Adherence and arm function improvements with home-based distal arm training using robotics and gaming after stroke

G.B. Prange, PhD[1,2]
S.M. Nijenhuis, MSc[1]
P. Sale[3], MD
A. Cesario[3], MD
N. Nasr[4], PhD
G. Mountain[4], PhD
F. Amirabdollahian, PhD[5]
J.H. Buurke, PT, PhD[1,6]

[1] Roessingh Research and Development, Enschede, the Netherlands
[2] Department of Biomechanical Engineering, University of Twente, Enschede, the Netherlands
[3] Department of NeuroRehabilitation, IRCCS San Raffaele Pisana, Rome, Italy
[4] School of Health and Related Research, University of Sheffield, Sheffield, United Kingdom
[5] Adaptive Systems Research Group, University of Hertfordshire, Hatfield, United Kingdom
[6] Department of Biosystems and Signals, University of Twente, Enschede, the Netherlands

1 Background

Functional recovery from stroke requires extensive rehabilitation with high training dose, active initiation and execution of movements, and application of functional exercises to stimulate restoration of arm function [1, 2]. In clinical practice however, intensity of post-stroke treatment is often restricted due to limited availability of healthcare professionals and/or high costs of neurorehabilitation.

Technological innovations provided an opportunity to design interventions that take many key aspects of motor relearning into account, of which rehabilitation robotics is a well-known example. Contemporary robot-aided therapy focuses mainly on the proximal arm, and results in improvements in the proximal arm only, without generalization to the wrist and hand [3, 4], while the wrist and hand play a major role in a person's functional independence [5]. If a system that supports active, distal arm practice can be applied in a patient's home within a telerehabilitation concept [6], a larger dosage of treatment can be delivered while the patient practices independently with remote supervision by a healthcare professional. In such a home-based application, the adherence of a patient to the training programme is an important but often unknown factor that likely affects the actual dosage of treatment delivered [7].

In the current study (Supervised Care and Rehabilitation Involving Personal Tele-robotics, SCRIPT), a custom-designed orthosis that passively supports wrist and hand function is combined with a motivational user interface with gaming environment, connected to a remote module for off-line supervision by a healthcare professional. This system (SCRIPT1) is used independently at home by chronic stroke patients for distal arm training. The present paper aims to examine the adherence of chronic stroke patients to home-based SCRIPT1 training and associated changes in arm function.

2 Methods

The present study applied a longitudinal (pre-post) experimental study design, with an intervention of six weeks of home-based arm/hand training with the SCRIPT1 system.

In total, 24 chronic stroke patients with impaired arm/hand function have been included in this study across 3 clinical sites: Roessingh Research and Development (the Netherlands), IRCSS San Raffaele Pisana (Italy) and University of Sheffield (United Kingdom). The study was approved by the local medical ethics committees of the 3 sites and all participants provided written informed consent before entering into the study.

Participants performed six weeks of self-administered distal arm training at home. It was recommended to exercise 180 minutes per week, but they were free to train as they preferred. They wore a custom-designed hand/wrist orthosis (Fig. 1) that passively supported wrist extension and hand opening across all fingers of the affected arm (details can be found elsewhere [8]). With the instrumented orthosis they played custom-designed games displayed on a touchscreen, while they were supervised remotely, off-line, by a trained healthcare professional (HCP). Additionally, all participants used the SaeboMAS (Saebo Inc, Charlotte NC, USA) arm support for the proximal arm, set to provide 100% of arm weight compensation.

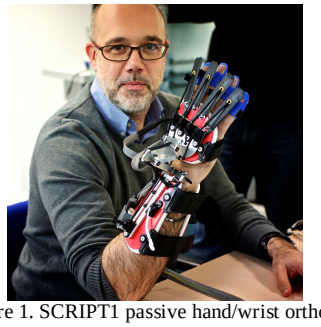

Figure 1. SCRIPT1 passive hand/wrist orthosis

Evaluation involved adherence in terms of actual use (training duration in minutes recorded in-game) and arm motor function assessment using the Fugl-Meyer scale (FM [9, 10]) one week before (T01) and after (T08) 6-week training. Changes in arm function were compared pre- and post-training using the Wilcoxon signed-rank test (significance level $\alpha < 0.05$).

3 Results

Of the 24 included patients, 3 have dropped out during the study, due to shoulder complaints acting up, dislike of

the system and technical issues. Mean age of the remaining 21 participants was 58 years, mean time post-stroke was 17 months.

Average training duration was 105 (±66) minutes per week. This comes down to about 15 minutes of self-administered training each day for 6 weeks. Individually, training duration varied substantially, ranging from 13 up to 284 minutes (4 hours and 44 minutes) per week.

Clinical outcomes showed improvements after training. FM scores increased significantly by 4.0 points (±4.8) on group level (p=0.002): from mean 33.1 ± 15.8 (median 37.0) to 37.1 ± 16.3 (median 41.0) points. On individual level, 8 out of 21 participants exceeded minimal clinically important differences (MCID: +6.6 points [11]).

4 Interpretation

The majority of participants (87%) were able to use the SCRIPT1 system as tool for self-administered training, with an average adherence of 105 minutes per week. This amount of use was associated with an improvement in arm motor function of on average +4 FM points and with clinically relevant changes in 38% of participants.

These improvements in arm function are along similar lines as those found in robot-aided studies in chronic stroke [3], as well as actively [12] and passively [13, 14] actuated arm support for the proximal arm. In contrast to the current intervention, these studies involved face-to-face supervision and a fixed schedule of practice (ranging from 1½ hours per week [12, 14] to 3 hours per week [13]).

There are only few studies that have examined home-based arm/hand training after stroke. A review by Coupar et al. 2012 included only four studies on telerehabilitation focusing on training of the upper limb after stroke in the home situation [15]. Although no negative results of home-based training were reported with regard to usual care or a similar treatment in the hospital setting, there was insufficient evidence to conclude whether home-based training is equally or more effective to improve arm function. In these studies, participants received direct real-time (remote) supervision from a therapist and the actual amount of self-administered training at home wasn't examined.

In contrast, the SCRIPT1 system allowed stroke patients to choose their own training time and duration and have a more active role in their rehabilitation, involving their family members and carers as well. This restricts a thorough comparison of adherence and associated improvements in arm function with similar studies. Anecdotal evidence from physiotherapists involved in the present study have mentioned that the achieved adherence of about 15 minutes per day is rather high for chronic stroke patients to exercise at home after discharge from rehabilitation, which is promising for the potential to engage people in home-based arm/hand training post-stroke.

The preliminary findings in the present study indicate that when provided with the opportunity, stroke patients have the personal incentive to perform substantial amounts of practice at home as a mean training duration of 1¾ hours per week was observed. Some participants even reached a recommended 16h of additional practice across the 6-week training that has been proposed as the minimal amount of additional training for achieving functional gains [7]. This highlights that technology-supported arm/hand training is a promising tool to enable self-administered practice at home for (certain) chronic stroke patients. Further research is needed to examine potential mediating or promoting factors for clinical improvements (e.g., initial stroke severity, age, motivation, etc.).

References

[1] J.W. Krakauer, "Arm function after stroke: from physiology to recovery," *Semin Neurol*, vol. 25, pp. 384-395, 2005.

[2] J.D. Schaechter, "Motor rehabilitation and brain plasticity after hemiparetic stroke," *Prog Neurobiol*, vol. 73, pp. 61-72, 2004.

[3] G.B. Prange, M.J.A. Jannink, C.G.M. Groothuis, H.J. Hermens, and I.J. MJ, "Systematic review of the effect of robot-aided therapy on recovery of the hemiparetic arm after stroke," *J Rehabil Res Dev*, vol. 43, pp. 171-184, 2006.

[4] J. Mehrholz, A. Hädrich, T. Platz, J. Kugler, and M. Pohl, "Electromechanical and robot-assisted arm training for improving generic activities of daily living, arm function, and arm muscle strength after stroke," *Cochrane Database Syst Rev*, p. CD006876, 2012.

[5] A.A. Timmermans, H.A. Seelen, R.D. Willmann, and H. Kingma, "Technology-assisted training of arm-hand skills in stroke: concepts on reacquisition of motor control and therapist guidelines for rehabilitation technology design," *J Neuroeng Rehabil*, vol. 6, p. 1, 2009.

[6] H.J. Hermens and M.M. Vollenbroek-Hutten, "Towards remote monitoring and remotely supervised training," *J Electromyogr Kinesiol*, vol. 18, pp. 908-919, 2008.

[7] G. Kwakkel, "Intensity of practice after stroke: More is better," *Schweiz Arch Neurol Psychiatr*, vol. 160, pp. 295-298, 2009.

[8] S. Ates, J. Lobo-Prat, P. Lammertse, H. Van der Kooij, and A.H.A. Stienen, "SCRIPT Passive Orthosis: Design and technical evaluation of the wrist and hand orthosis for rehabilitation training at home," in *IEEE International Conference on Rehabilitation Robotics (ICORR) 2013*, Seattle (WA), USA; 2013: pp. 1-6.

[9] A.R. Fugl-Meyer, L. Jaasko, and V. Norlin, "The post-stroke hemiplegic patient. II. Incidence, mortality, and vocational return in Goteborg, Sweden with a review of the literature," *Scand.J.Rehabil.Med.*, vol. 7, pp. 73-83, 1975.

[10] A. Deakin, H. Hill, and V.M. Pomeroy, "Rough Guide to the Fugl-Meyer Assessment: Upper limb section," *Physiotherapy*, vol. 89, pp. 751-763, 2003.

[11] J.H. Van der Lee, H. Beckerman, G.J. Lankhorst, and L.M. Bouter, "The responsiveness of the Action Research Arm test and the Fugl-Meyer assessment scale in chronic stroke patients," *J Rehabil Med*, vol. 33, pp. 110-113, 2001.

[12] F. Amirabdollahian, R. Loureiro, E. Gradwell, C. Collin, W. Harwin, and G. Johnson, "Multivariate analysis of the Fugl-Meyer outcome measures assessing the effectiveness of GENTLE/S robot-mediated stroke therapy," *J Neuroeng Rehabil*, vol. 4, p. 4, 2007.

[13] S.J. Housman, K.M. Scott, and D.J. Reinkensmeyer, "A randomized controlled trial of gravity-supported, computer-enhanced arm exercise for individuals with severe hemiparesis," *Neurorehabil Neural Repair*, vol. 23, pp. 505-514 (DOI:10.1177/1545968308331148), 2009.

[14] G.B. Prange, T. Krabben, G.J. Renzenbrink, M.J. IJzerman, H.J. Hermens, and M.J.A. Jannink, "Changes in muscle activation after reach training with gravity compensation in chronic stroke patients," *Int J Rehabil Res*, vol. 35, pp. 234-242, 2012.

[15] F. Coupar, A. Pollock, L.A. Legg, C. Sackley, and P. van Vliet, "Home-based therapy programmes for upper limb functional recovery following stroke," *Cochrane Database Syst Rev*, vol. 5, p. CD006755, 2012.