Design of a Motion Training Support System for Hemiplegic Upper Extremity

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Abstract

The purpose of this study is to develop a system to support early rehabilitation training and home-based training. The subject is the rehabilitation training for hemiplegic upper extremities. During the rehabilitation training, motion training for the hemiplegic parts is carried out. The training also encompasses another hand (non-hemiplegic hand) to replace the function of the hemiplegic hand. Some patients are frustrated with operating small tools during the training. Some also want to carry out voluntary training in the patient room or at home under the guidance of occupational therapist. Thus, we developed a prototype system in which patients can conduct motion training of upper extremity while having fun. Our experience of developing the system is described in this article.

Keywords: rehabilitation, mirror box therapy, slate-type computer

1. Introduction

In this study, we developed a system to support the patients to conduct finger motion training under the guidance of occupational therapists during the recovery rehabilitation period [1]. In cases of losing the function of one hand due to illness, training for normal hand (non-hemiplegic hand) to transfer the functionality of the hemiplegic hand to the non-hemiplegic hand is conducted, in addition to the motor training of the hemiplegic hand. If the hemiplegic hand is a dominant hand, the training for non-hemiplegic hand includes practices with chopsticks and calligraphy, which require the patients to use small tools [2]. We want to minimize such requirements of the patients, and develop a system that allows patients to easily conduct exchange training of the hemiplegic hand and the dominant hand that will not wear out the patients.

The patients who are moved from acute stage to sub-acute stage (recovery stage) begin rehabilitation training to be able to return home. Depending on the condition of the patients, it is sometimes better to begin rehabilitation training at an early stage. However, if the patients have physical difficulties to go to the rehabilitation center, they have to wait until their condition improves. If these patients can begin a part of the training in the patients’ room, their transition to the next step training will be smoother. Thus, we need a training system for hemiplegic upper extremity, that can be used anywhere. The purpose of our study is to develop the early stage rehabilitation training system to improve such a situation or to develop a system that supports the home-based training.

2. Overview of the system

The recovery of motion function and physical ability of hemiplegic upper extremity requires comprehensive and quantitative evaluations and interventions to improve range-of-motion and muscle as well as motion function and cognitive function. The system using virtual reality technology is designed based on this theory, and the system is being test-used in the clinical setting as a robotic therapy [3-7]. However, the improvement of virtual reality technology and maintaining the compact size of the system are in a trade-off relationship. The concepts of our system design are “rehabilitation training in the patient room”, and “home-based rehabilitation training”. Thus, in this study, we emphasized the compact size of the system.
In our study, we tried to replicate the finger training using pegboard on the computer screen. The pegboard is often used as evaluation/exercise equipment for the upper extremities’ basic motion in the field of occupational therapy. Fig. 1 shows a hand-made pegboard which is being used in the rehabilitation room at the Kanazawa Medical University Hospital. The training using pegboard includes repeating the motion of removing pegs from the board and inserting them back to the board. Fig. 2 shows a Purdue pegboard. There are four cups on the near side. The patients remove the pins from the cups and insert them into the holes on the board. Then, they place washers on the pins. This is a tool developed by Dr. Joseph Tiffin, an Industrial Psychologist at Purdue University [8]. It is used to test gross movements of fingers, hands and arms, and fingertip dexterity.

Figure 1. Wooden pegboard

Figure 2. Purdue pegboard
Our system is targeting the patients who are receiving training using the pegboard. On the slate-type computer, information on the display is manipulated by fingertips. The basic motion of the fingertips on the touch panel includes tapping, dragging, flicking, pinching out, and pinching in. On the computer screen, we replicated the motion of pegs on the pegboard using dragging and pinching in motions. Fig. 3 shows the training screen we developed. As shown, the “pieces pretending to be pegs” in different sizes move from upper to lower part. The user needs to pinch them and put them in the designated areas. This is a replication of the motion of pinching pegs and moving them to different locations on the actual pegboard.

3. Design of prototype

The system is composed of a mirror box and slate-type computer. The mirror box was proposed by Ramachandran et al., and the therapy using the mirror box is called the mirror box therapy [9]. The mirror box therapy gives visual illusion of a functional paretic limb and provides the patients with the sense of actual motion of the paretic limb. This therapy can be used for the upper extremity rehabilitation training among the hemiplegic patients due to cerebrovascular disorder [10-14]. In the system we developed, we carried out the training using the slate-type computer for the non-hemiplegic hand, while facilitating the re-structuring of sense/motion in the brain using mirror box for the hemiplegic hand.

Fig. 4 shows the overall structure of our system. The user places the slate-type computer on the non-hemiplegic hand side in the mirror box. In Fig. 4, the non-hemiplegic hand is placed on the left side. The user looks at the non-hemiplegic hand on the mirror and gains the sense as if the treated hand (hemiplegic hand) is moving. If the mirror box is not being used, it can be stored in a compact space as shown in Fig. 5.
Figure 4. Prototype System

Figure 5. At the time of storing the mirror box
Fig. 6 shows the scene where a female patient in her 60s who has a hemiplegic right hand is actually using the device. This patient comes to the rehabilitation room of the Kanazawa Medical University Hospital every week to receive treatment for her hemiplegic right hand. She is a collaborator of our study and gives us opinions on the system from the user’s perspective. In the case of this patient, the slate-type computer is placed on the left side of the mirror box. Both hands are placed in the mirror box, and the patient plays the game on the slate-type computer using the non-hemiplegic left hand. The goal is to give a sense of playing a game using right hand by looking at the non-hemiplegic left hand on the mirror.

Figure 6. At the time of using the system
4. Conclusion

The system in this paper focuses on the compact size. The mirror box can be disassembled to save storage space when it is not being used. There is also no need to concern about the storage space of the slate-type computer. It is reported that a patient who has disorder with one hand due to cerebral infraction should receive the training of not only the hemiplegic hand but also the normal hand [15,16]. People have coordinated motion of dominant and sub-dominant hands in their daily lives. It can be said that our system provides a rehabilitation training that also takes into account this point. There is also a need to examine the contents of the game and motion of the slate-type computer from the patients’ perspective. We have not yet verified the extent to which our system is effective as a form of rehabilitation training. From here, we will conduct verification experiments for our prototype system, and will make improvements to our prototype model. Taking this into consideration, we are planning to develop a structure in which the effects of our system can be tested in the clinical setting.

5. Acknowledgement

We would like to express our appreciation to the female patient and her family who are collaborative to us in developing the prototype of the system.

6. References


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