Applying Human-Centered Design to Rehabilitation Device

Lan-Ling Huang and Dengchuan Cai

National Yunlin University of Science and Technology, Graduate School of Design,
123 University Road, Section 3, Douliu, Yunlin 64002, Taiwan, R.O.C.
{g9630806,caidc}@yuntech.edu.tw

Abstract. The current study investigated the patients' problems and needs during therapy process. The investigation results were transferred to the product requirements of the rehabilitation device. The features of the new rehabilitation device included the following: 1) a webcam that can provide patients to communicate with his/her families or doctors during the therapy process, 2) a visual display that provides patients the function to see their posture and is able to correct their actions immediately, 3) physiological data such as movement angle, strength, and exercise time which were provided for diagnosis application for the doctors and their families, and 4) the main operational was designed to be adjustable for different individuals including its height, angle, and direction. The current design obtained positive evaluation preliminary by the occupational therapists. The procedure, methods and design of this study can be used as a reference for rehabilitation product design.

Keywords: upper extremities, rehabilitation therapy, product design.

1 Introduction

The aging population has become a world-wide phenomenon. Health care for the aging has been a popular issue. With aging, the physical condition degenerates and diseasing become more possible. According to the analytical report [4], cerebrovascular disease has become one of the top three causes of death in America. In Taiwan, cerebrovascular diseases also occupied the third cause of death for the year of 2007 [2]. On the other hand, it is still a main cause contributing to stroke.

Upper-extremity motor deficit is one of the main symptoms for stroke patients [3]. About 85% of stroke patients have upper-extremity function impairment at the beginning stage of stroke, and about 40% of patients still are with the function impairment at the final stage of stroke [6]. Some common upper-extremity symptoms of stroke patients are feeble muscle strength, unnatural synergies, and deficit in coordination within the joints etc [5]. In order to recover the function for daily life, rehabilitation therapy is needed for stroke patients.

The six most frequently used products in hospitals in Taiwan for stroke patients are listed below. 1) Arm/ hand skate: the main movement direction is horizontal from left to right and reversed. 2) Climbing board and bar: the main movement direction is vertical from bottom to top and reversed. 3) Resistive pinch exerciser: the main

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movement direction is vertical from bottom to top and reversed. 4) Vertical ring tree: the main movement direction is vertical from bottom to top and reversed. 5) Single curved shoulder arc: the main movement direction is horizontal from left to right and reversed. 6) Incline board: the main movement direction is vertical from bottom to top combining with horizontal from rear to the front and reversed [9].

The study results [9] showed that 1) the main movement directions of the above six pieces of equipment can be summarized as: horizontal from left to the right and reversed, vertical from bottom to top and reversed, horizontal from rear to front and reversed, and small arc movements, 2) most of the equipment was old and outdated.

In many cases, using an unaffected extremity to promote the affected extremity for restoring its lost movement ability has been conducted and proved in many studies [1] [7]. The theory for using an upper extremity on the unaffected side of the body to facilitate the other extremity on the affected side to recover its original movement ability for the stroke patients has been proposed and verified in various experiments and products.

According to the above theory, using the unaffected muscles to facilitate the affected muscle in the same extremity to recover its lost movement ability was proposed

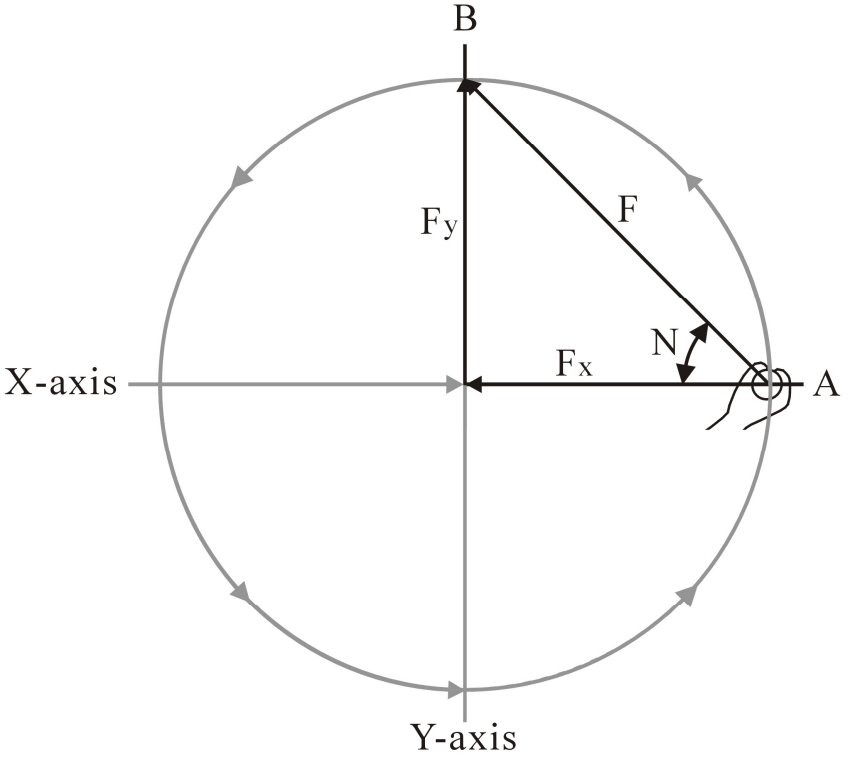

Fig. 1. Illustration for using unaffected muscle to facilitate the affected muscle

by the study. The idea is that supposing the affected muscle lost its movement ability along Y-axis direction and the unaffected muscle is still able to move along X-axis direction. Let the patients move their arms along a circular route, the unaffected muscle exercises a force F to move the arm from point A to point B witch made an angle of N between line AB and X-axis, then the affected muscle will be provided a component force Fy (F sin(N)) along Y-axis and the hand being forced to move to point B (Fig. 1). Therefore, the affected muscle will be trained by the component force Fy and will be facilitated in its movement ability along the Y-axis direction. When the circular movement continued, the movement ability of the affective muscles will be drilled and progressed continuously. The rehabilitation therapy theory was then applied to design an integrated rehabilitation product for the upper extremities.

2 Methods

The main methods in the study included a field observation and interview, a literature review for understanding state of the art of the rehabilitation products in Taiwan, a systematic design process, and applying a rehabilitation therapy theory and using a concept on human-centered design.

The field observation and interview were used to survey the patients' problems and needs during their therapy process. The results of the field observation and interview as well as the results of literature review were then transferred to the product requirements of the rehabilitation devices. During the design processes, serial design activities such as brainstorming, ides sketch, and 3D model making were used and a rehabilitation therapy theory (using unaffected muscle to facilitate affected muscle for restoring its lost function) and a human-centered design concept were applied into product requirements to design an integrate rehabilitation equipment.

3 Field Observation and Interview

3.1 Subjects

There were 10 patients served as participants interviewed in the study. The patients mean age was 66.2 years (SD=28.1 years). All of them patients were hemiplegia and treated with occupational therapy at the rehabilitation center of National Cheng Kung University Hospital DouLiu Branch. The recovery stages for arms of the patients are at stages 3 to 4. Patients at stage 4, their upper extremities and fingers have few functions and are able to bend. Besides the patients, we also investigated 3 therapists being employed in this hospital.

3.2 Interview Contents

The main interview contents included individual information, the needs of the patients during their therapy process and the requirements of the rehabilitation devices for the therapists which are described below:

1. The individual information include age and recovery stages for arms.
2. The needs of the patients included the following questions: a) are your psychologically feeling lonely during the therapy process? b) do you need family or friends to accompany you during the therapy process? c) what things do you want to have when you do the same and repetitive therapy movement ? d) do you want to know your rehabilitation progress every time when you finish the daily therapy process?
3. The needs of the therapists included the following questions: a) do you have any problems or needs for using the rehabilitation devices? And 2) what functions does the rehabilitation device should provide?

3.3 Procedures

First, the researchers described the study purpose to the therapists. The therapists selected suitable patients for the interview. We asked the patients if they were willing to participate. Then the researchers observed their activites during rehabilitation process. After observing the therapy process, we asked the interview questions to the patients and recorded their answers. The field observation and interview spent a week, 8 hours a day for the investigation.

3.4 Results

The investigation results indicated the following: 1) the patients usually had a sense of loneliness and helplessness during the therapy process and hoped their families or friends could be around them. 2) The patients felt uninteresting toward the rehabilitation devices and the repetitive activities. They hoped it could allow for them to chat with their family or friends, listen music or watch TV, etc. 3) The patients and therapists all preferred the product could record and display their rehabilitation performance and record physiological data for every patient. The data could be a good evaluative reference of the patient's recovery state by the therapists. 4) The rehabilitation devices should provide an adjustable function and fit to Taiwanese anthropometric data. 5) It should provide the functions of recording the movement state of the subject's body postures and the whole therapy process. As a result, the therapists can control the patient's posture easily.

4 Design Processes

According to the research results, the needs of the patients and therapists during the therapy process, the design objectives were formulated below.

4.1 Design Objectives

The design objectives included 1) the users were limited to the third to fourth level stroke patients. Patients' upper extremity at the fourth level his/her upper extremity and fingers have few functions and are able to bend, 2) the product needed to have a video and audio functions, 3) the movements should include flexion and extension, abduction and adduction, upward and downward and rotation, 4) product should

provide adjustable resistance and operational conditions, and 5) should provide a function to record rehabilitation data for patients.

4.2 Design Features

According to these design objectives, we used a systematic design process which was then followed to create the rehabilitation product. The main sizes of the parts of the product were designed to fit the body dimension measurements of Taiwanese. The range of rotation radius was designed with the arm length for those from 18-64 years. The lower limit was 525mm adopting the 5th percentile of arm dimensions of 64-years-old Taiwanese females and the upper limit was 685mm adopting the 95th percentile of arm dimensions of 20-years-old Taiwanese males [8].

The product design features are as follows: 1) The rotation bar has three segments. Each segment was 250mm which is a half hand length of a female. Therefore the adjustable range was 250-750mm (Fig. 2). This allows the subject to adjust it to fit their arm length. The product was also designed with a scale for showing the length (Fig. 3). 2) The product was set on a floor and could be operated along crown, sagittal, or transverse planes for rehabilitation (Fig. 4-7). 3) A brake mechanism was designed on the rotation shaft providing adjustable friction forces for different levels of rehabilitations (Fig. 8). 4) The handle was designed to fit the hand style and size of the Taiwanese (Fig. 9). 5) The height of the operated column and the display could be adjustable. This allows subject to adjust to fit their operating posture (sitting or standing) (Fig. 10). 6) The produce has video and conversation functions in the computer and includes a microphone on the operation column. It can provide the subject conversation with family or friends during their therapy process (Fig. 11). 7) The back of the product has a space to put a computer (Fig. 12). 8) The display is provided to show the rehabilitation data and video picture. It also has a camera that can track the movements of the subject and record the whole therapy process. The therapists can realize the patient's posture easily through the recording process and correct their posture immediately (Fig. 12). This design was evaluated by three occupational therapists and got a high evaluation.

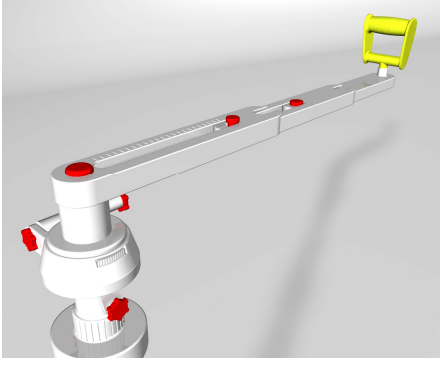

Fig. 2. Adjustable rotation radius

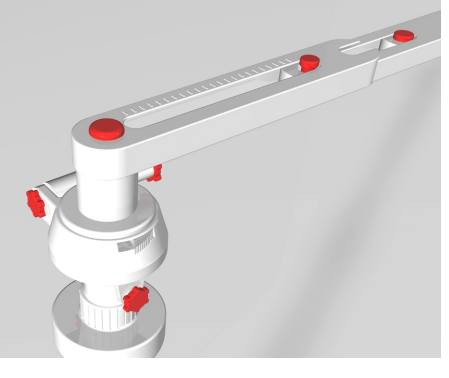

Fig. 3. Totation scale on joint

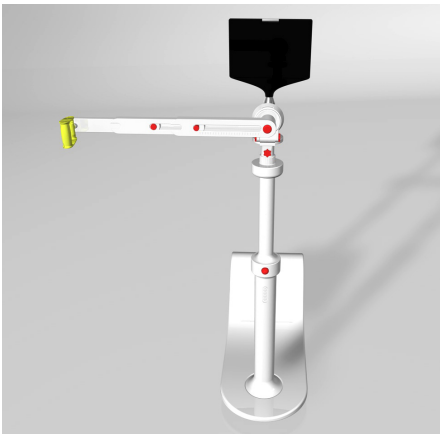

Fig. 4. Rotated on crown plane

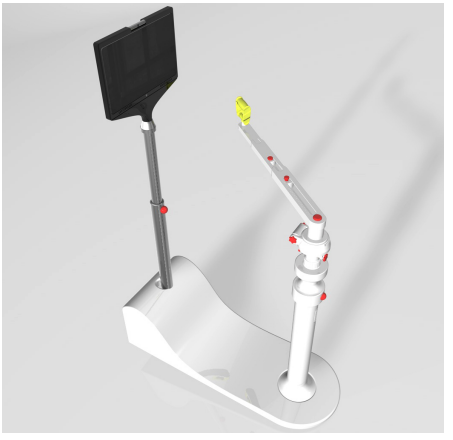

Fig. 5. Rotated on transverse plane

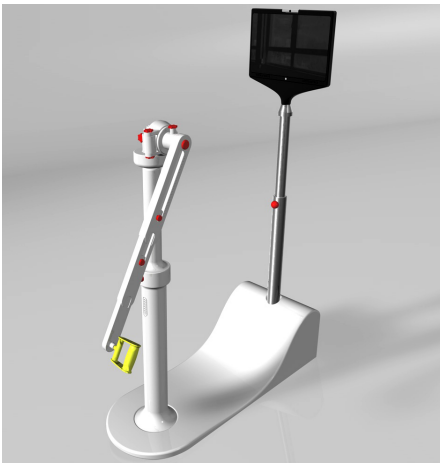

Fig. 6. Rotated on sagittal plane

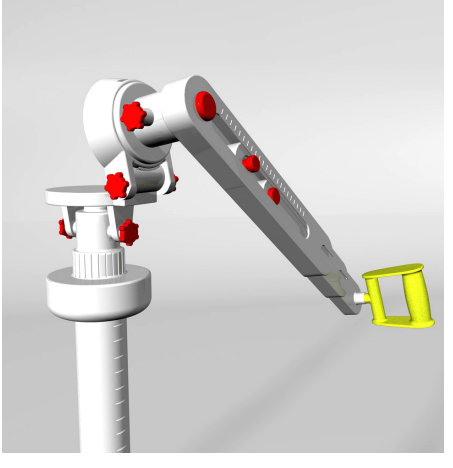

Fig. 7. Rotated on any plane

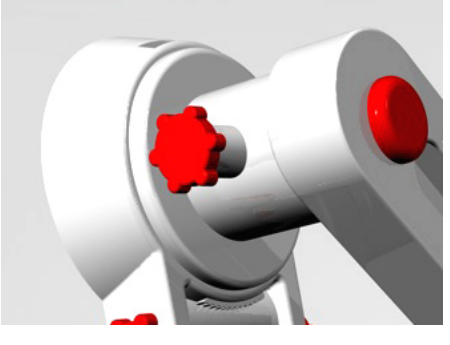

Fig. 8. A brake mechanism

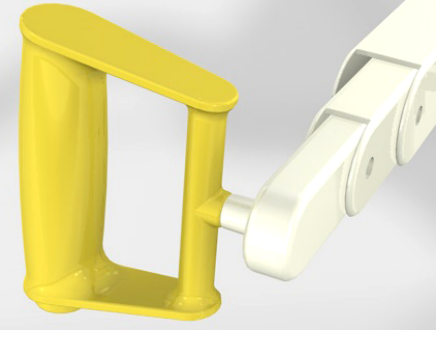

Fig. 9. Handle

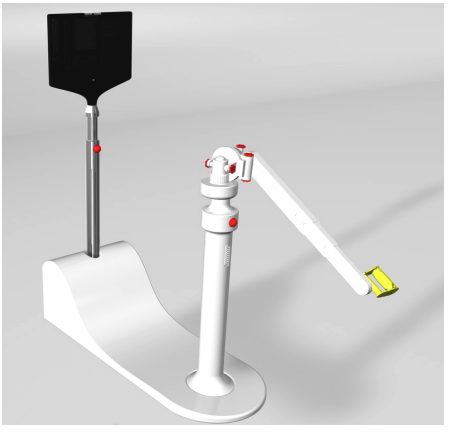

Fig. 10. The heightj of the operated column could be adjustable

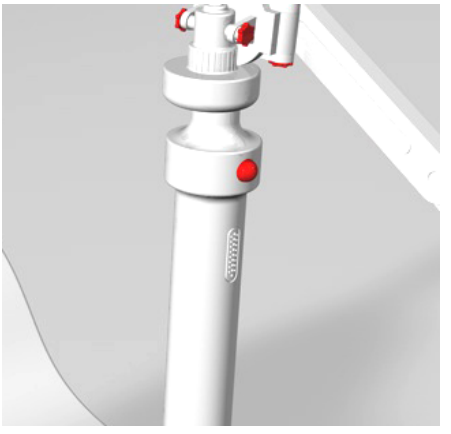

Fig. 11. Microphone on the operated column

Fig. 12. Space for computer

Fig. 13. Display

5 Conclusion and Suggestions

The investigation results indicated the following: 1) the patients usually had a sense of loneliness and helplessness during the therapy process and hoped their families or friends could be around them. 2) The patients felt uninteresting toward the rehabilitation devices and the repetitive activities. They hoped it could allow for them to chat with family or friends, listen music or watch TV, etc. 3) The patients and therapists all preferred the product could record and display their rehabilitation performance and record physiological data for every patient. The data could be a good evaluative reference of the patient's recovery state by the therapists. 4) The rehabilitation devices should provide an adjustable function and fit to Taiwanese anthropometric data. 5) It should provide the function of recording the movement state of the subject's body

postures and the whole therapy process. As a result, the therapists can realize the patient's posture easily. The results were then transferred to the product requirements for rehabilitation device. Through a serial design processes, the product was then proposed. The design features included: 1) a webcam that can provide patients to communicate with his/her families or doctors during the therapy process, 2) a visual display that provides patients the function to see their posture and is able to correct their actions immediately, 3) physiological data such as movement angle, strength, and exercise time which can be used to communicate with their families and doctors, and 4) an operational bar that is adjustable for different individuals including its height and operating direction. The current design obtained positive evaluation preliminary by the occupation therapists. The procedure, methods and design of this study could be used as a reference for rehabilitation product design.

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