Can telerehabilitation games lead to functional improvement of upper extremities in individuals with Parkinson's disease?

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Parkinson's disease (PD) is treated by medication, less with deep brain stimulation and physiotherapy. Different opinions on the clinical meaningfulness of the physiotherapy or recommended intensive physiotherapy were found. Our objectives were to design intensive target-based physiotherapy for upper extremities suitable for telerehabilitation services and examine the clinical meaningfulness of the exergaming at an unchanged medication plan. A telerehabilitation exergaming system using the Kinect sensor was developed; 28 patients with PD participated in the study. The system followed the participants' movements and adapted the difficulty level of the game in real time. The outcomes of the study showed that seven out of 26 participants could set up the equipment at home alone. Clinical outcomes of Box and Blocks Test (mean: 47 vs. 52, $P = 0.002$, Cohen's $d = 0.40$), UPDRS III (mean: 27 vs. 29, $P = 0.001$, $d = 0.22$), and daily activity Jebsen's test; writing a letter (mean: 24.0 vs. 20.6, $P = 0.003$, $d = 0.23$); and moving light objects (mean: 4.4 vs. 3.9, $P = 0.006$, $d = 0.46$) were statistically significant ($P < 0.05$) and considered clinically meaningful. The Nine-Hole Peg Test showed a statistically nonsignificant improvement (mean: 28.0 vs. 26.5, $P = 0.089$, $d = 0.22$). The participants claimed problems with mobility but less with activities of daily living and emotional well-being (PDQ-39). The findings lead to preliminary conclusions that exergaming is feasible, but may require technical assistance, whereas clinically meaningful results could be achieved according to validated instruments and an unchanged medication plan in individuals with PD. *International Journal of Rehabilitation Research* 00:000–000 Copyright © 2018 The Author(s). Published by Wolters Kluwer Health, Inc.

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Introduction

Parkinson's disease (PD) is a progressive degenerative disorder that affects the nervous system. Nigrostriatal degeneration is the pathological hallmark of PD leading to the classical motor symptoms such as increased muscle tone (rigidity), slow movement (bradykinesia), resting tremor, and gait and postural impairment (Melnik, 1995). These symptoms are associated with nonmotor symptoms including cognitive, behavioral, autonomic, and sleep disturbances that adversely influence the patient's quality of life (QoL). The motor signs of PD are mainly treated by L-DOPA and dopamine agonists, aiming to provide patients with independent functioning as long as possible. However, with disease progression, the patients often become less responsive to medication treatment and will develop motor (and nonmotor) fluctuations – dyskinesia (unintended, involuntary, and uncontrollable movements) after the first few years of disease. Therefore, physiotherapy has become increasingly more important in individuals with PD as they can retain more than three-fourth of all activities (Jankovic, 2008; Duncan and Earhart, 2011). Namely, motor rehabilitation ameliorates symptoms and improves movement functionalities and motor performance, and consequently increases the QoL (Angelucci *et al.*, 2016) and is related to patients' motivation for participation.

Physiotherapy increases participation and contributes toward the quality of movement, physical capacity, and manual activities, balance, walking, reaching, grasping, etc. However, studies to confirm the effectiveness are still in progress (Hindle *et al.*, 2013). Recently, Clarke *et al.* (2016) reported a randomized clinical trial, stating that the physiotherapy and occupational therapy in mild to moderate PD did not contribute toward clinically

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meaningful improvements in daily living or QoL by validated instruments. They suggested that more structured and intensive therapy programs should be applied in all stages of PD. More intensive exercises with computer games (exercise + games = exergames) have been introduced for the motor rehabilitation of individuals with PD (Pompeu *et al.*, 2014) and there have been several reports on functional progress and performance in balance (Dockx *et al.*, 2016). Most of the reports used commercial games (Nintendo Wii or Kinect Xbox) requiring too fast responses that patients were not able to follow and were found to be too demanding (Barry *et al.*, 2014). Commercially available games and applications also do not allow remote data management and control of the game difficulty on the basis of the functional performance outcomes (Susi *et al.*, 2007). A feasibility study (Pompeu *et al.*, 2014) on safety and functional outcomes (balance, dynamic gait, and QoL) reported on positive outcomes when using the commercial outfit of Kinect Adventures (Torres, 2008). Only a few studies have reported on the retention of intensive motor learning to improve daily tasks (Heremans *et al.*, 2016) as suggested by Clarke *et al.* (2016), for example writing, moving small objects, etc. There were only a few short-term improvements in walking speed and balance (Tomlinson *et al.*, 2013).

The objectives of the presented study were to assess the feasibility of delivery and the impact of the developed intensified exergaming with a gradual difficulty level control for individuals with PD beyond clinical programs, preferably at home. We hypothesized that the intervention can lead to functional improvements of upper extremities in patients with PD despite the progressing disease and without changing the medication plan.

Materials and methods

The requirements for intensified and target-based exercise therapy were a combination of variable difficulty level, physical exercise, cognitive, and coordinated movement capabilities (Farley and Koshland, 2005). Furthermore, for individuals with PD, the time for exercise therapy in the hospital is often limited. Continuation of exercise therapy at home could be an acceptable solution for the intensified exercising and prolonged period of training. A larger group of patients could perform the task according to a specific telerehabilitation protocol with less healthcare personnel at the same time than in the clinical settings. Primarily, we focused on the feasibility of home exercise therapy that requires simple, easy-to-operate, and nonobtrusive solutions with possible remote operation management, task scheduling, and data preview. An eye contact with the moving object and its manipulation (even virtual) may be a challenging task with enough physical exercise. We had checked whether the participants could set up, use, and follow the instructions on the screen without the assistance of the care person. Finally, we examined whether such an intervention could be clinically meaningful with an unchanged medication plan.

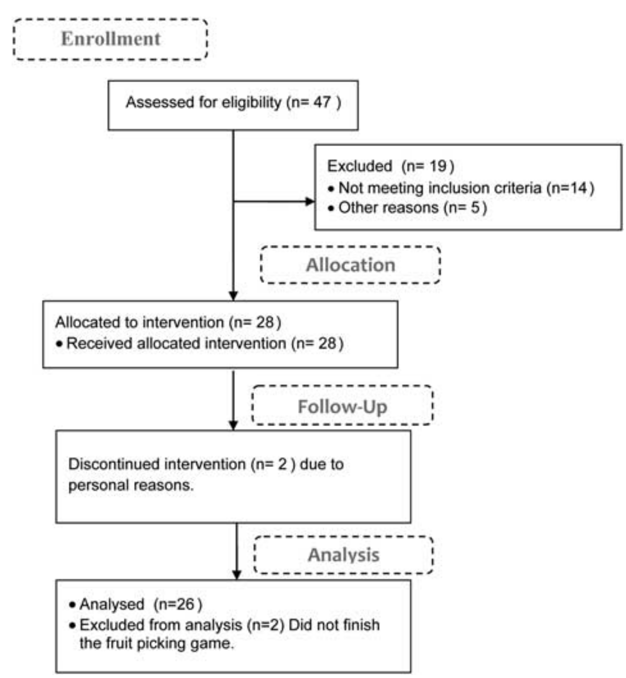
Participants

Forty-seven patients with PD were recruited at the University Rehabilitation Institute's hospital. Among these, 28 patients (16 women, 12 men, 68 ± 7 years old, 172 ± 6 cm, 79 ± 10 kg, and duration of disease 6 ± 4 years) were eligible for the study (Fig. 1), and fulfilled the following inclusion criteria: (a) participants with levels 2–3 in the Hoehn and Yahr Scale (Goetz *et al.*, 2004). (b) Mini-Mental Status Examination (Pachet *et al.*, 2010) above 24. The physician, a neurologist, carried out the enrollment process. The details of the treatments and planned activities to determine the patients' eligibility for participation in the study were unknown to the participants and the physician at the time of screening. They were also not aware of the participants' technical skills.

Exergaming design

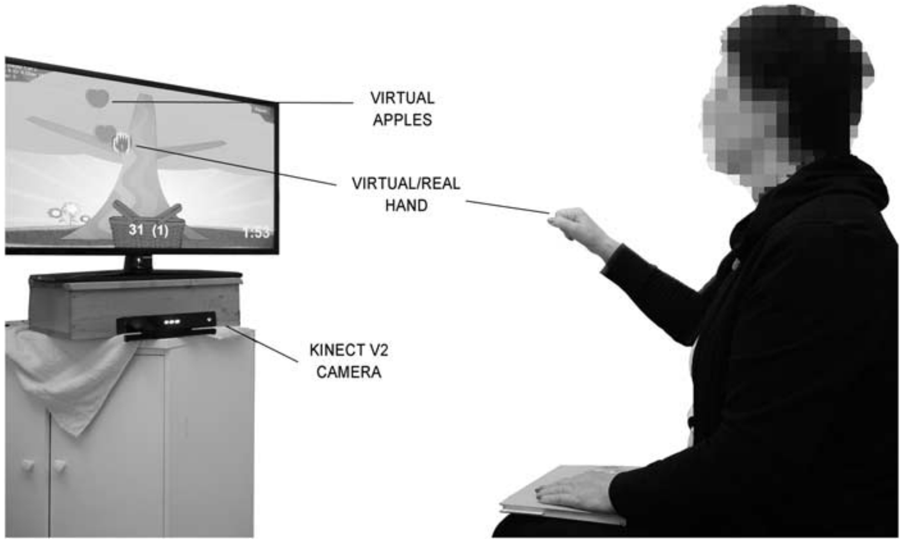
The 'Fruit Picking' computer game (Fig. 2) was developed with the Unity three-dimensional game engine (Unity Technologies, San Francisco, California, USA) and was designed as a target-based task (Paraskevopoulos *et al.*, 2014). The three-dimensional infrared camera (Kinect V2; Microsoft Corporation, Redmond, Washington, USA; Kinect V2 SDK, 2016) tracked the motion of the body segments. The Kinect V2 raw data were filtered and translated to the coordinate systems attached to each body

Fig. 1



Flow diagram.

Fig. 2



An individual with Parkinson's disease performing a target-based exercise at home. The game requires full cooperation and the difficulty level can be adapted in real time during the exergaming.

segment, the arm, hand, trunk, and head of the participant. The game was designed for upper extremities; thus, the physical interaction zone was above shoulder height. This means that the camera sensor was focused on the trunk, arm and hands movements, and ignored the movements of the legs or the head.

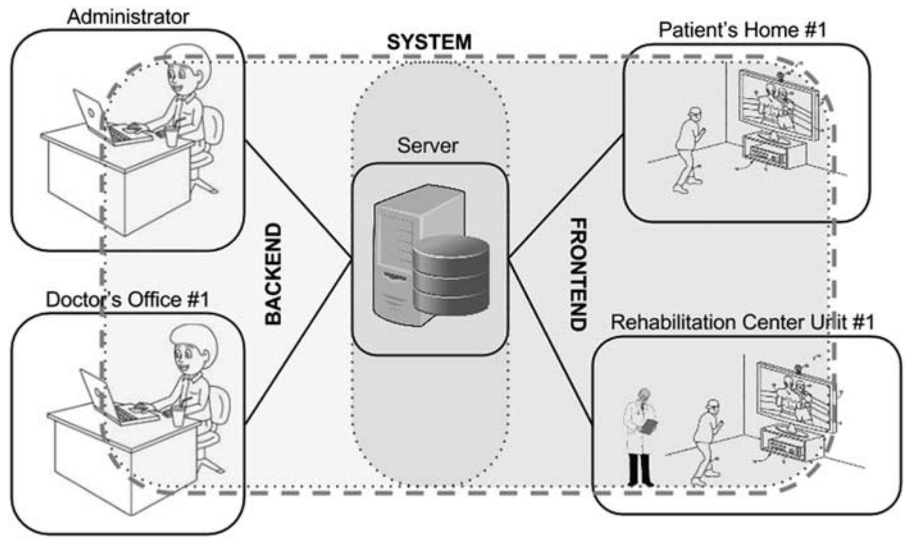
The goal of the 'Fruit Picking' game was to collect virtual apples before falling off the virtual tree and place them in the basket in the lower part of the screen. The participant was instructed to raise the arm, open the hand, and try to grab the virtual apple by closing the hand. Opening the hand again would have resulted in the virtual apple falling to the ground and the participant would not receive points. The virtual hands were approximately the size of the real hands. When the participant grabbed the virtual apple successfully, and placed it in the basket, the computer added points to the score. The number of scored points depended on the game difficulty level, which escalated with the success of the participant. The participant proceeded to the next difficulty level when he or she successfully collected 15 apples three times in a row. Primary difficulty level was defined by the physiotherapist. The higher the difficulty level, the more widely the apples were distributed on the tree branches and ripened and fell faster from the tree. There were also limitations. Once the apple began to fall from the tree, it could no longer be grabbed. Each game session lasted exactly 2 min.

Telerehabilitation design

Our design targeted exergaming with serious games (Susi *et al.*, 2007; Paraskevopoulos *et al.*, 2014) for upper extremity exercises, such as reaching and grasping desirably outside the rehabilitation center or at home. Therefore, the gamification platform (Fig. 3) technically consisted of two parts: frontend and backend. Frontends were interfaces/applications interacting directly with the users during the exergaming (Wattanasoontorn *et al.*, 2013). The users/patients exercised with the game and the system recorded and stored the data on a local computer. The backend part retrieved the stored data and enabled the medical professionals to review data remotely and plan/follow the exergame-based therapy. The system's administrator could update the entire gamification platform, could add new medical professionals or handle their access privileges, and grant access to a physician to start monitoring the patients.

Technically, the server part (Linux operating system, Apache http server, MySQL relational database management system) was divided into three functional parts: storing data of the gamification platform, communication with the clients' parts (gaming system), and administration over the web interface. The gamification platform comprised patients' data, game schedule, game settings, game session results, and administrative data. The communication with clients' parts consisted of web services providing game settings and synchronization of acquired data with the relational database. The administrative web interface enabled medical professionals to preview the patients' data, add a new patient, modify game settings, or create a schedule. The saved data could be exported to other software tools (e.g. Microsoft Excel, Matlab; Mathworks Inc., Natick, Massachusetts, USA) for further analysis.

Fig. 3



System for telerehabilitation of the upper extremities enables remote access to the data.

Study design and data analysis

Criteria for telerehabilitation

The exergaming (virtual reality supported exercise therapy) started during the rehabilitation program in the clinical settings where patients acquired the necessary skills to manage the equipment and took preliminary clinical tests. After that, the individuals continued with exergaming at home for additional 2–3 weeks, preferably in the morning 30–60 min after they took the medicine. The software was installed on a mini-PC Barebone (Gigabyte BRIX, i7, GIGA-BYTE Technology Co. Ltd., New Taipei City, Taiwan) and all connections were preset. The participant or the carer was only requested to connect it to the LCD TV (HDMI input) and establish a Wi-Fi internet connection at home.

The participants were seated in a comfortable chair in front of a 42″ LCD with Kinect V2 camera and started the upper extremity reaching and grasping exercise. The objective of the 'Fruit picking' game was to collect the apples falling from the tree (Fig. 2). The score depended on the number of apples collected and the difficulty level. The initial difficulty level was set to 1.

The participants took 10 exergaming trainings spanning over ~ 3 weeks. Each daily session lasted for a maximum of 30 min. Within the designated session, the participant had enough time to complete the 'Fruit picking' game at least five times. Short 2 min breaks were taken between the trials. No parameters were changed manually during the study. The final score for each session was defined by the number of apples collected and multiplied by the level of the game. The differences in the final scores between the entry point and after 3 weeks were tested statistically ($P < 0.05$).

The telerehabilitation task was considered successful if the participants finished the exergaming sessions alone, without any functional assistance of the care person or therapist. However, we monitored whether the care person provided any technical assistance at setup and when beginning to use the application.

Functional status assessment

Clinical instruments for functional assessment [Unified Parkinson's Disease Rating Scale (UPDRS) III (Movement Disorder Society Task Force on Rating Scales for Parkinson's Disease, 2013), Box and Block Test (BBT), Nine-Hole Peg Hole Test (9HPT); Gammon *et al.*, 2011], and daily functional tasks evaluation (Jebsen's test; Jebsen *et al.*, 1969) were used at patient admission and after the exergaming program. Jebsen's test was carried out by the occupational therapist and the other tests were performed by the physiotherapist. The participating patients were also asked to fill the Parkinson's Disease Questionnaire (PDQ-39) (Jenkinson *et al.*, 1997) to estimate the health status over the last month.

Statistical analysis of the clinical tests' outcomes was carried out using the Matlab Statistical Toolbox (MathWorks Inc.). Means, SDs, median values, SEMs, and confidence interval (95%) were computed for the 9HPT, BBT, UPDRS III, and all Jebsen's subtests [writing a letter (WAL), card turning (CTURN), stacking checkers (STCHK), stimulated feeding (SFEED), moving light objects (MLO), moving heavy objects (MHO), small objects picking (SOP)] before and after the study. Both assessments were also tested statistically for mean differences using a paired-sample *t*-test ($P < 0.05$). Before analysis, data were checked for normality (histogram, kurtosis, and skewness) and the standardized effect size (Cohen's *d*; Cohen, 1988) was calculated. PDQ-39's dimensions of mobility, activities of daily living, emotional well-being, social support, cognition, communication, and bodily discomfort were averaged for all participants.

In addition, we examined the relation between objective measurements and clinical tests by contrasting the final score (apples × level) to the clinical tests and calculating regression coefficients and a regression line for tests showing a statistically significant improvement in the functional capabilities

The study was approved by the Ethics committee of the University Rehabilitation Institute, Republic of Slovenia (13052015), and all participants provided an informed written consent. The standardized Mini-Mental Status Examination was used to assess the patient's capacity to consent. The procedure was in accordance with the principles of the Declaration of Helsinki on biomedical research on human beings, the provisions of the Council of Europe Convention on the Protection of Human Rights and Dignity of the Human Being with respect to the Application of Biology and Medicine (Oviedo Convention), and the principles of the Slovenian Code of medical ethics. The authors confirm that all ongoing and related trials for this drug/intervention are registered (ClinicalTrials.gov Identifier: NCT03175107; *https://clinicaltrials.gov/ct2/show/NCT03175107*).

Results

Criteria for telerehabilitation

Among the 28 participating patients with PD (age between 54 and 80 years), 26 participants completed the study successfully. These 26 participants also managed to complete each session of the 'Fruit picking' game. Nevertheless, two participants gave up because of personal reasons. Both participants could withdraw without any explanation at any stage of the study. None of the 26 participants complained about the exergame difficulty level, hardware setup, or application control. However, only seven out of the 26 participants reported that they were able to set up the equipment at home all alone. The rest needed at least minimal technical assistance such as connecting cables, switching the TV to the appropriate HDMI source, or establishing the Wi-Fi connection. The assistance was provided by the care person or a relative.

The success at the 'Fruit picking' exergame was also measured with the game score depending on the number of collected apples. The number of collected apples within the game decreased from the first session to the 10th session (mean: 35.26, SD: 13.92 to mean: 24.89, SD: 11.63) as the difficulty level increased from 1 to 10 (Fig. 4). However, the final game score ($P < 10^{-5}$, $d = 1.79$) increased significantly from the first to the last session (mean: 69.89, SD: 29.24 to mean: 237.76, SD: 129.08) (Fig. 4).

Functional status assessment

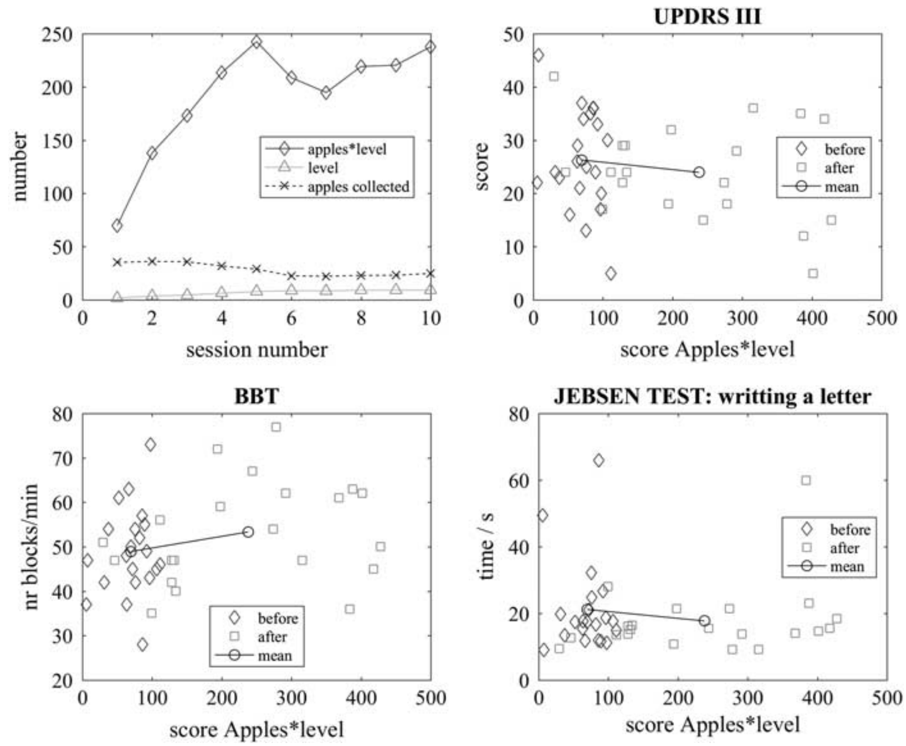
The participants showed clinically meaningful outcomes according to the validated instruments. The categories of Jebsen's test (Jebsen *et al.*, 1969) showed faster accomplishment of tasks, but with a large variability. In addition, the normal-like distributed samples were rather asymmetrical (kurtosis/skewness: 0.29–2.24/0.96–1.76). After exergaming, all the participants needed less time to write a letter (mean: 24.03, SD: 15.52 s to mean: 20.64, SD: 13.4 s), picking of small objects (mean: 8.51, SD: 2.82 s to mean: 8.25, SD: 3.15 s), stacking checkers (mean: 6.30, SD: 1.91 s to mean: 5.54, SD: 1.45 s), stimulated feeding (mean: 9.44, SD: 3.81 s to mean: 8.49, SD: 2.12 s), moving light objects (mean: 4.44, SD: 1.19 s to mean: 3.94, SD: 0.99 s), and moving heavy objects (mean: 4.31, SD: 0.82 s to mean: 4.06, SD: 1.15 s), but more time for card turning (mean: 6.42, SD: 2.03 s to mean: 7.28, SD: 7.53 s) (Table 1). Improvements in WAL ($P = 0.003$; $P < 0.05$, $d = 0.23$) and MLO ($P = 0.006$; $P < 0.05$, $d = 0.46$) tests turned out to be statistically significant (Table 1, Fig. 5).

The data of the BBT (kurtosis/skewness: 0.51/0.1 before and −0.32/0.59 after intervention) and the UPDRS III (kurtosis/skewness −0.32/−0.35 before and −0.11/0.09 after intervention) had an almost normal, symmetrical distribution. The 9HPT had an almost normal, more peaked, and less symmetrical distribution (kurtosis/skewness: 0.76/0.3). The two functional clinical tests, the 9HPT (mean: 28.01, SD: 6.59 s to mean: 26.48, SD: 7.30 s) and the BBT (mean: 47.27, SD: 10.68 to mean: 51.65, SD: 11.26 cubes) and the motor part of the UPDRS III (Movement Disorder Society Task Force on Rating Scales for Parkinson's Disease, 2013) (mean: 29.54, SD: 10.33 to mean: 27.29, SD: 10.38), showed improvements (Fig. 5). However, statistically significant improvements ($P < 0.05$) were found only in the BBT ($P = 0.002$, $d = 0.40$) and the UPDRS III ($P = 0.001$, $d = 0.22$). The UPDRS III showed a large discrepancy between the lowest (5) and the highest score (46 before or 50 after the exergaming). In addition, the range of the first quantile (25%) and the third quantile (75%) of the data and whiskers was 1.5 times the interquartile range (99.3% coverage) (Fig. 5). The outliers were data points beyond the whiskers.

The final game scores at the first session (before) and the 10th session (after), compared with the UPDRS III, showed that the higher final game score yielded a lower UPDRS III score and less WAL time and a higher BBT score. However, the regression coefficients were rather low: $R^2 = 0.0649$, 0.0509, and 0.007 for the BBT, the UPDRS III, and the WAL, respectively (Fig. 4).

The PDQ-39 (Jenkinson *et al.*, 1997) showed that the participants' major problems were related to mobility, body discomfort, and emotional well-being (Fig. 6), but

Fig. 4



The outcomes of the 'Fruit picking' game compared with the clinical tests. The final game score (apples × levels) increased from 69.88 to 237 ($P = 0.000$, $d = 1.79$) until the end of exergaming therapy as shown in the upper left plot. However, regression coefficients were rather low for a direct match between the game score and particular clinical tests; $R^2 = 0.0649$ for Box and Block Test (BBT), $R^2 = 0.0509$ for Unified Parkinson's Disease Rating Scale (UPDRS III) and $R^2 = 0.007$ for writing a letter (WAL) in the lower right plot.

less stigma or social support. On average, the participants could manage their day-to-day activities.

Discussion

Criteria for telerehabilitation

Our outcomes showed that the participating patients with PD were not technically skilled and mostly relied on their care person. Although the seven participants set up the system at home on their own, we did not observe any discrepancy between their data and the data of the other participants who were provided technical assistance. All results were stored regularly and no errors were recorded during the sessions. Similar findings on easy to use systems at home that can be controlled remotely over the internet were also reported by Pachoulakis *et al.* (2016).

All participants showed a significant improvement in their final game scores. Indeed, their score improved on a daily basis up to the fifth session, and then the score suddenly decreased because of the increased difficulty level. From then onward, the participants achieved the same or higher score as at the fifth session. The information on the game score can be useful when the participants perform the exergaming at home and these are the only available data because of the reduced number of outpatient clinical tests. The improvement in the final score was related to the improvement in the clinical tests (BBT, UPDRS III, and WAL). The BBT score increased with the final score and the other two clinical tests also showed an improvement as the final score was higher. However, none of these regressions could be statistically confirmed because of the outliers and small-scale changes in the clinical tests. Perhaps a population above the mid-stage of the PD would increase the statistical range, but severe motor problems at that stage can prevent successful participation in the exergaming.

Functional status assessment

Our findings showed that with the target-based task and the difficulty level control, we may achieve clinically meaningful results. The statistically and highly significant results of Jebsen's tests (Jebsen *et al.*, 1969), WAL, and MLO confirm that some functions of daily living had improved. In addition, improvements in the mean/median values were observed in the MHO, STCHK, and SFEED. These results, in combination with the significant changes in the BBT and the UPDRS III, may indicate a short-term increase in the QoL of the

Table 1 Outcomes of the clinical tests before (1) and after (2) the exergaming.

Clinical tests: results	Jebsen test/s														Nine-Hole test		Box and Blocks		UPDRS III	
	Writing a letter		Card turning		Small objects picking		Stacking checkers		Stimulated feeding		Moving light objects		Moving heavy objects							
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Mean	24.03	20.64	6.42	7.28	8.51	8.25	6.30	5.54	9.44	8.49	4.44	3.94	4.31	4.06	28.01	26.48	47.27	51.65	29.54	27.29
SD	15.52	13.47	2.03	7.53	2.82	3.15	1.91	1.45	3.81	2.12	1.19	0.99	0.82	1.15	6.59	7.30	10.68	11.26	10.33	10.38
SEM	3.17	2.75	0.41	1.54	0.58	0.64	0.39	0.30	0.78	0.43	0.24	0.20	0.17	0.23	1.29	1.43	2.09	2.21	1.95	1.96
Confidence interval (95.0%) for the mean	6.55	5.69	0.86	3.18	1.19	1.33	0.81	0.61	1.61	0.89	0.50	0.42	0.35	0.48	2.66	2.95	4.31	4.55	4.01	4.03
Median	17.64	15.60	6.08	5.81	7.49	7.81	6.26	5.14	8.86	8.13	4.41	3.93	4.34	3.98	25.99	26.61	47.00	48.50	30.00	28.50
t-Test: paired two samples for means																				
t-Statistics	3.37		−0.67		0.47		1.92		1.39		3.03		1.73		1.77		−3.54		3.72	
$P\ (T \leq t)$	**0.0027**		0.5069		0.6438		0.0670		0.1768		**0.0060**		0.0969		0.0897		**0.0016**		**0.0009**	
Cohen's *d*	**0.23**		0.16		0.09		0.45		0.31		**0.46**		0.25		0.22		**0.40**		**0.22**	

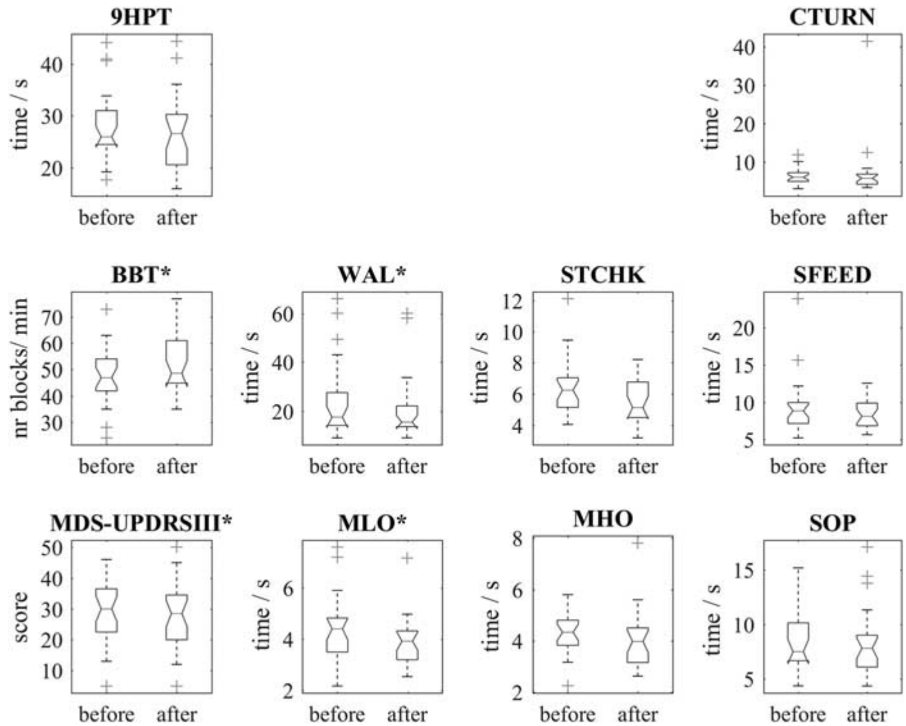
Bold values indicate ($P < 0.05$).

participants. This might be in contrast to the findings of Clarke *et al.* (2016), but we need to consider that our study was limited to the upper extremities. However, motor functions in patients with PD rarely improve over time; therefore, the clinical outcomes presented as a result of the target-based exergaming are noteworthy. This is supported by the study on amplitude-based behavioral intervention (Farley and Koshland, 2005) reporting on reduced bradykinesia and hypokinesia because of targeted large range of motion. We believe that the improvements might be a consequence of higher motivation of the participants and we should have extended the exergaming period. However, more time spent on such games may not necessarily lead to additional improvements in motor functions (Miller *et al.*, 2014). Apparently, the short-term improvement in motor functions (BBT, UPDRS III) and daily activities (Jebsen's test) also led to an improvement in cognitive functions and consequently the quality of life of the participants with PD without changes in the regime of medications and lifestyle. A recent research review (Oertel and Schulz, 2016) reported that pharmacotherapy has also not been very successful in disease modification and emphasizes the importance of further research in the field of efficient treatment of motor symptoms. The outcomes of the self-reported questionnaire PDQ-39 (Jenkinson *et al.*, 1997) showed that our participants had major problems with mobility, but fewer problems with the activities of daily living and emotional well-being. This may suggest that the specific changes were related to the exergaming rather than just recovery from a poor health condition.

Limitations of the study and future work

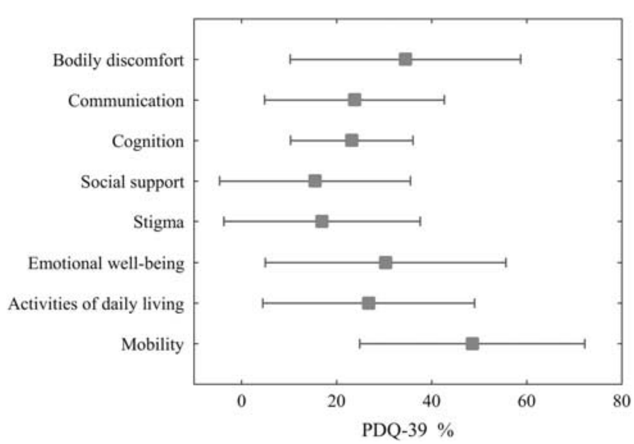
Apart from the technical assistance and errorless functionality of the system, it was very difficult to monitor the exact time when the patient took a medicine and what kind of activity they were engaged in alone and what kind of activity they performed with their carer. Here, we entirely relied on the patients' reports. Preliminary instructions for use and testing with each participant should take place within the clinical settings to enable the patients to learn how to use the system at home independently. Nevertheless, we may encounter problems with the Wi-Fi connection (the software records the data locally and transfers the data when connection is available) and participants could regularly interrupt the exergame for various reasons. Our study does not cover users' experiences or an intrinsic and extrinsic motivation survey that may provide additional information and reveal the weaknesses of the system in real-life applications. We estimated that 50 participants would yield enough sample power (>0.8) and effect sizes of around 0.4 for a pilot. To detect smaller effect sizes, a larger group (>100) would be required. However, the BBT and Jebsen's MLO tests yielded moderate effect sizes and considerable improvement. If all 47 participants were

Fig. 5



The results obtained from the clinical tests Nine-Hole Peg Hole Test (9HPT), Box and Block Test (BBT), Unified Parkinson's Disease Rating Scale (UPDRS III), and Jebsen's test [writing a letter (WAL), Card turning (CTURN), Stacking checkers (STCHK), stimulated feeding (SFEED), moving light objects (MLO), moving heavy objects (MHO), small objects picking (SOP)]. The changes marked with * are statistically significant ($P < 0.05$). The boxes present the first quantile (25%) and the third quantile (75%) of the data and whiskers are 1.5 times the interquartile range (corresponds to 99.3% coverage). Data points beyond the whiskers are outliers.

Fig. 6



Parkinson's Disease Questionnaire (PDQ-39) results assessed in the patients with Parkinson's disease continuing with exergaming at home. The total score of each dimension ranges from 0 (never have difficulty) to 100 (always have difficulty). Lower scores indicate better quality of life.

eligible, we would have had enough participants; with 26 participants, we would still have statistical power of around 0.7 for an effect size of 0.4. We also need to consider that subjective evaluations may affect the reliability of some clinical tests.

Home and telerehabilitation services are comparable with conventional therapy (Dhurjaty, 2004; Cikajlo *et al.*, 2012), but can provide service to larger number of patients. Besides, require less travel and fewer healthcare personnel resulting in increased quality of life (Melnik, 1995). We found in a single group of participants that even with an unchanged medication plan and progress of the disease, there were improvements in motor functions in the upper extremities with exergaming. However, we did not find that such an intervention was better than a conventional approach. Future work shall include a follow-up and a multicentre trial in a larger group of participants to confirm the clinical value of the approach.

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Conflicts of interest

There are no conflicts of interest.

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