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ORIGINAL RESEARCH

VIRTUAL REALITY IN PHYSICAL REHABILITATION OF PATIENTS WITH PARKINSON'S DISEASE

Gisele de Paula Vieira[1], Daniela Freitas Guerra Henriques de Araujo[2], Marco Antonio Araujo Leite[3], Marco Orsini[4], Clynton Lourenço Correa[5]

Abstract

Introduction: The Virtual Reality (VR) can be a therapeutic tool used in neurorehabilitation field. It is considered a ludic activity that provides visual and auditory feedbacks, facilitating the patients' adherence to treatment. AIMS: To perform literature review about influences of VR in rehabilitation of patients with Parkinson's disease. **Methods:** Data banks were used from the following virtual libraries: Medline, PEDro, Lilacs, Scielo and PubMed using the following keywords: Parkinson's disease and Virtual Reality; Parkinson's disease and Wii as well as analogous keywords in Spanish and Portuguese to obtain the scientific papers. PEDro scale was used to analyze the methodological quality of the papers. **Results:** From fifty papers obtained after inclusion and exclusion criteria were retained 16 papers to analyses. According to PEDro scale most of the papers had low score. The results suggest that VR shows positive aspects in velocity and movement time, balance, gait, postural control and functionality of upper extremities. The ludic activity provided by VR and the contribution of visual and auditory feedbacks of this intervention can be the great potential of this new tool. **Conclusion:** The VR is useful to make potent: motor control, functionality, cognitive capacity and balance, but still need more scientific studies with methodological qualities to confirm the results of the VR in Parkinson's disease.

Key words: Parkinson's disease, physical therapy (modalities), video game, rehabilitation.

INTRODUCTION

A new epidemiological profile occurs due to the aging of population. This profile generates an increase in chronic and degenerative diseases. Parkinson's disease (PD) is one with a higher incidence in elderly people[1]. It is estimated that, in 2020, more than forty million people around the world will develop PD[2]. People older than 55 years old are most affected by this disease and it is clinically characterized by bradykinesia and, at least one of the following signs: rest tremor, rigidity and, at a later date, postural instability[3]. According to the progressive evolution of this disease, patients tend to reduce the quantity and variety of their activities and consequently, a reduction in physical fitness[4].

For this reason, drugs and physical therapies are indicated in PD. It has also been hypothesized that physical activity performed in the early stages of the motor manifestations of PD can delay the emergence and the progression of the cognitive and physical alterations by the stimulation of neuroplasticity leading to the improvement of functional capacities[5,6].

In recent years, a new concept of intervention in the physical rehabilitation field has been proposed: virtual reality (VR), a therapeutic approach used for attenuation of deficits in balance, and upper and lower extremities. This occurs in different groups of people, such as: elderly with balance deficit, patients with Stroke, Multiple Sclerosis and PD[7,8]. VR is an interaction technique between the user and a computer system that recreates the artificial environment in virtual interface. The objective of this technique is to recreate and to maximize the sensation of reality for the user. Besides, the VR allows analysis of the motor and/or cognitive aspects in diseases or situations of deteriorating health in which there

1 Fisioterapeuta, Mestre em Ciências da Motricidade Humana, Membro do grupo de Estudo sobre Doença de Parkinson – GEDOPA/UFRJ, Departamento de Fisioterapia Cardiorrespiratória e Músculo-esquelética, Curso de Fisioterapia, Universidade Federal de Juiz de Fora, Minas Gerais, Brasil.
2 Graduanda do curso de Educação Física na Universidade Federal do Rio de Janeiro – UFRJ, Membro do Grupo de Estudo sobre Doença de Parkinson – GEDOPA / UFRJ.
3 Médico, Doutor em Neurologia pela Universidade Federal Fluminense – Serviço de Neurologia/Setor de Desordens do Movimento/Hospital Universitário Antônio Pedro - Professor Adjunto de Neurologia da UFF - MMC/CCM/HUAP/PG Neurologia e Neurociências/UPC – Niterói - RJ.
4 Médico, Doutor em Neurologia pela Universidade Federal Fluminense e Professor do Programa de Mestrado em Ciências da Reabilitação – UNISUAM - Bonsucesso - RJ - Brasil.
5 Fisioterapeuta, Doutor em Ciências Morfológicas, Pesquisador do Laboratório de Neurobiologia Comparativa e do Desenvolvimento, IBCCF; Coordenador do Grupo de Estudo sobre Doença de Parkinson – GEDOPA/UFRJ, Professor Adjunto do curso de Fisioterapia da Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brasil.
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Corresponding author: clyntoncorrea@hucff.ufrj.br

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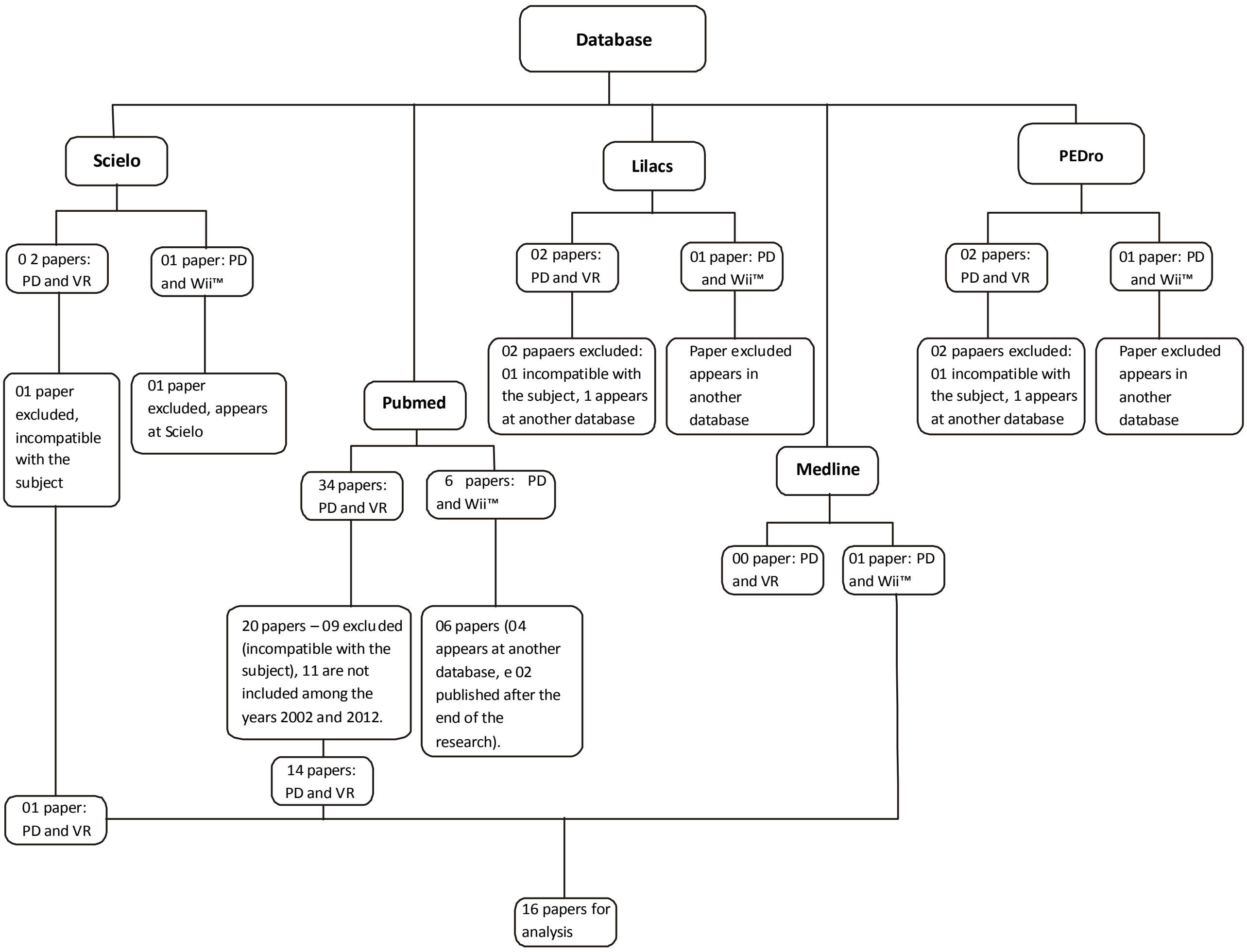
is, for example, involvement of the motor system[9]. VR has two main characteristics: immersion and interaction. Immersion can be classified as immersive and non-immersive. Immersion is when the user is conducted predominantly to control the application through multi-sensorial devices that capture their movements and behavior and react to them (for example, by helmets, caves and their devices), producing a sensation of presence inside the virtual world as if it was real. Non-immersion is when the user is partially conducted to a virtual world but preserves predominantly the sensation of the real world using, for example, common screen or console, mouse, joystick, keyboard allowing modification of the virtual environment. The term interaction is the capacity of the person to interact with virtual objects through devices that generate this sensation (gloves and digital glasses, among others) [10]. However, there are few scientific publications that analyze the effects of VR as a physical therapy tool applied to patients with PD. Until now, it is not clear the possible effects of the use of VR as a therapeutic strategy in patients with PD. Therefore, the issue raised by the authors is the following: Does VR promote benefits in patients with PD? In this way, the objective of this paper is to provide and to discuss, by literature review, the therapeutic effects of VR in these patients.

METHODS

Scientific papers that assessed the effects of training based on VR in neurorehabilitation were selected from the combination of the following keywords: Parkinson's disease, Virtual Reality; Parkinson's disease, Wii and analogous keywords in Spanish and Portuguese were used to obtain the papers. The papers analyzed should be in Portuguese, English or Spanish. The literature review was made from papers available in data banks online Scielo, Pubmed, Lilacs, Medline and PEDro between 2002 and 2012. The search and obtaining of the papers for reading and analysis were carried out between September 2011 and October 2012. From the papers obtained, we assessed the full texts included in this study and their bibliographical references were verified in an independent way to identify possible papers that could be included in this study, until then, not found in electronic search (Figure 1).



Abbreviations: PD (Parkinson's disease), TUG (Timed up and go), STST (Sit-to Stand Test), CBM (Community Balance and Mobility Scale), POMA (Performance-Oriented Mobility Assessment), VR (Virtual Reality).

Figure 1: Flowchart of scientific papers obtained in electronic databases

The following inclusion criteria were used: epidemiological studies (case series, cross-sectional, longitudinal, case-control, cohort studies), with information concerning virtual reality, video games and neurorehabilitation, applied in humans with PD. The exclusion criteria were: papers published in journals not indexed; studies carried out in animal models and review papers. All papers had their methodological quality analyzed by PEDro scale. This scale is constituted by 11 criteria, varying from 0 to 10, in which ten questions are scored and the higher the score, the better the methodological design of the paper. The objective of PEDro scale is to identify the internal validity (criteria 2-9) of the papers, and could contain enough statistical information so that their results can be interpreted (criteria 10-11). Although, the criterion 1 is not scored, this criterion considers the origin of the subjects and the list of requirements used to determine what subjects eligible are to be included in the study. Besides, in PEDro scale it is important to know if the effect of the treatment was sufficiently expressive to be considered clinically justifiable, if the positive effects exceed the negative effects, and evaluate the relation cost-benefit of the treatment. Each criterion is scored according to presence or absence in study assessed, then, each satisfactory item (excluding the first item) contribute with 1 score for total scoring of the scale. The items not described in studies are classified as "not described" and are not scored. At the end, the scores are calculated, obtaining all positive responses[11]. The indexed studies on PEDro data bank already presented assessment of methodological quality. The non-indexed studies on PEDro data bank were assessed in an independent way[11].

RESULTS

Although the keywords used in this research were mentioned in the Material and Methods Section, we observed that there were only 50 papers in total, of which 40 papers were obtained on Pubmed, 01 paper on Medline, 03 papers on Scielo, PEDro and Lilacs respectively. However, only 16 papers were concerned with VR in PD according to criteria adopted in this study. No papers were included by analysis of bibliographical references of the papers obtained in electronic data banks. Most of the papers were characterized by longitudinal studies and by self-applied questionnaires. The main characteristics of the papers included in this review are summarized in Table 1.

Table 1: Papers selected to analyze the methodological quality

Authors	Objectives	Type and size of samples score	Results	PEDro
Arias *et al.*, 2012	Evaluate the rhythm of hand movements by immersive VR in PD patients and healthy elderly and young participants.	34 individuals divided into three groups: 12 healthy young, 12 healthy elderly and 10 patients with PD.	The similarity of the results obtained in the virtual and real environments reinforce the fact that the means between both conditions did not indicate significant differences between them.	5
Ching-Yi Wang *et al.*, 2011	Compare the performance of the reach of fixed and dynamic targets in the virtual and real environments in PD patients.	54 individuals divided into two groups – 29 patients with PD and 25 healthy elderly participants in the control group.	The PD group in virtual and real environment activities, showed greater movement time and lower velocity peak when compared to the control group for the stationary activities. However, the PD group showed significant improvement related to movement time and speed in the activities with dynamic targets.	4
Hui-Ing Ma *et al.*, 2011	Investigate if the training to reach dynamic targets by VR will be able to improve the motor performance of upper limbs in the PD patients.	33 individuals – 17 PD patients in the VR and 16 PD patients in the control group (activities in the real environment).	The VR group made significant improvements in the speed of movement and increase of velocity peak to reach the virtual balls, while the control group did not show significant changes in both variables.	7
Esculier *et al.*, 2012	Evaluate the effects of one training program carried out at home using Nintendo Wii Fit™, in the balance and functional abilities of lower limbs in PD patients.	18 individuals divided into two groups – 10 patients with PD and 8 healthy elderly participants.	The PD group obtained significant improvement in the results TUG, STST, single-leg posture, walk test 10-m, CBM, POMA and strength platform. The control group obtained significant improvement in TUG, STST, single-leg posture and CBM	4
Synnott *et al.*, 2011	Display an approach of motor and non-motor evaluation carried out at home, using the Nintendo Wii Remote™.	Study of a prototype	Initial tests of software showed that the approach is able to differentiate the users without motor conditions of those that imitate symptoms of PD.	2

Authors	Objectives	Type and size of samples score	Results	PEDro
Klinger *et al.*, 2006	Develop a virtual environment to explore planning and the examination of the efficacy of the VR in the assessment of cognitive planning for PD patients	10 individuals, divided into two groups: 5 patients with PD and 5 healthy elderly participants in the control group	The parameters registered showed a different behavior between the PD patients and participants in the control group. Patients need more time to execute the task and cover a greater distance. This difference is not related to motor difficulties. It is related to the numerous hesitations, stops and search for products.	5
Messier *et al.*, 2007	Investigate the effect of PD and normal aging in the process of learning using a visuomotor learning task for upper limbs.	28 individuals, divided into three groups: 8 patients with PD, 10 healthy elderly and 10 healthy young participants.	The healthy elderly participants were slower than the young participants to learn the task for upper limbs. However, they obtained an improvement in their performance during reverse learning.The patients with PD were able to learn the activity in the virtual environment, but were slower than the control group of the same age. They were not able to create the corrections of movement.	3
Griffin *et al.*, 2011	Evaluate the effect of visual cues in the real and virtual environments in the gait of PD patients.	22 patients with PD.	The cues provided by VR placebo procedure did not offer improvement in gait of patients, but reduced conclusion time of the task. The transversal lines placed on the floor caused a significant improvement in gait with reduced cadence, increased length step and reduced frequency of freezing of gait. These results endorse the use of transversal lines and justify more tests using cues in the virtual environment for PD.	3
Pompeu *et al.*, 2012	Investigate the cognitive and motor effect of Nintendo Wii™ training, in balance, compared to exercise training for balance in patients with PD.	32 individuals, divided into two groups – 16 participants in the control group and 16 patients in the experimental group.	Patients with PD were able to improve the performance in three games. Wii™ based in the motor and cognitive training improved the performance of the participants regardless of task. This was maintained for 60 days after the end of training. The improvement was similar to those obtained for the participants who underwent exercise therapy without training and led to improvement in the balance during the dual task.	6
Mendes *et al.*, 2012	Compare the effects obtained by motor training guided by virtual tasks (motor cognitive), with an exclusive motor training, evaluating the gait, the functionality (trunk and upper limbs) and cognitive capacity of patients with PD.	27 individuals: 16 patients with PD and 11 healthy elderly participants.	The patients with PD showed normal learning and retention in seven games compared with the healthy elderly participants, but showed lower performance in five games.The patients with PD were not able to improve their performance in three games after training, while the healthy elderly participants showed good learning and retention.	5
Albani *et al.*, 2002	Create motor behavioral strategies using external stimuli to facilitate the general movements of patients with PD.	12 individuals: 2 women with PD and 10 healthy elderly participants.	When compared to controls, the results showed a big difference in score with relation to speed.In the other tasks carried out, the patients with PD showed some difficulty with tasks that linked memory and orientation.	2
Suarez *et al.*, 2011	Describe the postural adjustment in patients with PD. In	43 individuals: 24 patients with PD and 19	While the control group did not show significant differences in the	3

Authors	Objectives	Type and size of samples score	Results	PEDro
	order to study the balance in these patients from a stable visual to dynamic visual field to analyze the impact of the balance in these patients.	healthy participants in the control group.	postural control between two sensorial conditions, the patients with PD showed significant differences in the central pressure area and the reservation values of the functional balance between the static visual field and optokinetic.	
Chang-Yi Yen *et al*., 2011	Examine the effects of VR in balance training, sensory integration of postural control(varying attention demand) and compare the results with the conventional balance trainingin the trained control group and the untrained control group.	42 patients with PD.	There were no significant differences in scores for balance between the VR and control groups. However, the scores of balance in the sensory organization test with opened eyes from VR group increased significantly more than the control group after training. The balance test scores with closed eyes in the control group also increased significantlymore than the control group after training.	7
Loureiro *et al*., 2012	Verify the application of VR in patients with PD for the improvement in balance and quality of life.	6 patients with PD	Statistically significant differences were found in the following tests:Borg andBerg Scales,Lateral right and left Functional Reach comparing pre and post-training in the same group.	3
Park et *al.* 2011	Investigate if the speed control and adaptation of VR system provides a secure environment for the gait in a real environment, thus, allowing patients to walk naturally and respond to visual stimuli.	3 patients with PD.	The freezing of gait occurred with 2 patients with PD for more than five years, at the time they approached a virtual wall, and passed through a narrow corridor. The other patient did not show freezing on the test. During the freezing phenomenon, it was observed a reduction in the step length, gait velocity and the increase of execution of the test.	3
Shine *et al*., 2011	Identify the pattern of activation and deactivation during the "on" and "off" phases that occur in association with: gait, gait with dual task and freezing time.	1 patient with PD.	The number of freezing episodes during walking with dual task was clearly higher in the "off" period (78 episodes per session on average) compared to the "on" period (5 episodes per session on average). Despite this correlation with cognitive load, only 7.5% of patients had episodes of freezing, and these occurred immediately after the presentation of a dual task.	3

The average score obtained by the use of PEDro scale was 4 scores, verifying that the papers evaluated presented low methodological quality, regarding the maximum score of 10. Considering the 16 papers referring to VR in PD, only six of them obtained a higher score than the average in methodological quality analysis using PEDro scale. Literature shows that the validity of the conclusions from reviews depend on the quality of studies which were included, such recommendation directed the choice of the papers for this review, and however the majority of the studies presented limitations methodological. The mains limitations of the papers evaluated are related to lack of: appropriate description of the procedures, evaluator-blind and follow up. From 16 papers obtained, the characteristics were: five papers studied cognitive function and learning capacity of the patients with PD, one paper investigated functional abilities refers to movement velocity and time, four papers studied the balance, two papers studied the gait, one paper verified the activation and deactivation patterns during "ON" and "OFF" periods that occur in association with: gait, gait with dual task and freezing, and only three papers approached the functionality of the upper extremities in patients with PD using immersive VR.

DISCUSSION

Currently, there is difficulty in verifying by clinical practice (imaging method) what occurs in encephalic structures during the motor learning process regarding the approach to physical rehabilitation in PD. It is still unclear the physiological mechanism of motor learning process in PD, considering that the depletion of nigral dopamine due to degeneration observed in PD affects this process, even though many studies that investigated PD had diverse results[12]. Even so, it is necessary to investigate the potential of motor learning in patients with PD using new therapeutic strategies and to validate their utility[13]. Thus, VR is a therapeutic tool that offers the chance of intensive repetition of tasks with increased feedback (visual and auditory) so that this resource can be more interesting when compared to conventional physical therapy, not imposing any kind of serious threat or physical limitations in participants.

VR allows changes in difficulty levels in execution of task and of dynamic interaction of patient with the task. The utility of VR in physical rehabilitation can be discussed based on three key concepts that guide the motor learning: repetition, feedback and motivation. These are interdependent factors and necessary to reach the expected results offered to participants of VR[10]. Besides, due to the complexity of tasks involving cognitive stimulation and motor abilities, the VR can promote a higher integration of the motor and cognitive abilities contributing to a higher independence in Activities of Daily Life (ADL) compared to training based only on motor exercises[14].

Although the practice can improve the performance, some types of practice are more efficient than others[15]. For this reason, the search for a better training strategy must be a subject of the endless study for physical rehabilitation professionals. Physical therapy based on VR constitutes one of the most innovative and promising technologies applied as a current rehabilitation tool to treat motor disturbances due to neurological lesions. This therapy involves gait and balance training as well as posture and functional adjustment of the upper extremities[16-21].

Studies concerning motor learning in a virtual environment suggest that the patients with PD show limitations when transferring from a virtual to a real environment. Researchers trained the gait of patients with PD using real and virtual external cues. They showed that the patients obtained improvement of gait speed after the training. However, these effects were higher when the patient was evaluated performing the gait with external cues. Gains were lower when the patient was evaluated without external cues, suggesting the difficulty of the patient with PD to transfer the learning to a real environment without external cues to facilitate the gait[22]. Although visual cues can be considered as a therapeutic strategy to improve gait speed, the use of this strategy is limited for therapeutic and/or home and can not be used, for example, in public, i.e. open environment and which causes patients more difficulty to perform a more functional gait.

As we know, the freezing of gait in patients with PD is a phenomenon still not completely understood. Thus, researchers used the VR to comprehend this phenomenon. In a recent study[23], researchers developed a new approach using treadmill with body weight support, allowing the participant to control voluntarily the speed of the treadmill by using a modified speed controller which is integrated to the VR system. For assessment of the kinematic gait, a treadmill was used connected to a system to capture movements (Nexus Vicon).

Three patients with PD used a belt that supported 4.5 kg of their body weight while they walked on a treadmill using special glasses to visualize in 3D in a precise way the images shown. The combination of treadmill and 3D system can or cannot generate the freezing of gait. By the end of the study, the authors observed that the freezing of gait occurred while the patients walked on treadmill with exhibition of VR. Two patients that presented freezing were diagnosed with PD for more than 5 years and the freezing phenomenon occurred when patients were close to a virtual wall and passed through a restricted corridor. During the phenomenon it was observed that the step length and gait speed reduced, while the time taken to cover the distance was increased.

The interface between the 3D visualization system and VR allows the participants to walk as in a real environment, but the researchers did not carry out an assessment of patients in real environment for confirmation or not of freezing in similar conditions. The authors concluded that it was difficult to distinguish if the freezing that occurred in two of the three patients was due to a fault of familiarity with the treadmill or by influence of visual cues offered by VR.

To better understand about neural alterations occurred during the freezing of gait in a patient with PD, researchers looked for in VR a tool that reproduced the moment of freezing of patients with PD allowing an analysis of neural alterations associated with functional magnetic resonance (fMR). This study[24] corroborated with the data mentioned before.

It showed that the freezing of gait can be elicited by a task based on VR, by an exploration of neural alterations through fMR. The authors followed up a patient with PD for 10 years with freezing of gait in "ON" phase. To understand the correlation between neural behavior and freezing of gait, the authors looked for alternatives to provoke simultaneously identifiable episodes of freezing in PD while performing the gait.

Therefore, a virtual gait laboratory was designed specially to use with fMR. The purpose was to identify the activation and deactivation cortical pattern during "ON" and "OFF" phases in gait, dual task (association between gait and other task) and freezing time. The patient was evaluated at two moments in time. The first moment was at "ON" phase under effect of medications. The second moment was fourteen days after the patient was re-evaluated at "OFF" phase after the usual dose of medication was withdrawn the night before the test. In gait, the patient with PD observed a VR screen while using pedals to simulate the gait for ten minutes during the session. Therefore, for analysis of gait with dual task, a cognitive load was increased requesting the patient with PD to perform simultaneously a set of tasks while walking in a corridor. The number of the episodes of freezing during the gait with dual task was higher in "OFF" phase with an average of 78 episodes of freezing per session compared to an average of 5 episodes of freezing per session in "ON" phase.

Although this correlation with cognitive load, only 7.5% of all episodes of freezing occurred immediately after performing a dual task. In analysis obtained by fMR the periods of freezing showed bilateral activation in motor pre-complementary areas and parietal regions. Due to low frequency of events of freezing in "ON" phase, it was not possible to characterize a pattern in this phase. Although only one patient was studied, the data showed a possibility to identify, by fMR, the behavior of freezing in a patient with PD and what encephalic areas were activated in this process. The fMR can be a useful tool to identify areas involved in this phenomenon, but it is still a technique scarcely accessible for most patients due to high cost.

To compare the performance to reach static and dynamic targets in VR and real environment, one study was carried out with patients with PD and healthy elderly participants[25]. The patients with PD took longer to reach static target and showed a lower velocity peak in both VR and real environment than healthy elderly participants.

The performance in dynamic target in both VR and real environment was similar between patients with PD and healthy elderly. The authors concluded that fast virtual stimulus promoted improvement of movement velocity of patients with PD. This study suggests that the fast external dynamic cues influence more positively the bradykinesia than static cues.

The majority of games used by patients with PD presented fast dynamic visual stimulus that contributed to the improvement of bradykinesia in patients. This study confirmed the relevance of visual feedback as a stimulus for patients with PD to perform tasks, as well as, the establishing of movement velocity during functional practice so that the physical therapy causes positive effects.

Although the study mentioned before had found positive results for reaching dynamic objects, another study showed different results. The objective of the study was to investigate if the practice to reach the virtual dynamic target could improve the motor performance of patients with PD. This study included kinematic variables of the arm: movement time, range of velocity peak and the percentage of the movement time for acceleration phase. The authors observed that the training of VR was more efficient than the control group in real environment, improving the performance of the participants to reach static balls through a task similar to the prior study.

The results suggest that the success rate in training using VR did not help the participants to improve their visual-motor coordination for reaching dynamic objects. According to the authors, these results can be attributed to the degree of difficulty to perform the task. The difference between the context and the conditions of the practice was due to the reaching activities using dynamic balls.

This required more visual-motor processing and execution of movement compared to reaching of static balls[26]. Perhaps the divergence found in these two studies mentioned above lies in the fact that different clinical measuring tools were used as well as different training protocols adopted in the studies.

Concerning bradykinesia, the authors indicate immersive VR as a tool to evaluate rhythmic hand movements of the patients with PD. Using an avatar, the patients performed a finger tapping test in a virtual environment: ie, index finger used to perform flexion-extension movements of the metacarpophalangeal joint, while visualizing the hand that performed the task.

The task was performed for patients with PD, healthy elderly and young participants. The participants repeated the test three times in both virtual and real environments. Two sessions were performed on different days. The similarity between the results obtained in virtual and real environments reinforce the fact that the average between both conditions showed no significant difference as compared to the virtual and real environments.

The authors reported that the system allowed analyzing the motor behavior; however the objective of this study was to observe the changing of movement performance, especially in cases that the movement already was pathologically altered, thus providing positive motor adaptations by virtual environment training, in elderly and PD patients[27].

This study has some limitations, because the authors did not report the possible pathological alterations in PD patients that were included in this study. The authors reported that the improvement provided by VR in motor performance need many sessions of training, however this study describes the VR as a tool for evaluation of rhythmic movements and not as for motor training.

A concurrent study[14] had as an objective to compare the effects of 2 different types of balance training programs. One based on Wii Fit™ and other based on traditional therapeutic exercises without videogame. This program was based on balance, functionality, ADL and cognition of patients with PD. This study was carried out for 14 sessions, two sessions per week with 1 hour each session for 07 weeks.

The results of the study confirmed that patients with PD are able to improve the performance of the virtual tasks trained using Nintendo Wii Fit™ videogame. The authors suggest that performance improvement reflects an improvement in abilities required by virtual tasks, considering that it would be impossible to increase the scores in games without improvement in abilities.

However, different evidence from literature suggests advantages for training using games. The results showed that in both virtual and real training ADL, in balance and cognition of patients with PD enabled gain in the same magnitude. There was no dominance of training carried out in a virtual environment over training carried out in a real environment. Although there were significant gains reported by authors, the study shows limitation in the lack of follow up to observe the retaining period of possible improvement reached by therapies used. This does not allow an analysis in the long term of the possible benefits of therapy.

In another study[28], researchers verified the applicability of VR as a rehabilitation method of balance and improvement of quality of life in patients with PD. In this study, different to the research mentioned above, six participants were trained only using VR by Nintendo Wii Fit™ for 12 sessions, twice a week, 20 minutes each session. The therapy was carried out with Wii Fit™ based on three movement planes (sagital, frontal and transverse) using the easy level of the game to carry the stretching and balance (Balance Platform) exercises.

The authors showed results significant statistically related to balance, using Balance Berg Scale as a tool for assessment. However, the quality of life was evaluated using Nottingham Scale. The results were not statistically significant. The authors point out that, after treatment of Wii Fit™, there was a significant difference related to Timed Up and Go that is a way of quick monitoring to detect problems related to the balance that influence ADL.

However, the authors verified that the participants took more time to cover the same distance in the initial test compared to period post-intervention evaluated by Borg Scale. Thus, the authors point out that the gains obtained by participants showed an improvement in balance, as well as, fall in stress and fatigue levels obtained using Borg Scale. Although the positive results were showed in this study, different to the research mentioned above, this study has no control group preventing a comparison between VR and real environment therapies.

Researchers[13] investigated the effects of training with VR related to motor learning, retention and transference of these motor abilities for real tasks. The study was carried out in 14 sessions, 2 sessions per week, 60 minutes each session.

At the beginning of each session, the participants did 30 minutes of warm up using exercises of mobility and for the 30 minutes remaining, the patients played 10 games on Wii Fit™ platform. The results showed that the patients with PD had normal learning and retention in 7 games in comparison with healthy elderly people. These patients obtained a worse performance in 5 games. The patients with PD were unable to improve their performance in 3 games after the training, while the healthy elderly participants showed good learning and retention. In this study, it is evident the difficulty to overcome functional limitations imposed by PD in a virtual environment.

In 3 games, the patients did not reach improvement in performance. These games were composed of activities that offered the freezing of these participants in a real environment. Thus, the activities offered in a virtual environment can mimic those of a real environment to avoid possible real risks in activities performed by patients and participants. This generates difficulties similar to those faced by patients and participantsin a real environment.

Studies to evaluate cognitive conditions of patients with PD compared to healthy subjects of a similar age were also carried out. Researchers constructed a virtual environment like a medium supermarket to evaluate the cognition, especially the planning of tasks.

The participants were oriented to find items presented in a list well defined of products, put them in a cart and take the items to cash a register to pay for the products. The authors concluded that all tasks developed by patients with PD obtained worse results when compared to the control group. The walking covered between the corridors of the supermarket was characterized by interruptions in walking, turning at the shelf and many hesitations to reach the objects.

The parameters registered highlighted that patients with PD need to take more time to perform the task. This difference is not related to motor difficulty, according to explored space, but with numerous hesitations, stops, and searches for products that were not included on the list.

Thus, the authors concluded that the difference between the groups was related to difficulty of patients to plan the tasks. These data suggest a deceleration of planning processes in patients with PD, as well as inefficient utilization of contextual elements[29]. This study shows a ludic way to perform activity necessary for the functional independence of patients with PD as a good tool to be explored in the clinical environment. Thus, tasks from virtual environment can be transferred to functions in the real environment on a day to day basis.

The data described above confirm others studies that used immersive VR simulating a home environment to test the adaptation of patient with PD in a virtual environment to determine if the VR could offer more information concerning clinical and neuropsychological approaches. In this study the virtual environment reproduces situations of ADL: there was a furnished flat with some rooms where the participants could move and interact with the objects. In comparison with the control group composed by healthy participants with similar ages, the patients with PD showed a light difficulty in tasks which need memory, orientation in space and they were slower during every practice, especially when they were invited to walk through doors or a narrow space like a restroom. However, the authors defend that the VR offers a new opportunity in the neurorehabilitation field to provide clinical support by detection of predictive markers for disturbances of motor execution.

The VR, based on rehabilitation protocol, teaches the patients to develop autonomy, self-efficacy, social integration and improvement of quality of life[30]. Although the VR studies show advantages related to mimic ADL of patients in a therapeutic environment, controlled and assisted by a therapist, it is important to consider that not all virtual tasks could represent exactly the real tasks. The VR may have limitations to mimic real tasks. For example, grasping objects and the necessity to impose strength to support and handle these objects can be hard to reproduce in virtual tasks.

Considering VR as an assessment tool, a research introduced the Nintendo Wii Remote™ as software projected specifically to assess the patients with PD. This software was able to capture, analyze and visualize longitudinal changing of motor and non-motor conditions. This provided an intuitive experience for the user capable of detecting a much larger range of measurements than any other solution presently available. Besides, this software is a low cost approach.

The motor assessment was inserted in mini-game format that was chosen to provide benefits. First of all, this format has the potential to combine the ludic, intuitive, with the analysis of movement, removing the monotony of repetition and adding a competitive way to complete the tasks and increasing the acceptance in the long term. Secondly, the development of mini-games allows an inclusion of tasks similar to those performed in a clinical assessment. However, this study shows limitation because it has not yet been applied to humans[31].

One of the symptoms developed with the advance of PD is postural instability. Researchers studied the effects of balance training, sensorial interaction and attention for postural control in a virtual environment. In this study the authors compared the virtual environment training with that similar to a real environment and a control group without intervention. The training took 6 weeks for both groups. The activities included 10 minutes of stretching exercises to increase flexibility of the trunk and lower extremities.

Next, the participants of the virtual environment group performed 20 minutes of VR training and the participants of the real environment group performed 20 minutes of balance training, totalizing 30 minutes per session. At the end of the study, no significant difference was found related to balance scores between the VR and conventional groups.

However, the balance score in the sensorial organizational test with opened eyes in VR group increased significantly in comparison with the untrained group after the training period. The balance score in the sensorial organization test with closed eyes in the conventional group also increased significantly in comparison with the untrained group.

Thus, the authors concluded that in both groups (VR and conventional) there was an improvement in the sensorial integration for postural control in patients with PD. However, the necessity for attention to postural control was not altered in both groups[32]. These data confirm those results showed in a previous study[14] that there were not found any significant differences between the VR and the trained groups with activities in a real environment.

In a recent study using non-immersive VR (Nintendo Wii Fit™ and Balance Board) at home, the authors[33] assessed the effects of the balance training and functional abilities in patients with PD. The participants performed a specific program of 40 minutes, 3 days per week, during 6 weeks, totalizing 18 sessions.

After this training period under supervision of researchers, the participants were guided to perform the training in their homes and to take note of scores of the games. At the end of 18 sessions, the patients with PD improved significantly their results in following variables Timed Up and Go (TUG), seat to stand test (SST), Unipodal stance test (UST), Mobility Assessment, POMA and force platform. On the other hand, the group of healthy elderly participants obtained a significant improvement in TUG, SST, UST and Mobility Assessment.

Based on data showed, the authors suggest that the program of balance training using Wii Fit™ with Balance Board performed at home may improve the static and dynamic balances, functional mobility and abilities of the patients with PD. These results are contrary to the studies mentioned above, considering that the PD group obtained improvement in all post-training tests. The VR can be an easy therapeutic tool, usable at home, allowing patients with displacement difficulties to perform the treatment at Rehabilitation Centers.

The motor system and the cognition of patients with PD may influence in negative way the learning, according to demands imposed by tasks trained. Thus, it is important to define the criteria for selection of games with more therapeutic potential for patients. In addition, it is important to consider learning and retention aspects using games based on VR with different characteristics in order to study the effects of transfer to real tasks[13].

The VR includes the principles of motor learning and equally offers training involving engagement and challenge for participants in a complex environment[31]. Thus, the VR can be a potential tool to solve motor deficits showed by patients with PD. However, many studies based on well-designed methodology are necessary to confirm these hypotheses.

Due to the degenerative nature of PD, physical therapy guidelines suggest that treatment must occur on a long term basis. This can commit the continuation of therapy by patients for treatment because exercises, generally, are repetitive and monotonous. The VR can be used as a new tool in association with physical therapy to improve the motivation. Thus, the regularity of patients in long term rehabilitation can contribute to improve functional aspects and to prevent negative consequences of immobility[13,14].

Positive results were obtained in previous studies[13,14,23] although all studies have limitations in their conclusions. The following variables must be considered: criteria for selection of games, number of samples, absence of control group, definition of post-intervention data collection immediately afterwards or by follow up estimate of retention.

Perspectives

The scientific literature shows that VR is a therapeutic tool with potentiality for the use in physical neurorehabilitation. However, it is important to highlight some issues, such as: 1) Technological innovations are even more present in our lives and for this reason, in a short period, videogames based on VR can be substituted by new technologies.

Thus, it is important to understand the mechanisms and phenomenon that explain the benefits of the use of these devices instead of obtaining only the validity as a therapeutic purpose; 2) How does the learning processing occur in patients with PD using VR? It is important to consider that this resource offers: visual and auditory cues, cognitive-motor integrative training and possibility of number of repetitions; 3) Most of the studies focus variables on the lower extremities and it is important that other studies emphasize the effects of VR on the upper extremities in patients with PD. For example, scales that evaluate functional aspects, such as: 9-hole peg test, TEMPA and the impact of physical training of these patients in rest tremor by assessment and measurement, using accelerometer; 4) Requirement to investigate the quality of life in patients with PD submitted to physical therapy using VR.

The results in literature discovered until now suggest that, VR should play a real role in: the potential of motor learning and control, functionality, cognitive capacity and the balance of PD. Besides, other benefits are described, such as: higher adhesion for neurorehabilitation process.

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