games after playing. One of them mentioned that in order to upgrade the score, he would try to improve the strength of his upper extremity by practicing. The other two patients also mentioned that they would challenge the last score.

S4. Satisfaction. All the eight patients agreed that they were satisfied with using these devices for treatment (Wii: mean=4.0, SD=0.0; XaviX: mean=4.3, SD=0.5).

S5. Motivation. Eight patients agreed that these devices used in the treatment promoted their treatment motivation (Wii: mean=4.3, SD=0.5; XaviX: mean=4.0, SD=0.8).

S6. Fun. Eight patients agreed that these devices were more interesting than traditional rehabilitation equipment (Wii: mean=4.3, SD=0.5; XaviX: mean=4.0, SD=0.8).

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Five of them mentioned that these devices provided useful information, such as the scores, audio and video feedback, as well as interesting interactions, making them feel positively toward doing the treatment activities.

IV. DISCUSSIONS.

Many studies have reported that digital gaming is able to promote motor recovery after stroke, but most trials were small in scale and had some design limitations [2][10][11]. However, one clear advantage of the use of these games for rehabilitation is the psychological effects. It facilitates interest and motor learning, promoting motivation through the in-built commentary prizes, visual and verbal cues, tapping into patients' innate competitive natures and into their desire for interaction [2][6]. These effects are unavailable from conventional rehabilitation equipment. These advantages may be a reason to affect the effectiveness of the patients' rehabilitation therapy. It is worth preserving and incorporating them into digital rehabilitation device design or conventional rehabilitation equipment redesign.

Effectiveness of Wii and XaviX could compare to conventional equipment. In order to be fairer when comparing the effectiveness between the three groups, we tried to reduce the differences according to the age range of the patients in each group. Although, no statistically significant differences in the effectiveness indexes between the three groups were found, patients in the Wii and XaviX groups had improved upper extremity motor functional ability. This result seems to demonstrate that Wii and XaviX could be equivalent to conventional rehabilitation equipment for improving upper extremity motor functions.

Therapists and patients' perspectives about satisfaction. Therapists considered that patients generally were willing to use the digital game for rehabilitation. Therapists mentioned that only some elderly patients tended to prefer using the traditional rehabilitation equipment, because they felt that the traditional equipment are tangible objects that can be held and manipulated, hence giving a feeling of their effectiveness in treatment. However, all patients in this clinical trial were satisfied with using the digital gaming devices for rehabilitation. They expressed the hope that the digital gaming devices could be included in conventional rehabilitation therapy programs, and they felt that they increased the diversity of the rehabilitation activities. In addition, they also suggested that it would be better if the controllers of such devices were adjustable in weight.

The interface was difficult to use. In this study, the stroke patients' upper extremity rehabilitation convalescent levels were in the Brunnstrom stages III to IV, their fingers were mostly not restored at all. Hence, they had difficulties in performing fine movements, such as pressing the buttons on the Remote. To resolve this usage problem, it seems that the existing XaviX-Eyehand operation could be applied for such patients. This software is operated by the Glove Sensors worn on the user's hands. The user can move a cursor with the movement of the gloved hand, and select a menu item by clenching his/her fist (to hide the reflective sheets on the Glove Sensors). Though such an operation is easier than operating a controller to press the button, it is not preferable for patients in these stages, who still have difficulty in clenching their fists. An improvement of the design can be achieved by having users only to move the cursor to a fixed-point for some seconds, indicating a purposeful choice. In addition, some newly developed technologies can also be adopted.

The problem about device set-up. Observation of the therapists and patients in setting-up the XaviX revealed that they spent much time in determining the sensing range between the host and the controller in order to optimize the operating area for the players. To improve this problem, it is recommended that the device be designed with a mechanism to sense the region in a graphic fashion. This mechanism would let users immediately know whether the controller is in the sensing region or not, hence enhancing the efficiency of device set-up.

The difficulty levels of the games were too limited. People with stroke have different levels and complex impairments of varying severity. The impairments may include weakness of the arm, impaired vision, a variety of cognitive and executive problems or a combination of these impairments. These all can reduce their upper extremity function and response capacities. However, the difficulty levels provided by most of the commercial digital game devices are unable to meet the real needs of clinical rehabilitation therapy. For example, the XaviX- ladder climbing has only three difficulty levels, which is clearly not enough. Furthermore, Wii Sports even has no grade distinction at all. It was observed that two of the patients in the XaviX group were slow in response and had difficulties to timely respond to the game task. Therefore, in order to meet the treatment needs of different upper extremity function levels of the stroke patients, the device should be designed with more difficulty levels. How to define the scope of the game difficulty levels requires further trials in the future.

V. CONCLUSION AND FUTURE WORK

From the results obtained from the interviews and observations, it was found that the digital game devices currently used in clinical rehabilitation have been evaluated by professional therapists as useful and effective in supporting the treatment, though some design improvements may be necessary. This report mainly presents the results of the interview with occupational therapists and patients and observations of the clinical use of existing digital game devices in rehabilitation. Conclusions can be summarized into the following points:

1. All patients in this clinical trial were satisfied with using the digital gaming devices for rehabilitation. In addition, therapists also suggested that it would be better if the controllers of such devices were adjustable in weight.

2. Design guidelines concerning the improvement of existing digital game devices can be synthesized as follows, where items *a* to *d* are about software design, and items *e* to *i* about hardware: a) To increase the response time and difficulty levels of the games in order to better suit the various patients with different abilities of upper extremity functions. b) To expand the sensor's sensing scope. c) To be

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able to record movement data. d) To provide a Chinese version of the software interface of the games. 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.

In order to make these devices more suitable to use in rehabilitation, a comprehensive follow-up design development based on these proposed guidelines would be necessary. The newly designed devices would be more suitable for rehabilitation therapy, and enhance the use safety and effectiveness for people of all ages and abilities.

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REFERENCES

[1] L. L. Huang, C. F. Lee, and M. H. Chen, "The investigation of design improvement requirements for the upper extremity rehabilitation devices in Taiwan". Proc. Asia Pacific Industrial Engineering & Management System Conference (APIEMS 2010), Dec. 2010.

[2] G. Saposnik, M. Levin, and stroke outcome research Canada working group, "Virtual Reality in Stroke Rehabilitation: A meta-analysis and implications for clinicians," Stroke, vol.42, 2011, pp.1380-1386.

[3] L. Y. Joo, T. S. Yin, D. Xu, E. Thia, P. F. Chia, C. W. K. Kuah, and K. K. He, "A feasibility study using interactive commercial off the shelf computer gaming in upper limb rehabilitation in patients after stroke," Journal of Rehabilitation Medicine, vol.42, no.5, 2010, pp.437-441.

[4] Y. J. Chang, S. F. Chen, and J. D. Huang, "A Kinect-based system for physical rehabilitation: A pilot study for young adults with motor disabilities," Research in Developmental Disabilities, vol.32, no.6, 2011, pp.2566-70.

[5] B. Lange, S. Flynn and A. Rizzo, "Initial usability assessment of off-the-shelf video game consoles for clinical game-based motor rehabilitation," Physical Therapy Reviews, vol.14, no.5, 2009, pp.355-363.

[6] M. R. Mouawad, C. G. Doust, M. D. Max, and P. A. McNulty, "Wii -based movement therapy to promote improved upper extremity function post-stroke: a pilot study," Journal of Rehabilitation Medicine, vol. 43, no.6, 2011, pp.527–533.

[7] G. Saposnik, R. Teasell, M. Mamdani, J. Hall, W. McIlroy, D. Cheung, K. E. Thorpe, L. G. Cohen, M. Bayley, and the Stroke Outcome Research Canada Working Group, "Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: a pilot randomized clinical trail and proof of principle," Stroke, vol.41, 2010, pp.1477-1484.

[8] G. Yavuzer, A. Senel, M. B. Atay, and H. J. Stam, "Playstation eyetoy games" improve upper extremity-related motor functioning in subacute stroke: a randomized controlled clinical trial," vol.44, no.3, 2008, pp.237-44.

[9] J. Nielson, Usability Engineering, CA:Morgan Kaufman Publishers, 1993.

[10] P. Langhorne, F. Coupar, and A. Pollock, "Motor recovery after stroke: a systematic review,"Lancet Neurology, vol.8, no.8, 2009, pp.741-754.

[11] L. F. Lucca, "Virtual reality and motor rehabilitation of upper limb after stroke: a generation of process?,"Journal of Rehabilitation Medicine, vol.41, no.12, 2009, pp.1003-1100.

[12] Nintendo Wii, "Game Instruction Manuals and Wii System and Accessory - Instruction Manuals," 2012, http://www.nintendo.com/consumer/manuals/index.jsp

[13] XaviX Port, "User's guide," 2012, http://www.XaviX.com/products/manual/port_ug.pdf

[14] A. R. Fugl-Meyer, L. Jaasko, I. Leyman, S. Olsson, and S. Steglind, "The post-stroke hemiplegic patient. 1 . a method for evaluation of physical performance," Scandinavian Journal of Rehabilitation Medicine, vol.7, no.1, 1975, pp.13-31.

[15] P. W. Duncan, M. Propst,and S. G. Nelson, "Reliability of the Fugl-Meyer assessment of sensorimotor of sensorimotor recovery following cerebrovascular accident," Physical Therapy, vol.63, 1983, pp.1606-1610.

[16] V. Mathiowetz, G. Volland, N. Kashman, and K. Weber, "Adult norms for the Box and Block Test of manual dexterity,"The American Journal of Occupational Therapy, vol.39, no.6, 1985, pp.386-391.

[17] L. Brosseau and C. Wolfson, "The inter-rater reliability and construct validity of the Functional Independent Measure for multiple sclerosis subjects," Clinical Rehabilitation, vol.8, 1994, pp.30-41.

[18] K. J. Ottenbacher, Y. Hsu, C. V. Granger, and R. C. Fiedler, "The reliability of the functional independent measure: a quantitative review," Archives of Physical Medicine and Rehabilitation, vol.77, no.12, 1996, pp.1226-1232.

[19] J. F. Ravaud, M. Delcey, and A. Yelnik, "Construct validity of the functional independent measure (FIM): questioning the unidimensionality of the scale and the "value" of FIM scores, " Scandinavian Journal of Rehabilitation Medicine, vol. 31, no.1, 1999, pp.31-41.

[20] C. V. Heck, I. E. Hendryson, and C. R. Rowe, "Joint motion: method of measuring and recording,"American Association of Orthopaedic Surgeons, 1965.

[21] C. Y. Lee, C. Y. Wu, I. N. Lien, M. H. Hsu, and K. H. Lin, "Effects of modified constraint-induced movement therapy on stroke patients,"Formosan Journal of Medicine, vol.10, 2006, pp.429-437.

[22] J. Cohen, "Statistical power analysis for the behavioral sciences," Second Edition, Lawrence Erlbaum Associates, Hillsdale, 1988.

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