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Effects of virtual rehabilitation on cognition and quality of life of patients with Parkinson's disease

Efeitos da reabilitação virtual na cognição e qualidade de vida de pacientes com doença de Parkinson

Efectos de la rehabilitación virtual en la cognición y calidad de vida de pacientes con enfermedad de Parkinson

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Abstract

Introduction: Parkinson's disease causes progressive decline of motor and cognitive functions leading to a decrease in the independence and quality of life of people affected. Training through virtual reality is proving effective, as it promotes cognitive and motor stimuli, which can be beneficial for these individuals, improving their quality of life. **Objective:** To analyze the effects of virtual reality on the cognition and quality of life of patients with Parkinson's disease. **Methods:** A total of 11 individuals with a mean age of 65 (9.6) years classified in stages 1 to 3 of the Hoehn and Yahr Scale participated in this study. The subjects participated in fourteen sessions lasting one hour, twice a week for seven weeks in which they practiced four games of *Kinect Adventures!.* They were evaluated before, immediately after the intervention and 30 days after the intervention. Cognition was assessed using the Montreal Cognitive Scale (MoCA) and quality of life was assessed using

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the Parkinson's Disease Questionnaire (PDQ-39). **Results:** Only PDQ-39 activities from the domain of daily living demonstrated a statistically significant improvement. The MoCA scores, in general, remained the same. **Conclusion:** Although virtual reality training promoted improvement in PDQ-39 activities in the daily life domain, it was not effective in the other domains assessed for quality of life and cognition.

Keywords*:* Parkinson's Disease. Virtual Reality Exposure Therapy. Quality of Life. Cognition.

Resumo

Introdução: *A doença de Parkinson provoca declínio progressivo das funções motoras e cognitivas, levando a uma diminuição da independência e da qualidade de vida das pessoas acometidas. O treinamento por meio de realidade virtual tem se mostrando eficaz, pois promove estímulos cognitivos e motores, o que pode ser benéfico para estes indivíduos, melhorando sua qualidade de vida.* ***Objetivo:*** *Analisar os efeitos da realidade virtual na cognição e qualidade de vida de pacientes com Doença de Parkinson.* ***Métodos:*** *Tratou-se de uma série de casos. Participaram deste estudo onze indivíduos com média de idade de 65 (9,6) anos classificados nos estádios 1 a 3 da Escala Hoehn e Yahr. Os indivíduos participiaram de quatorze sessões com duração de uma hora, duas vezes por semana durante sete semanas no qual praticaram quatro jogos do* Kinect Adventures!. *Eles foram avaliados antes, imediatamente após a intervenção e 30 dias após a intervenção. A cognição foi avaliada por meio da Escala Cognitiva de Montreal (MoCA) e a qualidade de vida foi avaliada por meio do Questionário de Doença de Parkinson (PDQ-39).* ***Resultados:*** *Somente as atividades do PDQ-39 do domínio da vida diária demonstraram melhoria estatisticamente significante. Os escores da MoCA, em geral, permaneceram os mesmos.* ***Conclusão:*** *Embora o treinamento da realidade virtual tenha promovido melhoria nas atividades do PDQ-39 no domínio de vida diária, não foi efetivo nos outros domínios avaliados quanto à qualidade de vida e cognição.*

Palavras-chave: *Doença de Parkinson. Terapia de Exposição à Realidade Virtual. Qualidade de Vida. Cognição.*

Resumen

Introducción*: La enfermedad de Parkinson provoca una disminución progresiva de las funciones motoras y cognitivas, llevando a una disminución de la independencia y de la calidad de vida de las personas afectadas. El entrenamiento por medio de la realidad virtual se ha demostrado eficaz, pues promueve estímulos cognitivos y motores, lo que puede ser beneficioso para estos individuos, mejorando su calidad de vida.* ***Objetivo:*** *Analizar los efectos de la realidad virtual en la cognición y calidad de vida de pacientes con enfermedad de Parkinson.* ***Métodos:*** *Se trata de una serie de casos, participaron de este estudio once individuos con una media de edad de 65 (9,6) años clasificados en los estadios 1 a 3 de la escala Hoehn y Yahr. Los individuos participaron en catorce sesiones de una hora, dos veces a la semana durante siete semanas en las que practicaron cuatro juegos de* Kinect Adventures!. *Se evaluaron antes, inmediatamente después de la intervención y 30 días después de la intervención. La cognición fue evaluada por medio de la Escala Cognitiva de Montreal (MoCA) y la calidad de vida fue evaluada a través del Cuestionario de Enfermedad de Parkinson (PDQ-39).* ***Resultados****: Sólo las actividades del PDQ-39 del dominio de la vida diaria demostraron una mejora estadísticamente significativa. Los escores de la MoCA, en general, permanecieron iguales.* ***Conclusión:*** *Aunque el entrenamiento de la realidad virtual ha promovido una mejora en las actividades del PDQ-39 en el ámbito de la vida diaria, no fue efectivo en los otros ámbitos evaluados en cuanto a la calidad de vida y cognición.*

Palabras clave*: Enfermedad de Parkinson. Terapia de Exposición Mediante Realidad Virtual. Calidad de Vida. Cognición.*

Introduction

Parkinson's disease (PD) is caused by the degeneration of dopaminergic neurons of the substantia nigra from the nuclei of the base, which results in a progressive decrease in dopamine production. In individuals with PD, this compromise leads to the following classic signs: bradykinesia, rest tremor, stiffness, and postural instability [1]. Among motor signals, postural instability is the most refractory to pharmacological treatment [2].

The disease also leads to non-motor symptoms, such as cognitive, neuropsychiatric, behavioral, and sensory issues, sleep disturbances, and problems related to decision making, memory, depression, anxiety, and visual-spatial perception [3, 4], with depression and cognitive complaints being the most worrisome because they contribute to a reduced quality of life (QOL) among patients with PD [5]. It is believed that physical impairments comprise one of the precursors to decreases in the QOL of patients with PD, since they also lead to declines in cognitive, psychological, and emotional aspects of life [6 - 8].

Non-motor symptoms do not respond well to treatment and are common in approximately 90% of PD patients, representing some of the greatest challenges in managing the lives of these individuals [3]. The social stigma associated with these symptoms negatively influences the QOL of affected individuals [9] by discrediting them, resulting in their increased withdrawal from social participation and, ultimately, isolation [10]. Therefore focusing on QOL, especially with regard to psychological and cognitive health, should be a priority for individuals diagnosed with PD [11].

Virtual reality requires the player to effect quickly and centrally controlled multidirectional shifts of their center of gravity that are associated with cognitive demands, such as rapid decision making, division of attention, monitoring of the environment, selection of visual stimulus, and inhibition of responses; intense visual and auditory stimulation can promote positive effects on the postural control, gait, and cognition of individuals with neurological disorders, including those with PD [12]. Accordingly, we propose that the application of virtual reality in the treatment of PD patients can promote simultaneous motor and cognitive training.

In the Kinect system, individuals do not depend on controls or platforms to play, which provides them with more freedom to interact with games, to capture movements in a three-dimensional form, and, consequently, to increase their motor activity [13]. In addition, the system provides visual and auditory feedback to the players, which makes it possible for them to know real-time performance and the results of each attempt, factors that facilitate motor learning [14, 15].

Compared to conventional therapies, virtual-reality therapy might be more motivating and pleasurable for the patient. It is no longer perceived only as a rehabilitator but also as a leisure activity [15, 16]. Dockx et al. [12] report that virtual reality interventions are still inconclusive and future studies are needed to determine the relevance, duration, and frequency of the virtual reality intervention.

As cognitive alterations directly influence the autonomy and independence of patients with PD [17], there clearly is a need for further investigations on virtual reality, especially since previous studies have not found differences between groups trained with and without virtual reality in terms of cognitive outcomes [13].

Methods

Type of Study

A series of cases was carried out in this study. The approval number of the Ethics Committee is 226,672.

Location of the Study

The study was conducted at the Department of Speech Therapy, Physiotherapy and Occupational Therapy at the University of São Paulo, São Paulo-SP/Brazil.

Inclusion Criteria

Eleven individuals with a diagnosis of idiopathic PD and classified as being in stages 1 to 3 of the Hoehn and Yahr Scale (modified) were selected by convenience for the study [18]. Inclusion criteria were as follows: no other detectable neurological or orthopedic diseases; no clinical signs of dyskinesia; no signs of dementia as determined by the Mini Mental State Examination (MMSE), with a cut grade adjusted for schooling (illiterates: 17, 1 - 4 years of schooling: 23, 5 - 8 years of schooling: 25, 9 or more years of schooling: 27), normal or corrected visual and auditory acuity; no previous experience with the Kinect system; no participation in a rehabilitation program within the last 2 months; and submission of a signed informed consent form.

Exclusion Criteria

Patients who, during the study period, presented any type of clinical impairment that made it impossible to perform standing exercises, such as cardiorespiratory, orthopedic, or neurological impairment, were excluded.

Intervention

Fourteen individual sessions lasting 1 hour each (twice a week for seven weeks) were scheduled in a manner coincident with the administration period of medication used as a dopaminergic replacement.

Kinect Training

The Kinect system of the X-Box 360 is a last-generation video game that captures movement through cameras with an infrared signal sensor; thus, the movement of the player is captured by the camera and reproduced by an avatar in a virtual game environment [19].

The participants randomly played four games of *Kinect Adventures!* and completed five attempts for each game, all of which were performed at the same level of difficulty. In the first session, each game was demonstrated once for the participant and then played without counting the score and while receiving verbal and manual corrections by the physiotherapist in order to familiarize the player with the video game system and the individual games. When necessary, a second attempt was made with corrections, also without counting the score.

While playing the games, participants stood in front of a TV with a 50-inch screen. The games, which were previously tested in a study by Pompeu et al. [19] were selected based on their motor and cognitive demands and included the following: *20,000 Leaks, Space Pop, Reflex Ridge, and River Rush*. According to Cairolli [20] the games have demands for postural, cognitive, coordinating, musculoskeletal and perceptual control. In the game *20,000 Leaks*, the avatar is inside a glass cube at the bottom of the sea; fish and sharks begin to pierce the glass, which causes water to enter the cube. The player's goal is to cover the holes with their hands and feet, which requires the rapid displacement of limbs and efficient postural control. In the *Space Pop* game, several bubbles appear on the screen, and players have to fly and flutter their arms like a bird in order to burst the bubbles. In the *Reflex Ridge* game, the player moves on a platform on a track and must deflect obstacles by means of rapid sideways or downward movements. Finally, in the game *River Rush*, the avatar of the player is inside a boat on a river. To move the boat, players must shift their bodies to the sides to avoid obstacles and to take shortcuts; they also have to jump in order to reach coins.

Outcome

Initially the patients were evaluated by the Section III of the Unified Parkinson Disease Rating Scale (UPDRS), corresponding to the motor skill exam, to classify the severity of the symptoms. This section is composed of 27 items, each item ranges from 0 to 4, and the higher the score, the greater the motor impairment caused by the disease.

The patients were evaluated before, immediately after, and 30 days after the end of the intervention. They were not in any other type of rehabilitation during this period.

The analysis of cognition was completed via the Montreal Cognitive Scale (MoCA), and quality of life was assessed using the Parkinson's Disease Questionnaire (PDQ-39).

The MoCA aims to detect slight degrees of cognitive changes and evaluates the following eight cognitive functions: visuospatial and executive, naming, memory, attention, language, abstraction, late recall, and orientation; tasks and scores have been established for each of the functions. The total score of the scale is 30 points (totaling the points of each task performed), and scores greater than or equal to 26 indicate normal cognitive performance [21].

The PDQ-39 contains 39 questions that assess eight domains: mobility, daily life activities, emotional state, stigma, social support, cognition, communication, and body discomfort. The questions concern the frequency of PD-related difficulties the patients experienced during the preceding month. The total result of each domain ranges from 0 to 100; the lower the score, the better the perception of the quality of life of the individuals. A cut-off score was not established for this scale [8].

Data Analysis

A descriptive analysis of clinical and demographic data was performed through calculation of the mean and standard deviation and 95% confidence intervals. The Shapiro-Wilk normality test was applied. Because the variables did not present normal distribution, Friedman's Double Analysis of Variance of Related Samples was applied. The alpha value of 0.05 was adopted as the level of statistical significance.

Results

Table 1 shows the clinical and demographic characteristics of the 11 individuals who participated in the study, which included seven men (63.6%) and four women (36.4%) whose ages ranged from 48 to 76 years, with a mean age of 65 years; the average amount of schooling was 10 years. The MMSE average score was 28.4 points, which was over the cut-off score of 27 points for the average schooling presented [22]. The mean of the Unified PD Rating Scale, section III (motor examination) was 13.5 points; since the minimum value of this scale (which indicates the best general condition of the patient) is 0 and the maximum value is 56, the mean score of 13.5 points indicates that the study participants are in the early stages of the disease. The Hoehn and Yahr Scale showed that two of the 11 participants (18.2%) were in stage 1.0 of PD, 4 (36.3%) were in stage 1.5, 3 (27.3%) were in stage 2.0, 1 (9.1%) was in stage 2.5, and 1 (9.1%) was in stage 3; these results indicate that most of the study participants were in the early stages of the disease and therefore were expected to have mild motor deficits.

Table 1 - Clinical and Demographic Characteristics, Mean (SD)

Age (years)	65 (9.6)
Male sex, n (%)	7 (63.6)
Schooling (years)	10 (4.8)
MEEM, n	28.4 (2.2)
UPDRS-III, n	13.5 (7.1)
HY, n (%)	
Stage 1.0	2 (18.2)
Stage 1.5	4 (36.3)
Stage 2.0	3 (27.3)
Stage 2.5	1 (9.1)
Stage 3	1 (9.1)

Note: SD = standard deviation; n = number of participants; MMSE = Mini Mental State Examination; UPDRS = Unified Parkinson's Disease Rating Scale; HY = Hoehn and Yahr Scale

Table 2 presents the results for the PDQ-39; in this scale, the lower the score, the higher the perception of the individual's quality of life. Only the activities of daily living domain demonstrate significant improvement ($p < 0.05$).

Table 2 - Quality of Life Score — PDQ-39, Mean (SD)

(To be continued)

	Pre-intervention		Post-intervention		30 Days After Intervention		P-Value
Domains	**Mean (SD)**	**Median**	**Mean (SD)**	**Median**	**Mean (SD)**	**Median**	
Mobility	23.9 (27.5)	12.5	7.7 (5.9)	5.0	10.9 (9.6)	10.0	0.328
Activities of Daily Living	29.9 (22.7)	20.8	24.6 (17.7)	25.0	21.2 (21.8)	8.3	0.023*

(Conclusion)

	Pre-intervention		Post-intervention		30 Days After Intervention		P-Value
Domains	Mean (SD)	Median	Mean (SD)	Median	Mean (SD)	Median	
Emotional Well Being	22.0 (22.8)	16.7	20.1 (16.3)	16.7	21.2 (15.0)	16.7	0.794
Stigma	10.2 (15.6)	0.0	19.3 (31.4)	0.0	11.9 (17.3)	0.0	0.692
Social Support	65.2 (5.0)	66.7	65.2 (5.0)	66.7	68.9 (5.4)	66.7	0.135
Cognition	21.0 (13.8)	18.7	18.5 (15.1)	18.7	18.2 (15.9)	18.7	0.248
Communication	22.7 (25.8)	16.7	21.2 (28.7)	16.7	18.2 (21.0)	16.7	0.446
Body Discomfort	30.3 (23.9)	25.0	34.8 (23.5)	25.0	34.8 (25.8)	25.0	0.682
Total	27.0 (11.9)	22.4	22.4 (9.8)	19.9	21.8 (8.2)	21.8	0.135

Note: SD = Standard Deviation; PDQ-39, Quality of life scale in Parkinson's PDQ-39. *Statistically significant ($p < 0.05$).

The MoCA results are presented in Table 3. There were no significant differences between the functions assessed by the questionnaire before, immediately after, and 30 days after the intervention. The greatest change occurred in the late recall function, which presented a slight increase in the score shortly after the end of the intervention that was maintained for 30 days, indicating a slight (but not statistically significant) improvement in memory. Of the 11 patients, 9 received 1 point because they had fewer than 12 years of schooling.

Table 3 - Cognition Score — MoCA, Mean (SD)

	Pre-intervention		Post-intervention		30 days after intervention		P-Value
	Mean (SD)	Median	Mean (SD)	Median	Mean (SD)	Median	
Visuospatial/ Executive	3.5 (1.0)	4	3.0 (1.1)	3	2.7 (1.3)	3	0.065
Naming	2.7 (0.6)	3	2.9 (0.3)	3	2.6 (1.0)	3	0.273
Attention	5.0 (0.9)	5	4.5 (0.9)	5	5.0 (0.8)	5	0.607
Language	2.1 (0.7)	2	2.0 (0.8)	2	2.1 (0.3)	2	0.882
Abstraction	1.1 (0.7)	1	1.3 (0.8)	1	1.0 (0.7)	1	0.368
Delayed Recall	2.8 (1.2)	3	3.8 (1.5)	5	3.7 (1.1)	4	0.063
Orientation	5.8 (0.4)	6	5.8 (0.4)	6	5.9 (0.3)	6	0.819
Total	23.7 (1.7)	24	24.2 (2.7)	25	24.0 (2.6)	23.5	0.472

Note: MoCA = Montreal Cognitive Assessment; SD = Standard Deviation.

Discussion

The results of the present study showed that virtual rehabilitation using the Kinect Adventures! games promoted positive effects in the daily life activities domains of PQD-39. This particular domain may have improved due to the benefits of virtual reality in relation to balance and postural control, since Kinect games use visual and auditory cues and thereby facilitate motor learning and help to improve postural control [12]. One study has shown that this domain is strongly associated with improving the overall health of patients with PD [23]. And in Dockx et al. [24] meta-analysis involving four trials and 106 participants with PD, was found no significant difference between VR and active control interventions for quality of life.

Despite the statistically insignificant result, there was a mean difference of 16.2 points between the pre- and post-intervention evaluations of the mobility domain, which was greater than the minimum detectable change defined by Fitzpatrick et al. [25] (12.2 points), indicating that the improvement can be detected clinically. For the other domains, the mean difference was lower than the value defined by the author [25].

The improvement in mobility after training with the *Kinect Adventures!* games was verified by Pompeu et al. [19]. The authors concluded that the improvements in mobility could be associated with the strong cognitive-motor stimulation promoted by the Kinect games [13, 19, 26, 27].

In general, the games stimulated multidirectional weight transfer, reaction time, reaching static and dynamic targets close to stability limits, jumping, squatting, and lifting, among other motor functions [23, 28]. In addition, several factors may have contributed to the improvement of postural control, such as the games' visual and auditory feedback and scoring as well as their playful and competitive aspects [29, 30].

The study by Pompeu et al. [13] showed that the use of *Nintendo Wii Fit* games promoted positive effects in the daily life activities of PD patients. Although this study used a different virtual-reality system, the results were like those found in our study. Like *Kinect Adventures!, Nintendo Wii Fit* promotes intense, highly challenging cognitive-motor stimulation for postural control and cognitive functions. This study suggested that improvements in the activities of daily living could be a result of the enhancement of postural control and cognition, both of which are directly associated functions and fundamental to performing the activities of daily living. We believe that *Kinect Adventures!* games have promoted similar effects in daily life activities due to the same mechanisms suggested by Pompeu et al. [19].

The intervention through virtual reality did not have an effect on the social support and physical discomfort domains. These results were expected since the Kinect games do not offer any specific stimulus for these issues.

Individual observations of the mobility domain results revealed that most of the patients entered the study with very low scores that were practically maintained throughout the training, resulting in small variations in the pre- and post-intervention values. This can minimize the sensitivity of scales and questionnaires in detecting differences and the capacity for changes promoted by the interventions [31]. This domain presents a high, statistically significant correlation with the total score of the PQD-39 [8], while the domain of daily life activities presents a moderate correlation [32]; that is, these domains are those that best conveyed the real self-perception of the QOL of the participants.

The participants in this study had a good perception of QOL from the pre-intervention evaluation; in other words, they entered the study with low PDQ-39 total scores, which may be due to the fact that they were not at an advanced stage of the disease (i.e., above level 3 of the Hoehn and Yahr Scale) and do not present disabling symptoms [33]. Thus, it is more difficult for them to achieve significant improvements in terms of their results when compared to individuals who began with a poor perception of QOL [10, 31].

Still in relation to the PDQ-39, the stigma aspect showed significant decreases at the end of the 14 sessions, and the body discomfort aspect had a slight decline, possibly due to a new perception that the individuals had in relation to their bodies, because during the games they were expected to perform activities with which they were unfamiliar and thus found them difficult to perform. This must have caused a sense of frustration that negatively impacted their self-image. Reinforcing this possibility is the finding that the stigma aspect improved 30 days after the end of the intervention.

In general, the domains that showed improvement after the end of the intervention also maintained those approximate results in the last evaluation, demonstrating that the effects of the virtual reality application remained even 1 month after the end of the sessions.

There was little improvement in cognition domain in the PDQ-39 (only 2.5 points), however, there were no changes in the MoCA results.

The greatest variation (1.0 point) occurred in the late evocation function, which represented a small improvement. This function is related to patient memory. It is not possible to affirm that this result implied an effective improvement in the memory of the patients, since the values of minimal clinically important change or minimal detectable change were not established for MoCA [34, 35].

The absence of these values may be related to the fact that MoCA is a screening tool for mild cognitive impairment and has not been shown to be a sensitive and specific evaluation method for evaluating the improvement of cognitive functions stimulated by virtual reality.

Assessments with greater sensitivity and specificity, such as neuropsychological tests, could be used in future studies to analyze the improvement of cognitive demands stimulated by Kinect games [25].

The sample consisted of light individuals, and this may be the explanation of the fact that there was no difference with the intervention.

In general, the small number and great variability of participants were the limitations of this study. The results of some domains were close to being statistically significant and would probably have reached that level if the number of subjects had been higher.

The different preconditions of the participants, such as those who started the study with a good perception of their QOL, influenced the result, since the values of the mean differences between the pre- and post-intervention evaluations decreased. This low mean difference in turn influenced the statistically nonsignificant result.

One limitation of this study is the absence of control group in order to compare the results with a conventional intervention. The cognition evaluation based on MoCA test might not provide a wide overview of the cognition and one could suggest to incorporate other outcome measurements.

Conclusion

Virtual rehabilitation via the use of *Kinect Adventures!* improved the daily life activities of patients with PD. However, no effects on the other quality of life and cognition domains were demonstrated.

We suggest that randomized clinical trials be conducted with a more significant sample and a control group. In addition, we suggest that neuropsychological tests with greater sensitivity and specificity be used to evaluate the cognitive functions stimulated by virtual reality.

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