RESTORATION OF FINGER FUNCTION IN HEMIPARETIC STROKE PATIENTS USING GOAL-DIRECTED THERAPY: COORDINATION STATION

Theresa M. Sukal, Andrew H. Meisner, Rukayat T. Salako

Biomedical Engineering Department
The Catholic University of America
Washington, DC

ABSTRACT

The goal of this project was to develop a device that provides interactive, goal-directed finger therapy to individuals with hemiparetic stroke. The specific design requirements of the device were that it be safe, easy to use, adaptable to varying abilities, and able to record accurate force measurements. The device developed meets all of the design requirements, allowing hemiparetic stroke patients to perform repetitive, therapeutic exercises. We hypothesize that this type of therapy will lead to higher functional gains in stroke survivors, by re-establishing coordinated control over the finger muscles in the affected hand. The device can be used by therapists to track functional gains in hand function, and can be used at the clinic or at home.

BACKGROUND

According to the National Stroke Association, 750,000 people suffer a stroke every year in the United States, making it the leading cause of adult disability. Two thirds of these patients survive and require rehabilitation to compensate for the physical and neurological deficits associated with stroke. While rehabilitation therapy does not always reverse the functional impairments common to stroke, patients who receive intensive therapy make significantly greater gains in function than those who do not participate in therapy [1].

Hemiplegic stroke often results in the loss of fine motor control in the fingers, precluding these individuals from performing even the most basic activities of daily living, and in some cases, leads to depression and the inability to return to work. With 80% of acute stroke survivors losing arm and hand movement skills [2], effective therapeutic treatment modalities are required. As with learning a new skill, the important consideration in stroke rehabilitation is that the therapeutic task is carefully directed, well focused and repeated often [3]. Even in the "chronic" stage, individuals can regain finger control through repetitive exercise. Evidence from fMRI indicates that this increase in functionality is accompanied by brain reorganization [4].

STATEMENT OF THE PROBLEM

In many stroke patients, there is an abnormal co-activation of muscles while attempting to perform a specific task, translating into a patient's inability to selectively activate individual muscles at adjacent joints [5]. Current therapies are aimed at the recovery of functional ability, focusing on particular tasks to be completed, which can be ineffective because it does not specify the method to reach the goal. Also, most scales of impairment and improvement are based on observations rather than objective quantification of motor function.

It is therefore desirable, to have a device that can provide interactive, goal-directed therapy for a patient to selectively activate and thus control finger forces necessary to complete the specific task. This device will chart their progress as the patient retrains their muscles to produce progressively greater amount of force with each action.

RATIONALE

This system developed in this study is comprised of 3 components: a hand stabilizer unit, connections to the computer, and a user interface (Matlab program). The most critical consideration that was made involved the means for coupling the finger to the force sensing load cell because it must be held statically in order to fully transfer forces generated by the finger into the load cell. Possible designs have incorporated the use of an air evacuation device filled with glass beads, individual casting of patient's fingers, and a padded thimble unit to collapse over the finger.

Because the design was intended for use by patients of varying abilities, the load cell needed to be positioned such that it could be rotated and moved to accommodate different finger flexibility levels. There must also be a system of strapping to secure the hand, ensuring that the forces read by the load cell are strictly from the finger. It was critical for the program to focus on the goal-directed therapy, with a user interface that encouraged the patient to replicate specific finger movements.

DESIGN

The hand stabilizer and load cell are housed on aluminum platforms that can be adjusted relative to one another. Both are mounted on adjustable stands that can vary in height and rotational orientation. The load cell is mounted onto a ball and socket joint to allow 360° of rotation. A patient's finger would be placed in a padded thimble, inserted into a halo, and then tightened with thumbscrews, with an Aquaplast brace and Velcro strapping to hold their hand steady.

The load cell in our design is a Mini 20/40 from ATI Industrial Automation (East Garner, NC). Using a standard 9-pin RS232 Serial Port connection on the computer and a null modem adapter, the 8-bit signal was read from the load cell unit into the computer. Matlab was used to create a graphical user interface containing three figures. The main figure is the one where the target matching takes place, and where initialization begins. When this figure is initialized, it also calls up the settings screen, where the therapist can set the sensitivity, size of the target, number of trials they would like to run, and if they would like the data saved.

Once the variables have been entered into the system, the settings screen will pass the variables back to the target-matching screen, where they are used to control what the patient sees. After serial communications are opened, the screen will show two circles: one static target and one moving cursor. Movement of the cursor is dependent on both the forces exerted by the patient and the sensitivity setting, the latter being adjustable to the subject's ability. When the two centers of the circles match up, the target will turn red. After a specified holding time, the original target is erased and a new target will randomly pop up at another location on the screen. Matlab will automatically save this data in the base file name specified by the therapist, appended with the trial number.

If a therapist wants to review this data, there is a menu item to load saved data, which will bring up a results screen to import and display saved data. There is a graph for force in each direction, as well as a tracing of the path taken during the therapy. The values displayed are time of completion, and the maximum force generated in each direction. Pictures of these screens, as well as the mechanical design are included in the additional materials.

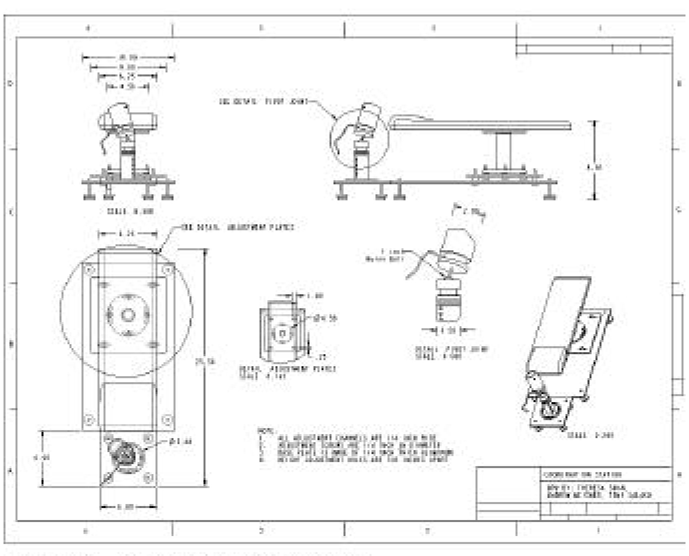

Figure 1. Schematic drawing of the device.

DEVELOPMENT

One goal in further development is to reduce the weight of the unit and make it more transportable. Additionally, a faster set up time could be achieved by reducing the locations of adjustment in the design. In the interest of cost, it would be better to replace the current load cell with a series of strain gauges and port the software over from Matlab into native code. Both of these changes will result in a device that patients could individually afford, since the mechanical pieces cost less than $200. Future developments in the software may include more features and additional analysis abilities, and making it web-based for therapists to track progress of home-based therapy.

EVALUATION

This design, although in its preliminary stages, has met our requirements of functionality, feasibility, and usability. Adjustability is such that the patient can get their finger into the device, and sensitivity can be adjusted accordingly to their ability, making it usable for nearly all patients. Although the pointer finger is the most important for functional pinching tasks, the device can be adapted for us by any finger because of the adjustability in the unit.

DISCUSSION

The most important design feature of this unit is that it encourages patients to engage in goal-directed therapy, such that the means taken to the goal are both directed and recorded. Using this interactive approach to therapy, patients are able to retrain muscle activation patterns and reduce problems with co-activation [5,4]. With this device, therapists have a measure to quantify the patient's level of function, objectively charting their progress over time. This form of therapy has the potential to significantly increase fine motor control in the hands of patients who have suffered a stroke. Further information on this novel device can be found on the project website [7].

ACKNOWLEDGMENTS

Dr. Joseph Hidler advised our design process, and we thank the CUA Biomedical Engineering Department for their generous sponsorship of the project.

REFERENCES

1. Barbeau, H., Norman, K., Fung, J., Visintin, J., and Ladouceur, M., "Does neurorehabilitation play a role in the recovery of walking in neurological populations?" Ann NY Acad Sci, vol. 860, pp. 377-392, 1998
2. Reinkensmeyer DJ, Pang CT, Messler JA, Painter CC. Web-Based Telerehabiltatin for the Upper Extremity After Stroke. IEEE Transactions on Neural Systems and Rehabilitation Engineering. June 2002 (10) 102-108.
3. Woldag H, Hummelsheim H.Evidence-based Physiotherapeutic Concepts for Improving Arm and Hand Function in Stroke Patients. J Neurol. 2002: 518-528.
4. Carey JR, Kimberley TJ, Lewis SM, Averbach EJ, Dorsey L, Rundquist P, Ugurbil K. Analysis of fMRI and Finger Tracking Training in Subjects with Chronic Stroke. Brain. 2002(125): 773-788.
5. Dewald JPA, Sheshadri V, Dawson ML, Beer RF. Upper-Limb Discoordination in Hemiparetic Stroke: Implications for Neurorehabilitation. Topics in Stroke Rehabilitation. Spring 2001: 1-12.
6. National Stroke Association: www.stroke.org
7. Project Web Site: http://engineering.cua.edu/biomedical/… faculty/hidler/courses/BE497/2002/Projects/StrokeHand/Home1.html