Precise hand movement telerehabilitation with virtual cubes for patients with Parkinson’s disease

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ABSTRACT

The preliminary study is focused on small range of motion and finger movements in persons with Parkinson disease. We presumed that such activity can increase participation and thus slow down the progress of the disease and increase the quality of life. For that purpose we have developed a virtual environment for pick and place of small virtual cubes. The person’s hand and fingers movement were detected by a small table-top 3D camera and shown in virtual environment.

In the 3-weeks study 18 patients with Parkinson disease participated. The participants carried out 10 sessions each lasting 30 min/day. A successful rate was measured as number of collected cubes within the limited time. Additionally clinical Jebsen, Box&Blocks, 9 Hole Peg Test and UPDRS tests were carried out before and after the study. The outcomes demonstrated the feasibility of the approach in small object manipulation. The preliminary results were encouraging in terms of functional movements and also demonstrated a potential objective evaluation.

Keywords

Virtual reality; rehabilitation; Parkinson disease; precise motion; hand; home therapy, gamification

1. INTRODUCTION

Parkinson's disease (PD) is a slowly progressive degenerative disease of the extrapyramidal system, for which the cause is unknown. Usually begins in later life, at the age between 35 and 60 years. Men become ill significantly more likely than women [16]. Often the clinical features of the PD are rigidity (muscle stiffness), bradykinesia (slowness of movement), tremor and postural disorders. PD typically affects the patient's daily activities, its functioning, participation and quality of life in all stages of the disease and at different ages of patients. Currently degeneration of dopaminergic neurons that triggers changes in the basal ganglia network [9] is mainly treated by levodopa/dopamine. However, this may cause that the patients become less responsive to the medication over time. Additionally, physiotherapy has become more and more important in individuals with PD as people with PD retain more than ¾ of all activities [2], [6]. Balance, posture or upper extremity functions often impact the quality of life; especially mobility related functions and is highly related to participation.

Physiotherapy significantly increases participation and contributes to the quality of movement, physical capacity and manual activities; balance, walking, reaching, grasping, etc. Recently exercise based computer games [1] have been introduced as a rehabilitation tool to the people with PD and this field is rapidly developing. There have been several reports on functional progress and performance, but less research was dedicated to safety and clinical benefits. Most of the reports applied commercial games (Nintendo Wii or Kinect Xbox) which were often found too fast and too complex [1]. However, a feasibility study taking into consideration safety and functional outcomes (balance, dynamic gait and quality of life) when using commercial outfit of Kinect Adventures™ reported on positive outcomes [13]. Some authors also reported on positive effects of computerized cognitive training in persons with PD [8] or positive cognitive

Figure 1. The “10 cubes” game for precise hand movement and grasping intended for people with neuromuscular disorders.

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REHAB 2016, October 13 - 14, 2016, Lisbon, Portugal

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ACM 978-1-4503-4765-5/16/10…$15.00
DOI: http://dx.doi.org/10.1145/3051488.3051493

effect when using video games [14]. Nowadays, most of the studies have been dedicated to mobility, balance and large range of motion movements. This is perhaps due to the inability of commercially available “exergames” and equipment (Kinect) to assess small scale movements. For small range of motion movement like reaching and grasping so far only limited equipment was available (CyberGlove Systems LLC and similar), while the resolution and ability to track motion with the optical Kinect like systems was not sufficient. However, grasping and fine finger motions may present an important task for persons with PD and may significantly contribute to the improvement of their quality of life.

Therefore a broader scope of the presented feasibility study is to develop and optimize the hand skill training program. An efficiency and hand functions of the persons with PD could be improved. To the best of our knowledge there are only little information on virtual reality supported hand and finger skills and coordination training in persons with PD, but the raising technology offers promising results [15][10]. Recently we have developed a small virtual object manipulation task and we expected functional and clinical improvement in terms of small range of motion movements.

2. METHODOLOGY

2.1 Subjects

In the preliminary feasibility study 18 patients with Parkinson disease (68±7 y old, 169±5cm, 80±11kg and 7±4 y duration of disease) were recruited. All patients participated in the same rehabilitation program at the hospital. Inclusion criteria comprised of: a). Parkinson disease or Parkinsonism with functional disorders in upper extremities and minor problems at daily activities. b). the participants should achieve the level 2-3 in the Hoehn and Yahr Scale [5]. All tests were performed in the morning when patients were calm and relaxed (1-2 hours after the medication)

The study was approved by local ethics committee and all participants gave a written consent.

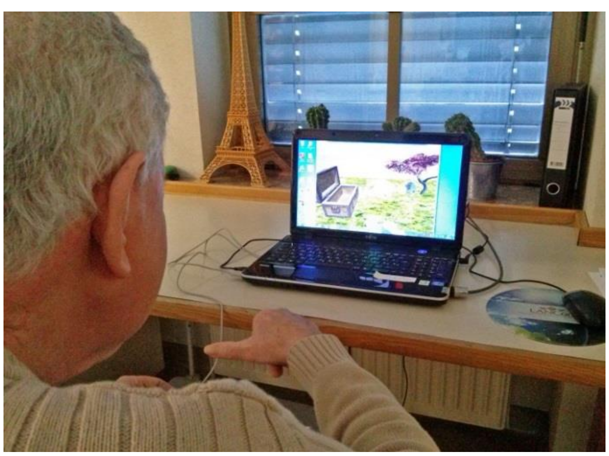

Figure 2. A person with Parkinson disease performing a precise movement task. Hand and finger motion is considered a small range of motion task.

2.2 Equipment

Two major hand tasks pinch and grip were mapped to the virtual environment (VE). The VE consisted of simulated grass floor, hidden reflecting walls and a physical model of a treasure box. All 10 cubes had a same physical model (weight, bounce stiffness, material, size), but different color. The VE was designed in Unity 3D (Unity Technologies, CA, USA). The interface to the VE was a virtual hand (left or right), also presented as a VR model. The kinematics of the VR hand was determined by the motion of the real hand. The movement of the real hand was assessed with a small, mouse size camera (Leap Motion Controller, Leap Motion Inc., CA, USA), that can detect besides 3D hand motion also the motion of the fingers (Fig. 1). Thus the participating subject can see his/her hand as a VR hand in the VE. The control software was written in C# using Leap Motion libraries and installed for the feasibility study purposes on the 15” laptop computer. Experimentally a 42” LCD screen was also used to screen the feedback. The game performance and hand and finger motion parameters were recorded locally and sent to the remote server.

2.3 Protocol

The participating subjects were seated in front of the table with laptop computer. The camera was placed on a small convenient table above the subject’s knees in order to cover the optimal working space (Fig. 2). A communication with the laptop was set through the USB port. The camera captured precise motion of the participant’s hand and fingers. Additionally a support for the participant’s arm was provided if needed. The participant’s task was to pick and place small virtual cubes (with physical model; weight, material, bouncing factor, etc.) lying around the virtual environment into the open treasure box (Fig. 1) by his/her dominant hand. When the participant dropped the cube into the treasure box, the cube disappeared. One cube by one until the last, 10th cube or until the time elapsed. To complete the task 120s were available. At the start 10 cubes were randomly spread over the virtual environment.

The participants took 10 training therapies spanning over approximately three weeks. Each session lasted for maximum 30 min. Within the designated session the participant had enough time to accomplish the VR task at least 5 times. Short 2 min. breaks were necessary between the trials.

Clinical tests (UPDRS motor function part [11], Jebsen Hand Functional Test [7], 9-hole peg test [4], Box & Blocks [3] Test) were carried out within inpatient treatment before the training therapies and after the training sessions at discharge from the hospital or within outpatient treatment.

2.4 Data analysis

The preliminary data assessed during the VR task were subject of statistical analysis (Matlab, MS Excel). Mean value and standard deviation were computed for the tasks (number of cubes collected and remaining time) carried out within each day. At least 5 measurements of the same day were taken into account. Data of the 10 consecutive assessments in three weeks were than compared. The performance was measured in higher score cubes/task and remaining time.

Additionally, the outcomes of the clinical tests (9 Hole test, Box & Blocks, UPDRS and Jebsen test) that were carried out before and after the training program have been followed and presented. A correlation between clinical test Box & Blocks [4] and game performance have been examined.

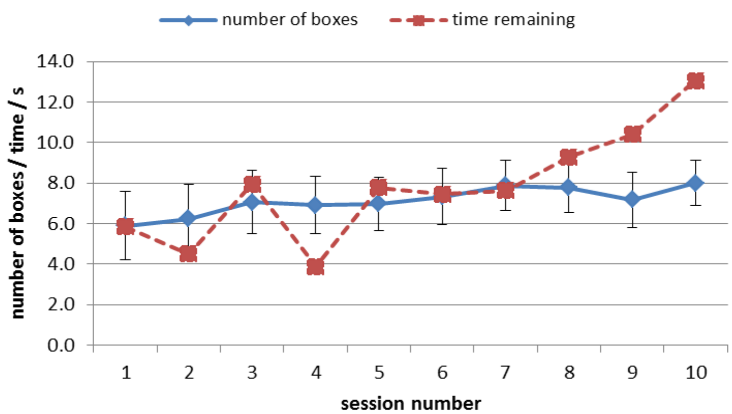

Figure 3. The outcomes of the practice with "10 cubes" virtual reality task. All patients' performance (collected cubes/task) has improved and after 10 sessions the patients even finished the task before time elapsed.

3. RESULTS

The results of the VR task (Fig 3.) demonstrate progress in grasping of small virtual objects in three weeks (10 sessions). At the beginning the participants were hardly able to pick 6 cubes in 2 min, while after 10 sessions they already picked and placed more 8.0±1.1 in average before the time elapsed (mean remaining time 13.1s). Some patients even demonstrated significant progress in the game score; .e.g. the particular participant picked and placed only 4-7 cubes in 120 min before the therapy, but after 10 sessions the results were amazing; in 4 out of 5 trials the participants managed to pick and place all 10 cubes with remaining time from 24 to 58s. The best patient improved his score from 6.8 cubes to 10 cubes with the mean remaining time 30.4±21.3. Actually all participants have improved their score and only three participants were not able to pick and place all cubes within the limited time after the therapy. However, even those participants have improved their average score from 4.6 to 7.9 cubes/task. But in 2 cases the score dropped in the last session.

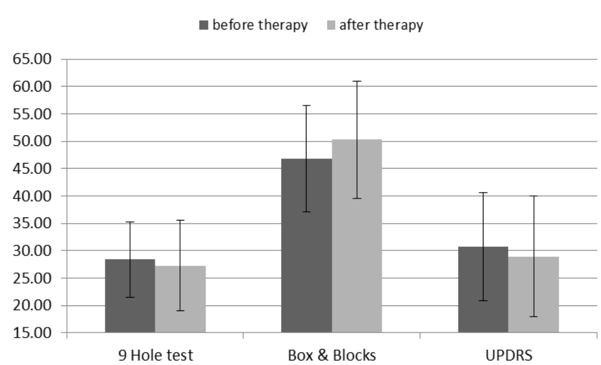

Figure 4. Clinical test Box & Blocks demonstrated overall improvement. The UPDRS showed slight improvement with high standard deviation. The patients were faster and more successful at the 9 Hole peg test.

Participants demonstrated significant progress in some of the Jebsen's test [7]. After therapy all the participants needed less time for writing a letter (24.4±15.1s to 21.1±13.0s), stimulated feeding (9.6±4.7s to 8.8±2.4s) and moving light objects (4.6±1.2s to 4.1±1.1s). The other tests did not reveal improvements after the therapy as expected, perhaps due to the variable motor capabilities of the participants. One of the participants had stronger tremor and his results were variable; e.g. picking small objects (10.4s to 17.1s), while the others did not show changes in results (8.8± 2.9s to 9.2±3.8s). There was also a patient with incredible results at picking small objects; 14.1s to 9.3s.

Clinical test UPDRS [11] demonstrated better results after therapy (30.8±9.9 28.9±11.0); however a high standard deviation was present (Fig 4.). In spite of that only one participant had less acceptable score according to UPDRS (45 to 50). The 9 Hole peg test [8] showed large standard deviation before the therapy; also one of the participant was very weak at this task (26.5s to 30.3s). The participants' performance at the Box & Blocks Test [9] also changed after the therapy (46.8±9.7 to 50.3±10.7). The 10 cubes game score also demonstrated good matching (linear regression) with the Box & Blocks Test the (Fig. 5).

4. DISCUSSION

The results reveal that participants demonstrated significant progress in playing the 10 cubes game. All individual participants as well as the group picked and place in the treasure box much more cubes in the designated time than at the beginning of the therapy and gradually improved their score. Besides, mastering the game consequently resulted in a fact that in the last session almost all participants accomplished the game prior to the elapsed

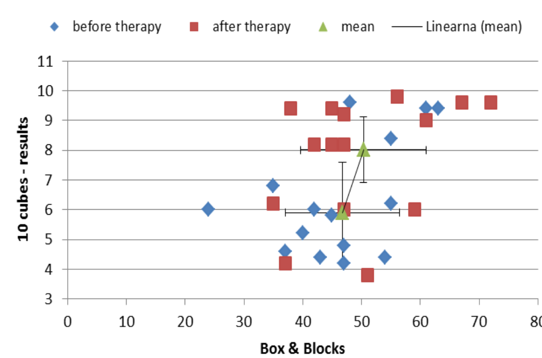

Figure 5. Good compliance between the game results and the Box & Blocks Test [3]. The line moves towards "higher game score, higher the clinical test outcome".

time. If this was the case for all participants, we would have concluded that the difficulty level of the game was too low. But it was not. Three participants improved their score gradually, but were still not able to pick all cubes. This was compliant with the clinical test 9 Hole Peg Test that in average showed similar outcomes before and after the therapy and is used by occupational therapists for assessment of finger dexterity [12]. However, taking in consideration that one of the participants achieved unexpectedly poor results after the therapy, we may suggest that such dedicated game can successfully lower the finger dexterity. Similar results were found with the UPDRS. Most of the participants achieved better results in motor examination. Box&Blocks test BBT) showed expectedly slight improvement in score. Furthermore, some participants demonstrated incredible progress; these results differed for 8-9 points. But the main reason for large discrepancy lies in the relatively small number of participants and their variable motor and non-motor disabilities. Similarities in the outcomes of both tests, BBT and the virtual 10 cubes, may lead to the consideration that the results of the 10 cubes game could be sufficient for the rough estimation of the patient's functional progress. The Jebsen test reveals some major improvement in accuracy at small range of motion movements; writing a letter has become quicker, stimulated feeding and moving light objects. These tests are clinically well accepted and may demonstrate the actual progress in terms of movement control. Nevertheless we assume that the developed virtual game has enormously increased motivation and thus also the participation of the patients. This may also lead to the improvement of cognitive functions and consequently the quality of life of elderly [14] and people with Parkinson disease. However, we have to take in consideration that even if the game increases motivation, the time of using such games may not necessarily improve the quality of life [14].

5. CONCLUSIONS

The system design was initially built for feasibility study; simple virtual reality task without specific user interface, short term evaluation protocol and easy-to-use hardware and software. The outcomes demonstrated that small scale and precise movements are very important and valuable for persons with PD. Such activities increase participation and may potentially influence on the PD progress.

However, the work is in progress and we expect to significantly increase the number of participating patients in the current year. The preliminary feasibility study is encouraging and provides promising outcomes for the development of the clinical tele(home) training program.

6. ACKNOWLEDGMENTS

The work of the authors was supported by the PD_manager project, funded within the EU Framework Programme for Research and Innovation Horizon 2020, under grant number 643706.

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