An Upper Limb Rehabilitation Training and Evaluation System for Stroke Patients

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Abstract. This system combines information technology and rehabilitation medicine. It adopts Motor Imagery (MI) intervention and mental rotation training mode in order to change the traditional inefficient mode of clinical stroke rehabilitation. We developed multi-functional side recognition rehabilitation and evaluation peripheral to evaluate the rehabilitation effect of stroke patients accurately and quantitatively. The healing effect, which reveals the degree of recovery to the patients, will no longer depend on the personal experience of the rehabilitation therapist. Based on the psychological hint and a client designed with Unity 3D, it makes the treatment less boring to stimulate the patients’ initiative during the training. This system confirms that the MI Intervention can to a certain degree improve function of limb motor and sensory feedback by analyzing 38 volunteer patients’ data in Huashan Hospital and Shanghai Jing’an District Central Hospital. Precise and quantitative evaluation results are given for the further treatment.

Introduction

The clinical manifestation of stroke is mainly the motor dysfunction and sensory dysfunction. There are nearly 13 million stroke patients in China, and 2.5 million new each year. Every year, 1.65 million Chinese die from stroke, which means stroke takes place every 12 seconds and one person dies of it every 20 seconds. Stroke is characterized with high incidence of disease, high incidence of disability, high incidence of death and the tendency of attacking the young. In the 20th century, numerous studies had shown that MI can strengthen memory and learning ability; in the 1990s, it had been gradually applied to the recovery of limb function in patients with stroke, however, it has so far only been used in routine simulation and qualitative training.

Rehabilitation experts believe that the upper limbs are very important to our bodies during the rehabilitation of stroke patients. For example, our hands are very functional so that we can use the hand to take, pull, push, lift and so on. We can also do a lot of different things with hands, such as typing, writing, using chopsticks to eat, bouncing the ball, driving, etc. Meanwhile, upper limbs can help us keep balance. In the study of stroke rehabilitation, a large number of researches have emphasized the importance of upper limb rehabilitation. In a sense, one with normal upper limb functional can meet most of the needs in one’s daily life.

In terms of rehabilitation treatment of upper limb function after stroke, I chose a few representative hospitals in Shanghai for field research, namely Huashan Hospital affiliated to Fudan University and Jing’an District Central Hospital (Cerebral Apoplexy Center). According to the survey, well-known Grade 3A hospitals like Huashan Hospital still use the one-on-one treatment and rehabilitation methods for rehabilitation of stroke patients. The rehabilitation training methods are more traditional and basically not intelligent. Equipment and rehabilitation process assessments are also based on qualitative scales, resulting in inexperienced rehabilitation specialists with low treatment efficiency. Secondary hospitals like Jing’an District Central Hospital are in extreme shortage of resources in rehabilitation specialists and advanced rehabilitation equipment. Also, there are some common
problems: in the process of rehabilitation treatment, technique is monotonous and dull. The degree of patients’ rehabilitation depends too much on the experience of clinical therapists. Lacks in precise, quantitative and efficient rehabilitation evaluation equipment strongly affects patients’ understanding of individual rehabilitation degrees in detail. They may gradually generate helpless psychological problems, which have a great impact on the effect of rehabilitation treatment.

On this condition, I have begun to study the intelligent equipment for stroke rehabilitation since the beginning of 2018 under the guide of professional teachers in Shanghai University. Through reading the literature, I had determined the means of MI and mental rotation and designed the “Multi-function left and right measurement identification evaluation box”. Also, a lot of pictures of left and right hands had been taken for practical operation. By determining the correctness and time consumption of the testers’ responses that the smart box quantitatively analyzed and through training and evaluation, the inconvenience of patients’ side limbs can be ameliorated and their motor function can be reconstructed.

System Design

System Overall Design

The core development platform of this system is the Intel Up Squared Board platform, also known as Up2 Board. The platform CPU is available for Intel Celeron N3350/Pentium N4200/Atom E3940. It is available for 1GB/2GB/4GB/8GB LPDDR4 and 16/32/64/128GB eMMC. It has excellent computing power which is provided for the normal operation of the system. At the same time, the platform also has abundant peripheral interfaces, such as fan power supply interface, hard disk interface, etc., as well as being able to expand the Bluetooth port and audio output through the extended version. The platform is possessed with strong communication and interaction capabilities.

The system can be divided into two parts according to the classification of the operating end: the patient operating end and the rehabilitation doctor operating end. The two ends exchange data through the connection of Bluetooth. The patient operation end uses the Arduino Uno platform as the data acquisition control core to complete the data acquisition for the evaluation and training of peripheral patients; the rehabilitation doctor end is based on the Unity3D engine design as the core to complete the registration of patient information and guide the content of training and evaluation of the patient. The training and evaluation results are displayed on the software side and saved in the local database. Rehabilitation specialists can provide more effective guidance by reviewing patients’ history data. (System hardware and software connection block diagram is shown in Figure 1).

System Hardware Design

For the requirement of motor imagery and mental rotation experiment, I innovatively summarized and improved the important link of active nerve intervention - "motor imagery training" from the traditional clinical rehabilitation practice. Then I developed a standardized, processed and quantitative equipment with the functions of rehabilitation, evaluation and training: multi-functionally left and right measurement identification evaluation box. The device is based on
the Arduino Uno platform, which has lots of interfaces such as digital I/O ports, analog I/O ports, and supports SPI, IIC, and UART serial communication. It can sense the environment through a variety of sensors. And it is simple and fast in the embedded development process. The evaluation box mainly records the cognitive selection of the left and right sides of the patients. It communicates with the software side on the PC through the Bluetooth module in order to collect the data of the correctness and time consumption of the patients and following procession by the Arduino Uno platform. Simple operation stimulates the visual and auditory senses greatly to attract the patients and motivate the initiative of the patients’ rehabilitation training.

![Figure 2. Multi-functional Left and Right Measurement Identification Evaluation Box.](image)

**System Software Design**

The client software design adopts the next-generation 3D game development engine—Unity 3D, which is based on interactive graphical development and can be distributed to Windows, Mac, WebGL, IOS, Android and other platforms or published as a web page. In view of its excellent graphical interface and strong interaction, it will open up a new world for CNS patients so that they can bid farewell to the previous rehabilitation treatment.

**The Operating Methods of Evaluation**

Test pictures of the system in the hospital is shown in Figure 3.

![Figure 3. Test Pictures of the system in the hospital.](image)

This Multi-functional left and right measurement identification evaluation box adopts the method of mental rotation experiment, which requires patients to rotate the visual stimulus pictures of their hands at different spatial angles, and then determine whether the hand in the picture is left or right. The test requires the patients to determine as quickly and accurately as possible, and to make the
judgment through the button. On the basis of hand recognition, we also add other dynamic pictures such as Chinese characters, letters and numbers.

![Examples of Psychological Rotation Judgment of Left and Right Hands.](image)

In the process of training and evaluation, the software will provide patients with a group of photos and guide the patients to complete the procedure through some warm voice prompts. After judging whether the picture is left side or right side, patients should select the appropriate option by pressing the corresponding button on the evaluation box. At the same time, the button will light up. If the patients had chosen the right option, the software would produce a sound effect of applause. Patients can be motivated to be enthusiastic during training through sound and light effects, including the friendly interfaces of software. This method can attract patients and mobilize their initiative for rehabilitation treatment effectively.

After the evaluation, the client software can automatically display the correct rate and time consumption of the patients in this test. At the same time, the rehabilitation therapists can also see the statistical information in the patients’ previous tests. Also, the software will generate simple reports to the rehabilitation therapists and the patients themselves. The report can accurately show the degree of recovery of the patients over a period of time in order to assist the rehabilitation therapists to develop follow-up rehabilitation training courses for the patients.

**Test Data and Analysis**

By the time the report is finished, we have carried out the clinical usability tests for the system on a number of volunteer patients and non-patients in Huashan Hospital and Shanghai Jing’an District Central Hospital. 38 valid testers are recorded, and the actual testing system is still being carried out.

The gender and age distribution of voluntary cases were analyzed, among which 39% patients are female, slightly less than 61% of male patients. Patients aged 20-39 accounted for 5%, less than patients aged 40-59 (37%), patients aged 60-79 (42%), and patients aged 80-99 (16%). Test sample analysis is shown in Figure 5.
During the clinical testing in the two hospitals, the system was well received by medical staff and patients. The patients showed great curiosity about our system, and the operation was full of laughter. First-class rehabilitation therapists and rehabilitation physicians have given great recognition to our system. The evaluation results obtained by the system are objective and reliable. Experts showed great approbation. At the same time, the patients’ training guided by the system has obvious effects. Part of the right and left sides quantitative test accuracy and time consumption statistics are shown in Figure 6.

**Conclusion**

The multi-functional left and right measurement identification evaluation box provides stroke patients with quantitative assessment of the improvement of limb movement and sensory feedback function in the rehabilitation treatment stage. The self-developed intelligent hardware equipment for quantitative evaluation breaks through the traditional qualitative evaluation mode. Meanwhile, using this equipment can reduce the dependence on the experience of medical experts. In the clinical tests, it has been unanimously affirmed by patients, rehabilitation therapists and rehabilitation experts.

At present, there are more than 13 million stroke patients in China. Rehabilitation medicine departments in every hospital are in urgent need of similar intelligent and informative rehabilitation aids. The market demand is very large. Stroke training and evaluation methods can be divided into three stages: early clinical stage (not easy to move in bed), rehabilitation training (a large amount of rehabilitation resources), and family return stage (more convenient action and the possibility of going
home). Currently, a large number of rehabilitation resources, including rehabilitation equipment, are concentrated in the second stage of rehabilitation. For the first stage and the third stage, the existing medical equipment and venues cannot be deployed. However, the evaluation box we have produced can work well in all stages. With just one mobile device, patients can even be trained and evaluated in bed.

The intelligent rehabilitation evaluation equipment developed by the system can accurately, quantitatively and efficiently evaluate the improvement of limb function and sensory feedback function of stroke patients. The system can also fully mobilize the training enthusiasm of patients with central nervous system injury and improve the participation of patients through personalized, processed and multi-sensory stimulation voice prompt guide.

Doctors can compare different rehabilitation training methods and historical conditions of patients through their evaluation information accumulated by the system and provide further rehabilitation schedule for them. Doctors can lay a foundation for the analysis of sample cases and data statistics while knowing patients’ rehabilitation conditions. Through long-term clinical testing and verification, a standardized rehabilitation training and evaluation system for stroke is finally formed.

References