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Rehago - A Home-Based Training App Using Virtual Reality to Improve Functional Performance of Stroke Patients with Mirror Therapy and Gamification Concept: A Pilot Study

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Abstract. Stroke is one of the prevalent diseases which leads to functional disabilities such as hemiparesis or hemiplegia. It is common practice to treat patients with proper rehabilitation as early as possible for better prognosis after the onset of stroke. One of the effective therapeutic techniques for treating stroke patients is mirror therapy, which can potentially facilitate patients' motor function recovery through repetitive practice. "Rehago" is a software as medical device that implements the concept of mirror therapy in combination with gamified exercises into virtual reality (VR) to provide a home-based rehabilitation environment for stroke patients. In this study, 48 stroke patients completed the full course of intervention with Rehago and their functional performance of pre- and post-intervention was investigated. The intervention with Rehago was predefined as 30 minutes training per day, 5 days per week over a course of 6 weeks. The patient's progress was evaluated by their therapists every 14 days, with a baseline assessment before the intervention began. The results showed an average improvement of 5.54 points in the Functional Independence Measurement score, and an improvement of 7.13 points in the assessed quality-of-life score (EQ5D-5L). An improvement of the FIM score and the quality-of-life score in EQ5D-5L was observed, indicating it is beneficial to the patients using Rehago as a home-based rehabilitation tool.

Keywords. virtual reality, VR, stroke, rehabilitation, home-based, mirror therapy, Rehago

1. Introduction

Cerebrovascular disease, also known as stroke, is one of the leading causes of death worldwide. 80% of stroke survivors suffer from motor impairments, muscle weakness (paresis) and pain [1]. The impairments and pains can dramatically reduce the patients' independence in performing activities of daily living (ADL) and quality of life. To retrieve the functions of the affected side, an intensive rehabilitation is typically introduced in the early stages of stroke. However, therapists often have limited time to treat each patient. Additionally, patients usually have lower motivation without professional guidance to continue rehabilitation at home.

Mirror therapy has been proven to be effective for stroke patients to improve motor function of the upper extremity and improve the performance of activities of daily living [2]. Unlike other conventional interventions relying on somatosensory stimulation, mirror therapy is mainly based on visual input to induce neurosynaptic reconnection via complex neurological mechanisms and commonly included in rehabilitation sessions [2]. As VR technology advances and becomes more cost-effective and accessible to the public, the possibility to offer the traditional rehabilitation in a digital form has been intensively researched and considered as a safe intervention [3]. Meanwhile, the concept of mirror therapy can be implemented in VR to help patients learn to complete simulated ADL tasks [3-5]. Weber et al. found that mirror therapy as a digital application improved upper extremity motor skills in stroke patients [4, 5]. Moreover, a playful and self-directed therapeutic method showed comparable effects to the conventional occupational therapy [5]. However, it is still unknown whether patients' functional performance can be improved with mirror therapy using VR. Therefore, the aim of this study was to preliminarily prove the concept that combining mirror therapy and gamification concepts in VR can improve the functional performance of stroke patients.

2. Methods

2.1. Subjects

Fifty-three stroke patients were initially recruited for this study. Five patients dropped out due to personal reasons, so in total 48 subjects (including 14 females and 34 males) completed the study. The detailed age distribution of the subjects is shown in Table 1. Inclusion criteria were (1) stroke survivors minimum two months post-stroke, (2) older than 18 years old, (3) able to understand and follow training instructions, and (4) able to use and operate a VR headset independently. Exclusion criteria were (1) musculoskeletal disorders such as shoulder pain or limited range of motion, (2) unstable cardiovascular status, (3) any cognitive or emotional disorder, and (4) other systemic disease such as epilepsy, diabetes, or hypertension. Additionally, patients were excluded if they were receiving conventional mirror therapy or other therapy using virtual reality.

Table 1. Subjects composition by age groups

Age group (year)	31-40	41-50	51-60	61-70	71-80	81-90	Total
Female	2	4	5	2	1	0	14
Male	2	6	9	8	8	1	34

2.2. Procedure

Before the study began, a brief introduction of this study was given to the subjects and the subjects signed the consent forms. Next, an explanation regarding the operation of the head-mounted display (HMD) and the Rehago software and a practice session was instructed and supervised by therapists to prevent any biased results due to technical issues. Therapists then suggested a series of training in Rehago to individual subject based on their ability and functional level. Daily training duration of 30 minutes was required for each subject to accomplish [11, 12]. After the subjects were fully informed with the training process and requirement, each subject's baseline data was evaluated by the therapists using Functional Independence Measure (FIM) and the EQ5D-5L, and a follow-up evaluation was conducted every 14 days using the same instruments (Fig. 1).

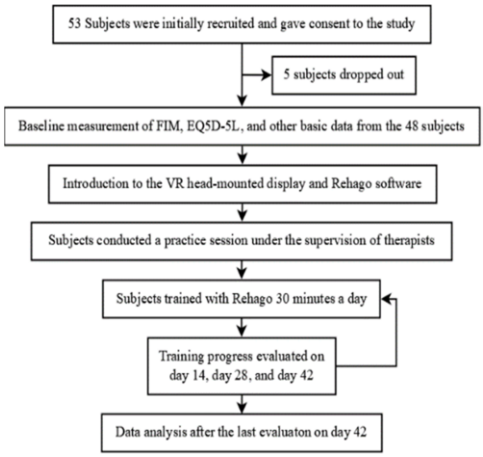

Figure 1. *Flow chart of the subject's journey*

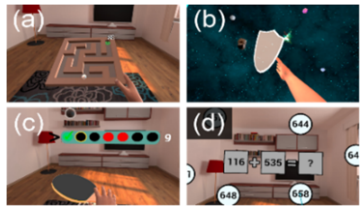

Figure 2. *Screenshots of training examples of Rehago (a) labyrinth (b) asteroids blocking (c) ball bouncing (d) calculations*

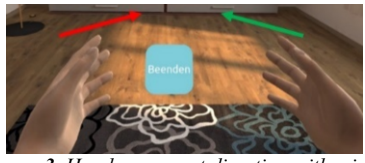

Figure 3. *Hand movement direction with mirror mode activated. If the controller is in right hand and move towards left (green arrow), the left hand will move towards right (red arrow).*

2.3. Hardware and Software

In this study, the standalone HMD Pico Neo 2 (Pico Interactive, China) was chosen for its performance and cost-effectiveness. The headset of Pico Neo 2 has 6 degrees of freedom (DOF) using inside-out tracking, 101 degrees of field of view, and is equipped with two controllers both with 6 DOF tracking. Meanwhile, Pico Neo 2 provides 4K display resolution to ensure the high fidelity of the content. Rehago software (v1.2.0, ReHub GmbH, Germany) was pre-installed on all the HMDs. Rehago is a CE marked software, which has 10 gamified trainings targeting different body parts for the purpose of upper limb rehabilitation for stroke patients. Screenshots of the example training in Rehago are shown in Fig. 2. A simulated mirror (therapy) mode was implemented in Rehago. If a stroke patient has left-side hemiplegia, he needs to hold the controller in the right hand and the movement of the right hand will be “mirrored” to the left hand, as shown in Fig. 3.

2.4. Outcome Measures

2.4.1 Functional Independence Measure (FIM)

This instrument measures the patient's independence of various aspects, such as self-care, including sphincter control, transfers, locomotion, communication, and social cognition. FIM is a reliable tool and is widely used to evaluate the progress of a patient's level of disability after receiving medical treatment or rehabilitation.

2.4.2 EQ5D-5L

The EQ5D-5L is a short questionnaire containing five questions with five possible answers each (5L), which was introduced by the EuroQol Group in 2009. EQ5D-5L contains five aspects, including mobility, self-care, usual activities, pain, or discomfort, as well as anxiety or depression. The “current perception of health”, Quality of Life (QoL), is evaluated on a scale from 1 to 100. This is a subjective score which reflects the

self-perceived health status of the subject. This parameter was recorded for quantitative analysis in terms of changes in QoL after using Rehago.

2.5 Statistics analysis

A paired t-test was performed to check whether there was a significant difference between the initial baseline and the follow-up evaluation (i.e., day 14, day 28, and day 42).

Table 2.: Mean scores (Mean ± SD) of the FIM, QoL, and EQ5D-5L from different time. The p-values were calculated against baseline scores (day 1) of each measure with the significance level set to 0.05.

Measures \ Time	Day 1	Day 14	Day 28	Day 42
FIM	101.48 ± 19.08	103.77 ± 17.79 (p = 0.001*)	105.96 ± 16.69 (p = 0.0002*)	107.02 ± 16.32 (p = 0.0001*)
QoL	69.25 ± 17.63	70.25 ± 17.93 (p = 0.397)	74.81 ± 15.53 (p = 0.003*)	76.38 ± 13.61 (p = 0.00003*)
EQ5D-5L†	12.52 ± 4.19	12.1 ± 3.85 (p = 0.044*)	12.15 ± 3.81 (p = 0.272)	11.62 ± 3.93 (p = 0.026*)

†EQ5D-5L ranges from 1 (more independent) to 5 (more dependent), lower score indicates higher independence.

3. Results

At the end of the study, 48 subjects completed the study, and their data was analyzed. Table 2 summarized the mean scores (Mean ± SD) of the FIM, QoL, and EQ5D-5L from different time. The p-values were calculated against baseline scores (day 1) of each measure with the significance level set to 0.05.

The baseline score of FIM was 101.48±19.08, and it increased to 107.02±16.32 at day 42. The FIM score between baseline and the last evaluation showed a significant difference with paired t-testing ($p < 0.01$).

The mean QoL score describes personal momentary well-being and is measured by the EQ5D-5L questionnaire. The baseline score of QoL was 69.65±17.63 and it increased to 76.38±13.61 at day 42. The QoL between baseline and the last evaluation showed a significant difference with paired t-testing ($p< 0.01$). The mean 5L score from the EQ5D-5L was 12.52±4.19 and it reduced to 11.62±3.93 at day 42. The 5L score between baseline and the last evaluation showed a significant difference with paired t-testing ($p< 0.05$).

4. Discussion

This study aimed to prove the concept that stroke patients can benefit from digital mirror therapy in virtual reality by examining the functional performance with reliable evaluation instruments. The main finding in this study showed that patients' functional performance improved after 42 days of training using Rehago. Because 82.5% of the subjects participating in this study were already in chronic stage (more than 12 months since the onset of stroke), a huge improvement in functional performance or motor skills may not be expected as suggested in the previous study [6]. Besides, the evaluation instruments used in this study may not be sensitive enough to detect subjects' improvement of functional performance due to the design. Nevertheless, an average

improvement of 5.54 points of the FIM and an average improvement of 7.13 points in the QoL during the study were observed, indicating that the subjects acquired improvement of independence in executing ADLs and a higher quality of life after training with Rehago. One thing to note is that the EQ5D-5L score shows a significant difference between the baseline and day 14 (p=0.044), baseline and day 42 (p=0.026), respectively. However, there is no significant difference between the baseline and day 24 (p=0.272), and the reason may result from the design of the instrument, the status of the subjects during the evaluation, and the relatively small sample size of this study. In addition, several publications advocate further research of digital technology in rehabilitation. The use of VR technology can not only increase the expected adherence but relieve the health care system and the therapists and thus counteract subsequent costs through additional home training [3, 5, 7].

5. Conclusion

The results of this pilot study show an observable improvement of patients' functional performance, which supports our hypothesis that the functional performance of stroke patients can be improved by conducting gamified mirror therapy in VR. Our results also align with other relevant publications [8-10]. However, to obtain more evidence of the training effects with Rehago, a comprehensive study with a structured interventional plan and subject grouping may be beneficial. Moreover, it is also meaningful to investigate whether the training effect of performing ADL tasks using VR can be carried over to real world scenarios. Therefore, Rehago as one of the pioneers of VR-based rehabilitation software will continue improving and constantly update new training content to offer better user experience and training effect to users.

References

[1] S. Knecht, S. Hesse, and P. Oster, "Rehabilitation After Stroke," *Dtsch. Aerzteblatt Online*, Sep. 2011.
[2] H. Thieme *et al.*, "Mirror therapy for improving motor function after stroke," *Cochrane Database Syst. Rev.*, vol. 7, p. CD008449, 2018.
[3] R. Ballantyne and P. M. Rea, "A Game Changer: 'The Use of Digital Technologies in the Management of Upper Limb Rehabilitation,'" *Adv. Exp. Med. Biol.*, vol. 1205, pp. 117–147, 2019.
[4] L. M. Weber, D. M. Nilsen, G. Gillen, J. Yoon, and J. Stein, "Immersive Virtual Reality Mirror Therapy for Upper Limb Recovery After Stroke: A Pilot Study," *Am. J. Phys. Med. Rehabil.*, vol. 98, no. 9, pp. 783–788, Sep. 2019.
[5] M. A. Ahmad, D. K. A. Singh, N. A. Mohd Nordin, K. Hooi Nee, and N. Ibrahim, "Virtual Reality Games as an Adjunct in Improving Upper Limb Function and General Health among Stroke Survivors," *Int. J. Environ. Res. Public. Health*, vol. 16, no. 24, 2019.
[6] G. Kwakkel, B. J. Kollen, J. van der Grond, and A. J. H. Prevo, "Probability of Regaining Dexterity in the Flaccid Upper Limb: Impact of Severity of Paresis and Time Since Onset in Acute Stroke," *Stroke*, vol. 34, no. 9, pp. 2181–2186, Sep. 2003.
[7] G. Burdea, "Virtual rehabilitation-benefits and challenges. Methods of information in medicine." 2003.
[8] Y.-W. Hsieh, Y.-H. Lin, J.-D. Zhu, C.-Y. Wu, Y.-P. Lin, and C.-C. Chen, "Treatment Effects of Upper Limb Action Observation Therapy and Mirror Therapy on Rehabilitation Outcomes after Subacute Stroke: A Pilot Study," *Behav. Neurol.*, vol. 2020, p. 6250524, 2020.
[9] J.-Y. Park, M. Chang, K.-M. Kim, and H.-J. Kim, "The effect of mirror therapy on upper-extremity function and activities of daily living in stroke patients," *J. Phys. Ther. Sci.*, vol. 27, no. 6, pp. 1681–1683, 2015.
[10] M. Invernizzi, S. Negrini, S. Carda, L. Lanzotti, C. Cisari, and A. Baricich, "The value of adding mirror therapy for upper limb motor recovery of subacute stroke patients: a randomized controlled trial," *Eur. J. Phys. Rehabil. Med.*, vol. 49, no. 3, pp. 311–317, Jun. 2013.
[11] S. B. O'Sullivan, T. J. Schmitz, and G. D. Fulk, *Physical rehabilitation*, 6th ed. Philadelphia: F.A. Davis Co, 2014.
[12] N. A. Aziz, J. Leonardi-Bee, M. Phillips, J. R. F. Gladman, L. Legg, and M. F. Walker, "Therapy-based rehabilitation services for patients living at home more than one year after stroke," *Cochrane Database Syst. Rev.*, no. 2, p. CD005952, Apr. 2008.