Virtual Rehabilitation after Stroke

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Abstract. The purpose of this project was to investigate the effects of Virtual Reality technology and haptics for stroke rehabilitation. Twenty-nine stroke subjects, 17 women, and 12 men aged 44-85 years, participated in three different studies. All participants responded favorable to the use of the VR activity station. A change of attitude took place after the subjects were exposed to playing computer games. The general experience with the VR application approach suggests that this treatment concept is promising in stroke rehabilitation, with a wide range of applicability.

Key words. haptics, rehabilitation, stroke, virtual reality

Introduction

Stroke is one of our most widespread diseases in the Western world and the principal cause of permanent physical impairment in the adult population in Sweden [1]. One of the most striking social consequences of stroke is a failure to resume activities, which are purely for enjoyment [2]. In addition, enjoyable and pleasurable activities seem to be even further decreased in older adults who have experienced a stroke [3]. This striking decrease is said to be due to depression, upper extremity motor dysfunction, or decreased visuo-spatial ability [4].

In the last decade of the 20th-century, virtual reality technologies first began to be developed and studied as potential tools for assessment and treatment in rehabilitation [5]. The idea behind creating Virtual Reality (VR) is simple; a simulated world runs on a computer system. Training with haptic devices has been suggested to enhance stroke rehabilitation using VR [6-8].

Employing computer games to enhance training motivation is an opportunity, illustrated by the growing interest in the field of Serious Games (www.seriousgames.org). A serious game is a computer-based game with the goal of education and/or training in any form. This stands in contrast to traditional computer games, whose main purpose is to entertain. Serious games include games for learning, games for health, and games for policy and social change. The healthcare sector is showing a steadily increasing interest in serious games. Integrating gaming features
into virtual environments has been reported to enhance motivation in adults undergoing physical and occupational therapy following a stroke [9].

The aim of this project was twofold: (1) to assess the application of a VR activity station as an occupational therapy assessment/treatment method in a hospital and non-hospital environment to see if it could be used there and to evaluate whether playing 3D computer games resulted in improved motor function in persons with prior stroke. (2) to apply the VR activity station as a tool for assessing visuospatial neglect.

1. Material and methods

1.1. Subjects

Twenty-nine stroke subjects, 17 women and 12 men, aged 44-85 years, post stroke 1-140 months, participated in three different studies. Thirteen subjects underwent in- or out-patient rehabilitation at the Department of Rehabilitation Medicine at Sahlgrenska University Hospital, and 16 underwent rehabilitation in a facility for community dwelling persons with stroke (Stroke Forum) in Göteborg, Sweden. A group of healthy individuals (self-perceived health) were recruited and served as reference subjects (range 33–85 years). The study was approved by the Ethics Committee of Göteborg University (Ö511-01), and all participants gave their informed consent.

1.2. System

A VR activity station was used (figure 1). The user stood in the real world and looked into a virtual world generated in the computer. He or she was now able to reach into a virtual space and interact with 3-dimensional (3D) objects through a handheld stylus (haptic device) positioned in the line of sight. It created an illusion of virtual objects for the user while the only real element was the handheld stylus and the computer equipment. Using stereoscopic shuttered glasses, the user observed a 3D image displayed above the tabletop. Every time an activity was run, data about the 3D hand movements of the patient was collected and analysed. The VR activity station features a library of engaging activities and “games” that are simultaneously entertaining for the patient and beneficial for rehabilitation (figure 2).

Telemedicine based on Skype™ with a camera (software version 2.5, freely available from the internet) was used as a communication tool between the therapist and the personal at the non-hospital environment, offering clinical and technical support.
1.3 Subject Assessment

A UE test developed in a previous study [10] was used. The subjects had to move the haptic stylus to different targets in the virtual world (Figure 3). The targets appeared one after the other on the screen and disappeared when pointed at. The target placements (32) in the three dimensional space, were apparently random to the patients, but actually set according to a pre-set kinematic scheme for evaluating purposes. The subject had to move as accurately and quickly as possible to each target. Hand position data (haptic stylus end-point) during each trial was gathered. The x-, y- and z-coordinates, which were time stamped, gave the basic pattern of hand movement. Time and distance to complete the whole exercise was recorded. From this average velocity and HPR (hand-path ratio - the quotient between actual hand trajectory and the straight-line distance between two targets) was calculated. The basic pattern of stylus movement in space was visualized in Matlab (www.mathworks.com), giving an indication of how hand trajectory and movement quality changed over time. A neglect test developed by our group was used (Figure 4). The VR environment consisted of 20 targets and 60 distracters (2.7 cm diameter). The target was the digit ‘1’ and the distracters were other numbers. The subjects had to press all targets marked with the digit 1, whereby the target changed color, and finally press the red button, indicating when they had finished their search.

Figure 3. VR-task (screenshot).

Figure 4. VR-task (screenshot).

Figure 5. Hand Path Ratio values shown as a boxplot (25th and 75th percentiles) for the treatment (n=16), control (n=11) and reference group (n=11). The median value (thick black line) with 10th, 90th percentiles are shown at the end of the lines.

---------- = Reference median values
2. Results

A comparison between pre/post testing suggests that all patients had a higher median in average velocity (m/s) and a decrease in median for the time (s) and HPR parameters as compared with baseline. Figure 5 gives the box plot for HPR parameter.

A further aim was to use the VR activity station as a tool for assessing visuospatial neglect, in order to analyse the manual search performance in a virtual cancellation task. Subjects with neglect as well as subjects recovered from neglect showed aberrant search performance in the VR cancellation task, i.e. mixed search patterns (Figure 6, an example), repeated target pressures, ipsilesional start of search and deviating hand movements. The data indicate that this VR task is more informative for deviating search performance.

3. Discussion

Stroke is one of the most common disabling conditions and the need for effective therapies and innovative rehabilitation is clear. The intervention studies show that the subjects made improvements in the kinematic variables measured with the VR system. Further, the VR system was placed outside the hospital to improve access to VR technology by a wider group of stroke subjects. The VR system worked without problems and made it possible to expose persons that otherwise would not have had the chance to try the VR system. Adherence to the programme was excellent and may have been facilitated by the novel technique of VR that would enhance their capacity for better UE function. A reason might be that the persons wanted to try the novel technique of VR with a hope for improving UE function [11]. Attitudes to new technology are affected by the perceived benefits of using it, positive past experiences, quality of information about it, training and follow-up, hands-on experience, the extent to which it meets user needs, and users’ enjoyment. Irizarry and colleagues [12] showed that older people welcomed high tech products, including computer-controlled ‘smart houses’ of the future, but want clearer instructions about how to use them and controls that are easy to read and handle. The use of telemedicine based on Skype™ with a camera was employed as an adjunct to communicate response to the intervention from the clinic to the non-hospital environment. This increased the efficiency while
maintaining a high quality of service to the personal and stroke subjects. When problem arose, i.e. the games would not start, the personal contacted the occupational therapist at the clinic and the problem was solved by remote instructions. Therapy-based rehabilitation is a promising approach in remote training [13, 14]. The computerized neglect test provided a quantitative analysis of detecting small variations in manual search performance otherwise not detected in standard paper-and-pencil tests. It was found that the presence or absence of visual inattention was identified for the same subjects either by using VR or the conventional neglect tests. This is consistent with earlier studies where, in visual search tasks, subjects with neglect not only exhibit omissions of visual targets but also demonstrate more general deficits in their search performance, such as an unsystematic search pattern [15, 16]. Further, both subjects with neglect and subjects who had recovered from neglect showed aberrant search performance in the VR task. The data indicate that this VR task is more informative for deviating search performance as compared with examination of search by more conventional paper-and-pencil tests.

4. Conclusion

The general experience of the VR application approach suggests that this intervention seems to be a promising tool in motor and cognitive rehabilitation, with a wide range of applicability. This project demonstrates that this technology can provide a real-time quantitative 3D task analysis and provides preliminary evidence that interactive computer use with the right training conditions may increase stroke subjects’ motor and cognitive skills.

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