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An Iterative Learning Game for Hand Rehabilitation in Stroke Patients: A Feasibility Study Case

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Abstract **- This paper aims to develop a gamified hand rehabilitation program tailored for stroke patients with finger muscle weakness. Additionally, the program aims to assist physiotherapists in monitoring stroke patients' progress during their rehabilitation, regardless of their location. The rehabilitation program is designed in the format of a game, with a keyboard serving as the input device. The layout of the keyboard buttons in the games is based on the physical structure of arm muscles and the average hand size of the Thai population. The results of collecting objects in the game are displayed in units of time. Furthermore, there is a reporting feature that stores the results of hand rehabilitation sessions and presents them in report format. In the experiments, a comparison is made between traditional hand physiotherapy and hand physiotherapy through the game. The findings indicate that designing a keyboard-based button system for hand physiotherapy in a game closely resembles traditional hand physiotherapy. The movements of the thumb and little finger were found to elicit the most responsive muscle activity. The accuracy of muscle responses was approximately 76%, with an overall accuracy rate of around 70%. Overall, this game is one of the techniques that can support hands' rehabilitation, and the fingers' muscles respond to the game.**

Keywords **- Rehabilitation Device, Therapy equipment, Rehabilitation, Stroke Patient, Elderly patients.**

INTRODUCTION

A stroke is caused by a lack of blood flow to parts of the brain. The blood supply to the brain is narrow, blocked, or damaged, causing cell death in the brain. It is considered a severe nervous disease and a cause of sudden death.

According to the World Stroke Organization (WSO) [1], stroke remains a leading cause of death. There are 80 million people affected by stroke across the world, and 50 million are disabled by stroke. In Thailand, the public health statistics report of the Ministry of Public Health revealed the death rate caused by stroke per 100,000 population from 2012 to 2016, and it seems that the deaths will be two times higher in the future.

After being affected by stroke, most patients have a disability as they become paralyzed." They have a loss of balance, mobility difficulties, and loss of sensation in paralyzed body parts [2], contributing to the disability or functional limitation of body parts such as arms and legs. Leg physical therapy requires assistance; patients cannot perform it by themselves. Therefore, hand physical therapy is important to significantly show the development of stroke patients, enabling physicians or physical therapists to assess the capacity of patients and provide the next treatment accordingly.

Physical therapy for rehabilitating the hand function capacity of stroke patients involves exercising hand and arm muscles [3], such as lying down and lifting arms, moving wrists up and down, closing hands, opening hands, bending and stretching elbows, gripping or moving to spread fingers away from each other, etc. Movements or postures used in physical therapy shall follow the development of patients that physicians or physical therapists diagnose. Physical therapy relies on repeated motions to show the development of each patient.

Consequently, there are several technologies brought in to help solve ongoing problems [4]-[6], such as a software platform designed to make physiotherapy fun and convenient for patients recovering from surgery and injury.

After the game ends, the program will display the results [7],[8]. These score results help players see advancement in their physical therapy performance, while physicians or physical therapists taking care of patients can use the results to examine conditions and adjust a treatment model to be suitable for the next phase. However, it has some limitations, as while patients are playing, their body parts, from head to toe, must be tracked. This will cause any difficulty for patients since they have mobility difficulties in the first place. Another researcher who can fix such problems is Gijbels et al. [9], who conducted a study on the physical rehabilitation of upper limb dysfunction caused by stroke. In this pilot study, the primary goal was to evaluate the practicality of an 8-week training program that incorporates mechanical assistance to improve the strength of upper limb muscles and enhance functional capacity in individuals who clearly exhibit muscle weakness. Zimmerli et al. [10] carried out a study to validate a system designed to adjust exercise difficulty levels in robot-assisted rehabilitation for stroke survivors. Their findings indicated that this system effectively adapted exercise difficulty to match the patients' abilities.

This research aimed to study the feasibility of applying the positions of keys on a keyboard and developing computer game programs to help rehabilitate the hand functional capacity of stroke patients and reduce boredom from undergoing regular physical therapy, ensuring that physical therapy can be performed more conveniently in different places.

METHODOLOGY

I. Hand functional capacity rehabilitation testing program

Since the development of patient’s attitudes towards treatment is diagnosed through repetitive motions or postures used in physical therapy, Therefore, fine motor practice or hand exercise in physical therapy for stroke patients includes practicing arm muscle and hand muscle activities divided into grasp, pinch, finger pinch, and grip or move to spread fingers away from each other [11]. The hand functional capacity rehabilitation program includes motions or postures in physical therapy in the form of a game ay. The positions of keys on a keyboard consistent with the distance of finger structure are brought to fine motor practice or hand exercise to help patients reduce stress and boredom from the treatment.

Development of a hand rehabilitation program for stroke patients with muscle weakness in their fingers. It is a design program for testing hand functions that includes designing the position of keys on the keyboard [12]. It adopts the principle of arm muscles and pressing positions from the postures of hand physical therapy in stroke treatment records of a rehabilitation medicine center and the structure of Thai people's hands to help analyze and design the positions of keys on a keyboard. The design of the positions of pressing keys on a keyboard is based on information from the survey research report on the body structure of Thai people [13],[14]. The calculation of the average width of each finger is shown in Figure 1. The calculated values are used to identify the positions for pressing the keys in various postures.

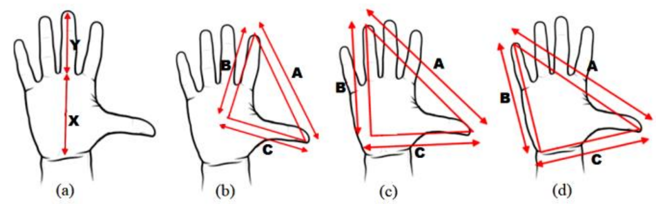

Figure 1 Finger Length Ratio,

(A) Length Ratio Between The Base Of Finger And The Base Of Palm,
(B) The Ratio Of Body Structure Between A Thumb And Index Finger,
(C) The Ratio Of Body Structure Between A Thumb And Ring Finger,
(D) The Ratio Of Body Structure Between A Thumb And Little Finger.

II. Designing hand functional capacity rehabilitation program.

The program designed to rehabilitate hand functional capacity for stroke patients with muscle weakness is more likely designed to be similar to a game. Test participants are allowed to use their fingers to press keys on the keyboard. The program will display results for the time of use. This output reveals the responses of hand muscles to different postures that test participants performed in each step of the program. In the process of getting input, the time value of hand muscle responses in each posture is collected according to five characteristics: 1) a thumb and index finger grip; 2) a thumb and little finger grip; 3) moving and spreading a thumb on the index finger; 4) moving and spreading a thumb on the ring finger; and 5) moving and spreading a thumb on the little finger. Moreover, the program gives a choice of difficult levels to be played. The time value of the hand muscle responses of test participants is calculated to give information to physical therapists. Finally, test participants’ outcomes in each physical therapy posture are indicated according to difficulty levels. The work process of the program has ended, as seen in Figure 2.

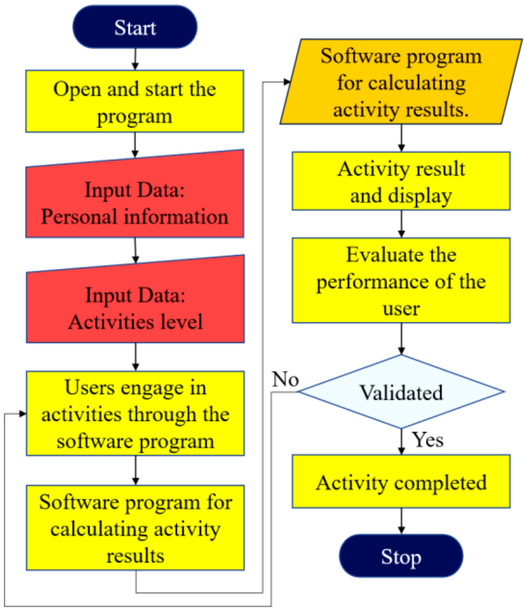

Figure 2 Flow Chart of the Hand Rehabilitation Program.

Figure 3 shows the physical program registration page. There are two main methods for using the program. It can be played with both the left and right hands. Normally, stroke patients in rehabilitation who have finger muscle weakness are able to have weakness in either the left or right hand. As a result, the program offers an option to allow test participants to select the one that meets their symptoms. The display page of the program when accessed is shown in Figure 4. After the test taker goes through the program operations from start to finish, the program will collect the response time values of the hand muscles of the test participants to calculate a score, which will be displayed on the usage results page. The program will display the score in report format, as shown in Figure 5.

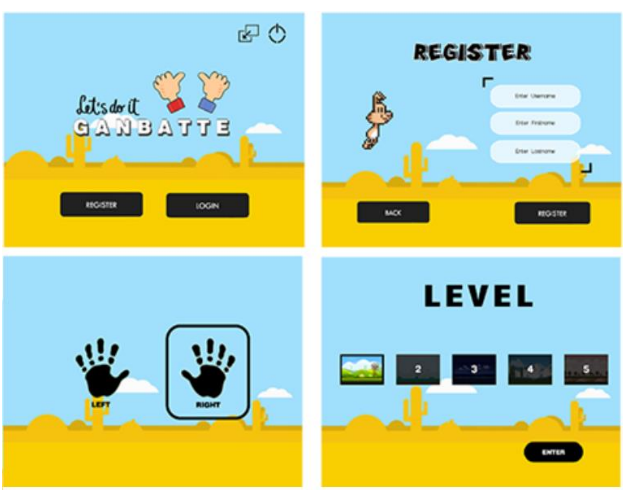

Figure 3 The Screen Shows How To Choose The Usage Level.

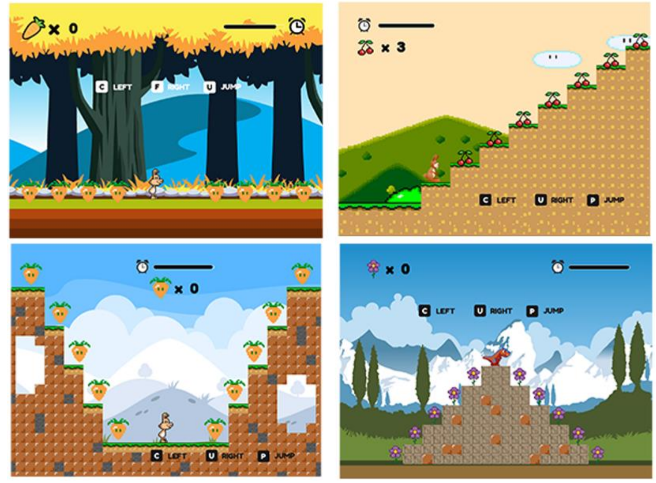

Figure 4 The Screen Displays Each Level Of The Game When Accessed.

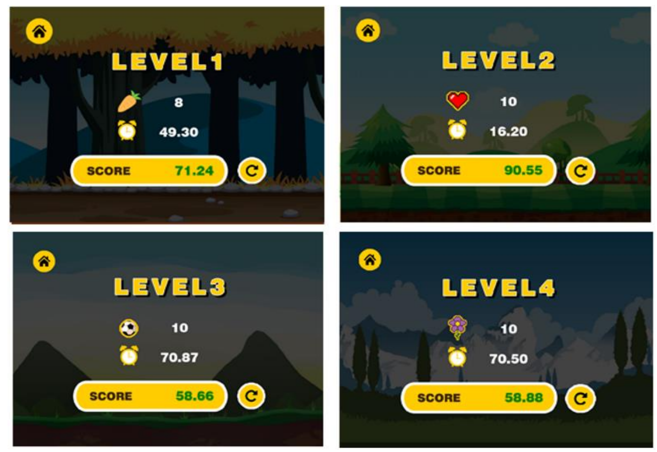

Figure 5 The Screen Displays Usage Results At Various Levels.

Results And Discussion

In order to assess the effectiveness of physical therapy by pressing buttons on the keyboard for 5 different postures designed to resemble general physical therapy, the efficiency of input from the keyboard was evaluated by calculating the average scores of activities from a sample group of 50 individuals aged between 15 and 60. They were asked to perform the five physical therapy postures using both their right and left hands, and the accuracy percentage of the test pattern was determined. The test results are as follows:

- *Level 1 test*: a thumb and index finger grip are used to test the capacity of a thumb and index finger in gripping posture.
- *Level 2 test*: moving and spreading a thumb and little finger is used to test the capacity of a thumb and little finger in moving and spreading posture.
- *Level 3 test*: moving and spreading a thumb and ring finger is used to test the capacity of a thumb and ring finger in moving and spreading posture.

- *Level 4 test*: moving and spreading a thumb and index finger is used to test the capacity of a thumb and index finger in moving and spreading posture.
- *Level 5 test*: a thumb and little finger grip is used to test the capacity of a thumb and little finger in moving and spreading posture.

The rehabilitation of hand dexterity will involve testing a program that compares the finger motion functions in response to various positions on the keyboard as designed. The test results of the program's usability based on finger positions on the keyboard are depicted in Figure 6.

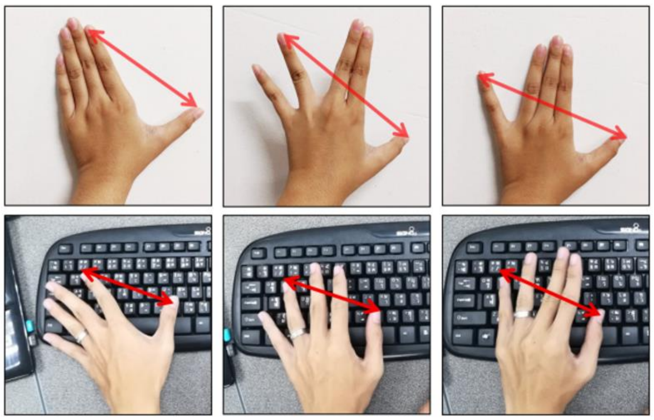

Figure 6 The Physical Characteristics Of The Hand When Moving.

Effective test results of input from muscle activity while pressing keys on a designed keyboard compared to activity from normal physical therapy are presented in Table 1.

Table I
RESULTS OF TESTING DATA FROM ACTIVITIES WITH THE PHYSICAL THERAPY PROGRAM COMPARED WITH ACTIVITIES FROM NORMAL PHYSICAL THERAPY

Test level	Left hand (%)	Right hand (%)	Average results (%)
1	71.89	63.23	67.56
2	73.28	68.59	70.93
3	69.13	71.41	70.63
4	50.42	75.21	62.81
5	79.42	73.22	76.32
Average	68.83	70.33	69.58

From Table 1 percentage of input efficiency from muscle activity in every posture of a sample group of 50 people, it was found that the percentage of accuracy of pose 1 was equal to 67.56% of pose 2 was equal to 70.93%, and of pose 3 was equal to 70.63%. Poses 4 accounted for 62.81%, and Poses 5 accounted for 76.32%. To summarize the results of the test, it can be seen that the test results for the left and right hands have similar average results, approximately 70 per cent. As a result, the accuracy of the muscle response was approximately 77%, and the accuracy of all positions was approximately 70%.

CONCLUSION

The development of a rehabilitation game focused on enhancing hand and finger functionality in stroke patients. Its primary objectives were to create a program designed to rehabilitate individuals who have experienced muscle weakness in their fingers and hands due to strokes while also assisting physical therapists in conducting initial assessments of these patients. This program comprises two main components: First, a muscle physical therapy program in game format. This segment of the program operates as a game and takes input through a keyboard. It is designed to facilitate muscle rehabilitation and finger dexterity exercises. Second, result presentation in report format: the program also includes a reporting feature that compiles and presents the results obtained from the time spent on object collection exercises during physical therapy. Comparing the outcomes of traditional physical therapy with those achieved through keyboard-based exercises in the game, it was observed that the latter approach can effectively contribute to rehabilitating finger functionality, yielding satisfactory results when compared to conventional methods. Additionally, this initiative involves the development of technology tailored for use in Thailand, reducing the reliance on imported technology.

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REFERENCES

[1] Feigin, V.L., Brainin, M., Norrving, B., Martins, S., Sacco, R.L., Hacke, W., Fisher, M., Pandian, J. and Lindsay, P., 2022. World Stroke Organization (WSO): global stroke fact sheet 2022. International Journal of Stroke, 17(1), pp.18-29.

[2] Salin, S., Zomer, E. and Attia, A., 2018. Words for Loss of Sensation and Paralysis in Assyro-Babylonian Medical Texts: Some Considerations". Le Journal Des Médecıns Cunéiformes [JMC], 31, pp.26-37.

[3] Belagaje, S.R., 2017. Stroke rehabilitation. CONTINUUM: Lifelong Learning in Neurology, 23(1), pp.238-253.

[4] Masia, L., Krebs, H.I., Cappa, P. and Hogan, N., 2007. Design and characterization of hand module for whole-arm rehabilitation following stroke. IEEE/ASME transactions on mechatronics, 12(4), pp.399-407.

[5] Morone, G., Paolucci, S., Cherubini, A., De Angelis, D., Venturiero, V., Coiro, P. and Iosa, M., 2017. Robot-assisted gait training for stroke patients: current state of the art and perspectives of robotics. Neuropsychiatric disease and treatment, pp.1303-1311.

[6] Timmermans, A.A., Seelen, H.A., Willmann, R.D. and Kingma, H., 2009. Technology-assisted training of arm-hand skills in stroke: concepts on reacquisition of motor control and therapist guidelines for rehabilitation technology design. Journal of neuro engineering and rehabilitation, 6(1), pp.1-18.

[7] Broetz, D., Braun, C., Weber, C., Soekadar, S.R., Caria, A. and Birbaumer, N., 2010. Combination of brain-computer interface training and goal-directed physical therapy in chronic stroke: a case report. Neurorehabilitation and neural repair, 24(7), pp.674-679.

[8] Connelly, L., Jia, Y., Toro, M.L., Stoykov, M.E., Kenyon, R.V. and Kamper, D.G., 2010. A pneumatic glove and immersive virtual reality environment for hand rehabilitative training after stroke. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 18(5), pp.551-559.

[9] Gijbels, D., Lamers, I., Kerkhofs, L., Alders, G., Knippenberg, E. and Feys, P., 2011. The Armeo Spring as training tool to improve upper limb functionality in multiple sclerosis: a pilot study. Journal of neuro engineering and rehabilitation, 8, pp.1-8.

[10] Zimmerli, L., Krewer, C., Gassert, R., Müller, F., Riener, R. and Lünenburger, L., 2012. Validation of a mechanism to balance exercise difficulty in robot-assisted upper-extremity rehabilitation after stroke. Journal of neuro engineering and rehabilitation, 9(1), pp.1-13.

[11] Vinstrup, J., Calatayud, J., Jakobsen, M.D., Sundstrup, E., Jørgensen, J.R., Casaña, J. and Andersen, L.L., 2018. Hand strengthening exercises in chronic stroke patients: Dose-response evaluation using electromyography. Journal of Hand Therapy, 31(1), pp.111-121.

[12] Maillot, P., Perrot, A. and Hartley, A., 2012. Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. Psychology and aging, 27(3), p.589.

[13] Dev Ritt Prasert Sri and Pairoj Lada Vijit Kul, 2015. Engineering Journal of Research and Development, 26(1), pp.79-85.

[14] Nutcha Mekcharoen and Phairoat Ladavichitkul, 2012, "Approximationof Anthropometric Data from Basic Factor for Workstation Design of Teens", IE Network Conference 2012, 17-19 October 2012, Phetchaburi Thailand.

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