User Centred Networked Health Care
A. Moen et al. (Eds.)
IOS Press, 2011

doi:10.3233/978-1-60750-806-9-676

Virtual TeleRehab: A Case Study

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Abstract. We examined the efficacy of a remotely based occupational therapy intervention. A 40-year-old woman who suffered a stroke participated in a telerehabilitation program. The intervention method is based on virtual reality gaming to enhance the training experience and to facilitate the relearning processes. The results indicate that Virtual TeleRehab is an effective method for motivational, economical, and practical reasons by combining game-based rehabilitation in the home with weekly distance meetings.

Keywords. Occupational therapy, Stroke, Telerehabilitation, Virtual Reality

1. Introduction

According to the WHO, by 2050, over 700,000 Americans and 920,000 Europeans will have a stroke each year, of whom more than 50% will survive [1]. There are several reports in the literature showing that virtual reality (VR) games in stroke rehabilitation can be successful [2, 3]. Nevertheless, there has been limited research involving telerehabilitation (TR) with the incorporation of VR games into the home setting [4]. In particular, evaluation studies of telehealth systems for the elderly and disabled are rare [5]. For stroke rehabilitation, motivation to continue work on improving functional abilities after returning home is a major issue for stroke veterans [6]. The authors conclude that designing home-based telerehabilitation programs have to improve functional mobility combining with weekly real-time contact.

We deployed a telerehabilitation system [7] in the rehabilitation process for continuous and frequent monitoring of the patient's functionality in order to deliver occupational therapy in the home environment and adapt it to the patient's progress. This differs from the typical telemedicine service that involves a short intensive session with one or more clinicians and a patient. In a previous study [8], on-line coaching meetings were shown to be feasible but not efficient enough.

The aim of the current study is to investigate the role of training progression interfaces as a *boundary object* for improving the meaning and effect of online meetings. A boundary object [9] allows people to use a shared information artifact supporting communication and interaction [10].

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2. The Telerehabilitation System

The TR system consists of a desktop-sized immersive workbench (www.curictus.com), which uses a three-dimensional (3D) virtual environment with games with an inbuilt rehabilitation component (serious games) designed for upper extremity (UE) movement therapy, and assessment. A patient care management system (PCMS) enables the transfer of real time system data and maintains an archive of all information. Furthermore, the PCMS logged effective training and overall time using the system, performance parameters such as results of each game; number of times run, and performance for each run. The occupational therapist (OT) can observe and graph subjects' progress and discuss games to be played, view progression data during the on-line meetings as shown in Figure 1.

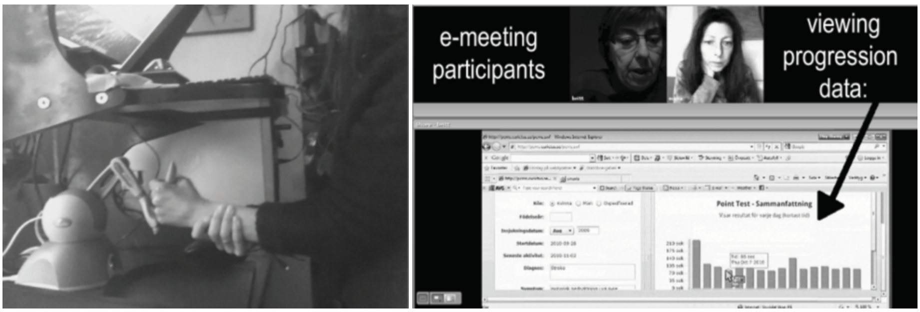

Figure 1. The telerehabilitation system (left) and a screen shot from a clinician-patient online meeting (right).

3. The Study

The scenario is that the user sits at home in front of a computer monitor with stereoscopic 3D visualization and holds a haptic stick (a robotic arm with a track stick, which mediates a feeling of touch and force feedback) with which he/she performs different "serious games". Prior to entering the study, the stroke subject learned utilizing the TR system and was instructed to play serious games for at least 20 minutes a day during 10 consecutive weeks. Once a week the OT monitors and coaches the subject from a distance. For collection of assessments and audiovisual communication between therapists and patient, the system had bidirectional contact with the home-based units. The referral criteria were 1) diagnosis of stroke; 2) hemparesis in one of the upper extremities, that is, box and blocks score lower than 45 [11]; and 3) no signs of neglect; Exclusion criteria were 1) joint problems or prior injury to arm/hand; and 2) language difficulty that affects information reception. The Regional Ethical Review Board in Gothenburg, Sweden, approved the study and the subject included gave written informed consent.

The subject was a woman in her early forties, right handed, and had a first-occurrence stroke. The time since the stroke was 1 year at the study admission. The cause was an infarct; and the diagnosis was determined by a neurologist after clinical examination and confirmed by computed tomography scan. The subject was able to ambulate independently and could move her arm partially with a weak lateral grasp. Her body awareness and spatial competence were normal. There were no limitations in understanding the information given. Most of her activities of daily living (ADLs) were accomplished by compensating with the right arm.

The intervention used a pre-/post-test design. The following outcome measurements were administered: 1) grip strength using an electronic dynamometer [12]; 2) unilateral hand and upper limb function (ARAT) [13]; and 3) current self-ratted health-related quality of life by the EQ VAS on a graduated (0–100) scale, with 100 indicating the best health status [14]. Movement kinematics were measured with the PHANToM Omni® (haptic stylus end-point); from this, time (s) to complete the test were recorded [15]. During intervention, seven online and 3 face-to-face (f2f) meetings were recorded. Conversational Analysis [16] was used to classify content in categories, to analyse fluency of conversation [8], and to identify occurrences of encouragements and positive feedback given by the therapist. Each conversational topic was classified into *social talk, health status, planning*, *training discussion,* and *technical issues*; and the duration was timed. Each motivational phrase was counted, and related to the topic. After the intervention, the subject and the therapist were interviewed.

4. Results

The data suggest that the improvement was most prominent in grip force and the UE test. Hand strength increased from 68 to 98 Newton and time to complete the UE test decreased from 227 to 87 seconds. Gains in manual ability (ARAT) were noted from 19/57 to 22/57. The EQ5D Vas score was stable through the whole continuum, i.e. 75 and 80 pre/post testing respectively. The subject had 10 hours of game play and a total time of 13.5 hrs using the system.

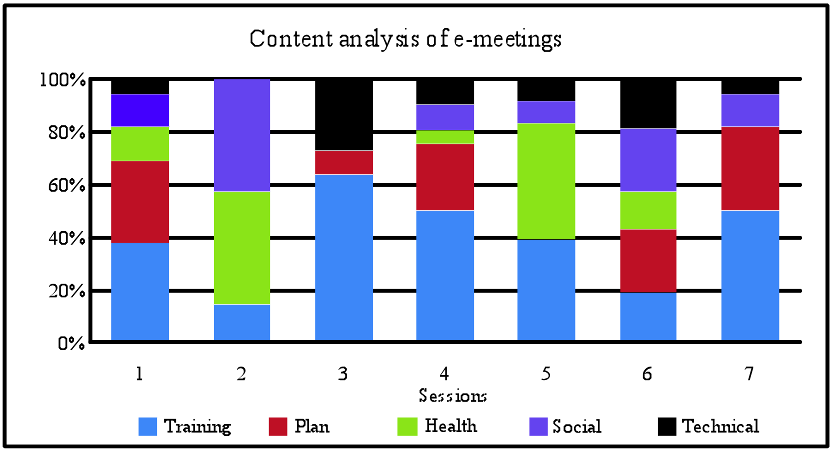

Figure 2. Topics discussed during e-meetings.

Categorizations and duration of topics in online meetings are shown in Figure 2. The first two lasted about 8 minutes, the remaining 5 when progression data was used, about 20 minutes each. Training was the most discussed topic, followed by future planning, health discussions and social talk.

For the f2f meetings, health discussions (i.e., hand position, grip, and tactile sensation) were by far the dominating topic. Technical issues concerned problems using the progression data interface at start (session 3), and issues of the workbench. There was no time spent on conversation management, a large improvement from the almost 50% in previous study [8]. Numbers of motivational phrases given by the therapist in the sessions were 3, 2, 11, 28, 8, 5 and 9, respectively. The high amount in session 4 was due to the subject's unusual lack of motivation and self-esteem, recognized by the therapist and acted on accordingly. As much as 82% of the motivational phrases were given during training discussions, which coincide with using the progression data interface. Despite being new to video-conferencing, the subject quickly became accustomed to the medium: *"You learn to wait and handle the turn-taking procedure,"* as mentioned in the interview. Perceived advantages of the e-meetings were the convenience and time saved, being aware of progressions and the objective measures *("It is difficult to judge yourself")*, and the "push" posed by having meetings where training data was reviewed *("You want to have something to show"*. The subject visited the progression-data herself for motivation: *"Wow, I've played a lot"*. The Mentioned disadvantage compared to f2f meetings was the feeling of inhibition in verbal and gestural expression. Yet, non-verbal communication was present during meetings such as demonstrating hand positions (Figure 3A), sharing affective states such as joy (Figure 3B), or waving goodbye (Figure 3C).

Figure 3. E-meeting screen shots: A) showing hand position, B) moment of shared joy, C) waving goodbye.

5. Results

The proposed TR gaming system (Figure 1) helped the OT to follow up the patient's involvement with the training program. The PCMS logged automatically the frequency and duration of training sessions, which allowed evaluation of the subject's compliance with the training program, and her progress. Furthermore, the subject improved in all outcome measures. The haptic technology offers unique possibilities to measure and visualize hand trajectories and obtains significant information about the analyzed patient's hand movements: precision, speed, and speed adaptation, force applied and force adaptation, search patterns, targets identification and others. In this study, we only analyzed the time to complete the UE test because the aim was to investigate the role of training progression interfaces as a *boundary object* for improving meaning and effect of online meetings. Previous studies by our group have shown positive effects on motor and cognitive rehabilitation.

Computer mediated communication can be learned to be almost as effective as f2f communication [17], also evident from this study. For a coaching situation, affective states of encouragement, confirmation, and acknowledgement, often transmitted with non-verbal subtle signal [18], were communicated effectively by a combination of face expressions, voice tone and verbal statements. The objective progression data, the boundary object, played a vital role as witnessed from the analysis and the interviews. Having rich, personal data depicting activities and progress, allowed the therapist to identify positive trends, confirm activities and encourage setting new goals. It was also used as incitement and self-confirmation for training. Combining f2f and e-meetings during intervention gave indications on topics appropriate for online and which require f2f meetings. As expected, physical examination and discussions require being present, but besides that the other coaching aims were achieved online. The appropriate meeting frequencies were estimated to about once a week for e-meetings and once a month for f2f meetings.

To conclude, our study indicates that virtual telerehabilitation can be an effective method for motivational, economical, and practical reasons by combining game-based rehabilitation in the home with weekly distance meetings and monthly physical meetings using progression and activity data as boundary objects.

References

[1] WHO, *International Classification of Functioning, Disability and Health: ICF,* World Health Organization, Geneva, 2001.

[2] Adamovich, S. V. Fluet, G. G. Tunik, E. Merians, A. S. Sensorimotor training in virtual reality a review, *NeuroRehabilitation* **25** (2009), 29–44.

[3] Henderson, A. Korner-Bitensky, N. Levin, M. Virtual reality in stroke rehabilitation: a systematic review of its effectiveness for upper limb motor recovery, *Top Stroke Rehabil* **14** (2007), 52–61.

[4] Crosbie, J. H. Lennon, S. Basford, J. R. McDonough, S. M.Virtual reality in stroke rehabilitation: still more virtual than real, *Disabil Rehabil* **29** (2007), 1139–1146.

[5] Koch, S. Home telehealth--current state and future trends, *Int J Med Inform* **75** (2006), 565–576.

[6] Lutz, B. J. Chumbler, N. R. Roland, K. Care coordination/home-telehealth for veterans with stroke and their caregivers: addressing an unmet need, *Top Stroke Rehabil* **14** (2007), 32–42.

[7] Broeren, J. Johansson, B. Ljungberg, C. Pareto, L. Sunnerhagen, K. Rydmark, M. Refinement of an ICT Based NeuroRehabilitation System Employing Telemedicine, Haptics, 3D-visualization and Serious-games. *European Notes in Medical Informatics,* Antalya, 2009.

[8] Broeren, J. Pareto, L. Ljungberg, C. Johansson, B. Sunnerhagen, K. Rydmark, M. Telehealth using 3 D Virtual Environments in Stroke rehabilitation - Work in Progress, *Proceedings Intl Conf on Disability, Virtual Reality and Assoc Technologies* (2010), 115–122.

[9] Star, S. L. Griesemer, J. R.Institutional Ecology, 'Translations', and Boundary Objects: Amateurs and Professionals in Museum of Vertebrate Zoology, *Social Studies of Science* **19** (1989), 387–420.

[10] Østerlund, C. The Materiality of Communicative Practices: The boundaries and objects of an emergency room genre, *Scandinavian Journal of Information Systems* **20** (2008), 7–40.

[11] Mathiowetz, V. Volland, G. Kashman, N. Weber, K. Adult norms for the Box and Block Test of manual dexterity, *Am J Occup Ther* **39** (1985), 386–391.

[12] Nordenskiold, U. M. Grimby, G. Grip force in patients with rheumatoid arthritis and fibromyalgia and in healthy subjects. A study with the Grippit instrument, *Scand J Rheumatol* **22** (1993), 14–19.

[13] Lyle, R. C. A performance test for assessment of upper limb function in physical rehabilitation treatment and research, *Int J Rehabil Res* **4** (1981), 483–492.

[14] Brooks, R. EuroQol: the current state of play, *Health Policy* **37** (1996), 53–72.

[15] Broeren, J. Rydmark, M. Sunnerhagen, K. S.Virtual reality and haptics as a training device for movement rehabilitation after stroke: a single-case study, *Arch Phys Med Rehabil* **85** (2004), 1247–1250.

[16] Mazur, J. M. *Handbook of research on educational communications and technology,* Lawrence Erlbaum Associates, New York, 2004.

[17] Cornelius, C. Boos, M. Enhancing Mutual Understanding in Synchronous Computer-Mediated Communication by Training Trade-Offs in Judgmental Tasks, *Communication Research* **30** (2003), 147–177.

[18] Walther, J. B. Loh, T. Granka, L. Let me count the ways: The Interchange of Verbal and Nonverbal Cues in Computer-Mediated and Face-to-Face Affinity, *Journal of Language and Social Psychology* **24** (2005), 36–65.