Original Article

acta FISIÁTRICA
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Effects of a commercial immersive virtual reality device-based training on gait and cognition in people with Parkinson's disease

Efeitos de um treinamento com dispositivo comercial de realidade virtual imersiva sobre a marcha e cognição de pessoas com doença de Parkinson

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ABSTRACT

Objective: Evaluate the effectiveness and the usability of an immersive virtual reality training using Samsung Gear VR OculusTM (SGVR) for gait and cognitive in people with Parkinson's disease (PD). Controlled, quasi-experimental and blinded clinical trial was carried out. **Methods:** Forty people with PD were divided into two groups. Samsung Gear Virtual Reality Group (VRG) participated in 10 sessions, twice a week, lasting one hour each, performing four games that required head movement and center of gravity shift. Control group didn't receive treatment. Participants were evaluated before, after the intervention and 30 days after intervention, with the Timed Up and Go test, 10 meters walking test, single and dual tasking 30 seconds walking test, verbal fluency test, forward and backward Digit Span tests and Stroop Color test. At the end of the training, VRG responded to the System Usability Scale questionnaire to assess the usability of the system. **Results:** Even though the system was rated with excellent usability by the users, there were no interaction effects and, therefore, our results do not support that immersive virtual reality training using SGVR games was superior to no training. However, when each group was examined separately, the VRG experienced improvements, after the intervention and 30 days after intervention, for gait velocity ($p<0.005$, $p<0.001$, respectively), working memory, attention, and information processing ($p<0.01$ in both evaluation time points), response inhibition, working and long-term memory ($p< 0.01$ in 30 days after intervention). **Conclusion:** Further evaluation of the SGVR device is required.

Keywords: Parkinson Disease, Cognition, Gait, Virtual Reality, Rehabilitation

RESUMO

Objetivo: Avaliar a eficácia e a usabilidade de um treinamento imersivo de realidade virtual usando o Samsung Gear VR Oculus^{TM} (SGVR) para marcha e cognitivo em pessoas com doença de Parkinson (DP). Foi realizado um ensaio clínico controlado, quase experimental e cego. **Método:** Quarenta pessoas com DP foram divididas em dois grupos. O Samsung Gear Virtual Reality Group (VRG) participou de 10 sessões, duas vezes por semana, com duração de uma hora cada, realizando quatro jogos que exigiam movimento da cabeça e deslocamento do centro de gravidade. O grupo controle não recebeu tratamento. Os participantes foram avaliados antes, após a intervenção e 30 dias após a intervenção, com avaliação da marcha por meio do teste Timed Up and Go, teste de caminhada de 10 metros, teste de caminhada de 30 segundos com tarefa simples e dupla e avaliação cognitiva com teste de fluência verbal, dígito para frente e para trás Testes de amplitude e teste Stroop Color. Ao final do treinamento, a VRG respondeu ao questionário System Usabilidade Scale para avaliar a usabilidade do sistema. **Resultados:** Embora o sistema tenha sido avaliado com excelente usabilidade pelos usuários, não houve efeitos de interação e, portanto, nossos resultados não suportam que o treinamento de realidade virtual imersiva usando jogos SGVR foi superior a nenhum treinamento. **Conclusão:** No entanto, quando cada grupo foi examinado separadamente, o VRG apresentou melhoras, após a intervenção e 30 dias após a intervenção, para velocidade da marcha ($p<0{,}005$ e $p<0{,}001$, respectivamente), memória de trabalho, atenção e processamento de informações ($p<0{,}01$ em ambos os momentos de avaliação), inibição de resposta, memória de trabalho e de longo prazo ($p< 0{,}01$ em 30 dias após a intervenção). A avaliação adicional do dispositivo SGVR é necessária.

Palavras-chaves: Doença de Parkinson, Cognição, Marcha, Realidade Virtual, Reabilitação

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Conflict of Interests
Nothing to declare

Submitted: August 17, 2022
Accepted: February 14, 2023

How to cite
Rocha PS, Silva AKS, Piemonte MEP, Mendes FAS. Effects of a commercial immersive virtual reality device-based training on gait and cognition in people with Parkinson's disease. Acta Fisiátr. 2023;30(1):13-20.

DOI: 10.11606/issn.23170190.v30i1a201169

INTRODUCTION

Parkinson's disease (PD) is neurodegenerative, chronic, progressive and compromises motor and cognitive functions.[1,2] Motor signs include rest tremor, stiffness, bradykinesia and postural instability.[3,4] Gait impairments are also present, with reduction in both speed and steps length.[5,6]

Non-motor signs, involving memory, attention[7] information processing and decision-making, spatial time organization[8] and inhibitory control,[9] impairments correspond to the main cognitive changes in PD. Exercise has already been shown to be effective in improving balance[10] and cognition[11] in people with PD.

The most studied non-immersive commercial VR systems are the Nintendo Wii™, which requires the use of manual controls to interact with the games, and the Xbox Kinect™, whose interaction takes place through infrared sensors.[12] There are currently several studies that have evaluated the effects of using these video games in PD patients. Intervention studies using the Nintendo Wii™ have demonstrated improvements in balance,[13-15] mobility, and gait,[16-19] in cognitive aspects including learning,[20,21] in quality of life[22] and in activities of daily living.[23] Although less numerous, studies using the Xbox Kinect™ were also found and found improvements in balance, gait, cognition, and upper limb function.[16,24-28]

Recently, commercial immersive VR systems (IVR), which allow the interaction of the player with virtual tasks, in real time, through playful interface, have emerged.[29] These systems use multisensory devices that promote virtual experiences, capturing head, trunk and pelvis movements, through of Head Mounted Displays (HMD).[30,31] Samsung Gear™ VR (SGVR) is commercially available, less expensive, has minimal visual latency, and offers positive patient experience,[32] in relation to other non-commercial IVR devices. The device is coupled to the player's head, whose displacements provide interaction with virtual environments and games, providing the execution of complex and motivating motor-cognitive tasks.[33] Games require movements that should be performed to achieve goals guided for cognitive demands.[31] Only one study so far[24] showed that VR training, using commercial devices that combine motor and cognitive demands, proved to be more effective than cognitive or motor training alone. Therefore more studies are needed to bring more reliable information.

So far, however, only two studies have been found on the therapeutic use of SGVR. The first concluded that hospitalized people obtained greater control of pain with the use of SGVR, with no occurrence of adverse symptoms.[32] The second study evaluated the feasibility and acceptance of the system by people hospitalized, after four months of use. It was concluded that the experience with SGVR was enjoyable and reduced the level of anxiety and pain of participants.[34] To our knowledge, no studies evaluated the motor or cognitive effects of using SGVR in people with PD.

Thus, despite the therapeutic potential, studies on motor and cognitive effects after using SGVR in people with PD have not been found so far. Our hypothesis was that training with the SGVR would promote improvements in participants' gait and cognition, superior to the group without training and that the system would have, at least, good usability.

OBJECTIVE

Therefore, the present study aimed to evaluate the effectiveness of a gait training with SGVR games, on the gait and cognition of people with PD, compared to a PD control group that received no training of any type. The secondary objective was to evaluate a usability of the SGVR system, in the people with PD`s view.

METHODS

This was a controlled, quasi-experimental and blinded clinical trial. All procedures were performed in the laboratories of the Physiotherapy Department of the Faculty of Ceilândia of the University of Brasília (UnB), Brazil, between January and July 2018. The study was approved by the Ethics and Research Committee of the Faculty of Ceilândia of UnB (CAAE 68491017.4.0000.8093).

Participants

The sample of this study consisted of 40 people with PD who were recruited through flyers and advertising banners fixed in the local community. All participants were diagnosed by a neurologist according to the UK Brain Bank criteria[35] and screened for eligibility by a physiotherapist. The inclusion criteria were: (a) reaching a minimum score of 24 in the Mini Mental State Examination, (b) demonstrating normal or corrected visual and auditory acuities, (c) scoring from 1 to 3 on the Hoehn and Yahr Classification, (d) having minimum education of 4 years and (e) using Levodopa regularly. The exclusion criteria were (a) having other neurological diseases or pathological conditions that prevented participation in training, (b) having previous experience with SGVR, (c) attending another specialized rehabilitation program and (d) scoring ≥ 6 on the Geriatric Depression Scale - GDS - 15 items. After screening, individuals who agreed to participate in the study provided informed written consent. Participants with PD were allocated nonrandomly.

Dependent Measures

All participants were evaluated, at all assessment time points, by a same researcher, that was blinded regarding to the allocation of study groups, and that was trained for the application of tests. All evaluations occurred at the same time of the day and under the same conditions. The evaluations were performed before the training (pre testing), 7 days after the training (post testing) and 30 days after the training (follow-up testing).

Gait Performance

Each test was repeated for three times and the mean performance was registered. The participants were instructed to walk at the maximum possible speed, without running. The following tests were performed: (a) Timed Up and Go (TUG)[36] The TUG evaluates functional mobility and proved to be reliable for people with PD, with intraclass correlation coefficient of 0.87.[36-39]

It measures the time to get up from a chair, walk three meters, return and sit again in this chair; (b) 10-meters walking test (10MWT).[39] The 10MWT is used to measure gait speed in people with PD, with an intraclass correlation coefficient= 0.96.[40] The test was performed in a hallway of 14 meters. The time required to walk the 10 central meters was recorded, disregarding the initial and final two meters;[41] (c) 30-second walking test under single and dual task conditions.[42]

The test, has been used due to the possibility of performing a cognitive task simultaneously to the motor task. Participants walked for 30 seconds in a straight line of 20 meters, performed a single turn and continued walking until completing the 30 seconds (single task) and later walked and evoked, simultaneously, words with a predetermined initial letter (dual task). The distance covered and the numbers of steps and words evoked were registered.

Cognitive Performance

The following tests were performed: (1) Verbal Fluency Test: used in patients with PD[43] it measures fluency, working and long-term memory. Participants should evoke the maximum number of words within a semantic category, in one minute; words said repeatedly were not considered (2) Forward and backward Digit Span tests.[44] Both tests assessed working memory and attention, but the Backward Digit Span test also assessed information processing. The examiner dictated the numbers and at the end the participant had to repeat the numbers progressively. Then the examiner dictated a new sequence of numbers and the participant had to repeat backward. (3) Stroop Color Test (Victoria version). It is used to assess inhibitory control. It is applied using three cards containing 24 colored rectangles or 24 colored words or 24 color names. The cards were shown to the participants who was asked to evoke, as fast as possible, the colors in which rectangles or words were colored. Time and number of errors are recorded.

Usability

At the end of the training, the usability, defined as the use of a product with effectiveness, efficiency, and satisfaction of user in a given contexto,[45] of the SGVR was evaluated in the VRG by means of the System Usability Scale (SUS). SUS is a questionnaire that evaluates the usability of a system, from the user's point of view. It is valid, reliable, and sensitive.[46] It consists of 10 questions on which the user must fill a scale from 1 ("I completely disagree") to 5 ("I completely agree"). The result was obtained from the sum of the scores of each item. The final score ranges from 0 to 100, representing the user satisfaction index, in percentage. Scores between 85-100 were considered as “the best imaginable”, 73-85 as “excellent”, 52-73 as “good”, 39-52 as “ok”, 39-25 as “poor” and below 25 as “the worst imaginable”.[46,47]

Intervention

After the initial evaluation, 40 participants with PD were allocated, through a convenience sample, non-randomly, into two groups of 20 participants each, forming the Samsung Gear Virtual Reality Group (VRG) and the control group (CG). The VRG training was delivered by means of the Samsung GearTM VR oculus (Ridgefield Park, New Jersey, USA). The training consisted of 10 individual sessions, lasting one-hour, distributed in two weekly sessions, for five consecutive weeks. The sessions were performed in the "on" period of dopaminergic medication.

One physical therapist (F. A. S. M.), with more than 20 years of clinical experience in PD, selected 4 games from the repertoire offered by SGVR. Games were analyzed and selected, based on the movements to be performed by the player and by their potential for using in gait training in people with PD. Those 4 games were also selected based on their potential utility for stimulating cognitive skills typically comprised in PD.

The games selected were: Goalkeeper, Great Header, Space Dodge and Oculus 360 Photos. The games´ main motor and cognitive demands and their tasks descriptions are presented in Chart 1. A smartphone (Samsung^{TM} S6) was coupled to the SGVR device and fixed to the participant's head. The smartphone displayed the images and sounds of the games. Additionally, the images viewed by the participants were reproduced on computer monitor, through the MirrorOp^{TM} app, so that the trainer could visualize the participant´s performance and guide their movements. The objectives of the games were explained to the participants at the beginning of the first training session and one familiarization attempt was allowed. Three attempts were performed per game, in each session, in which the participants received verbal and proprioceptive stimuli, by a physiotherapist, to help them to move correctly. Rest intervals were respected during the training as needed individually. For clinical safety, the participants´ heart rate and blood pressure were monitored in all sessions and any type of adverse event was reported.

Chart 1. Games´ main motor and cognitive demands and their task descriptions

Games	Motor Demands	Cognitive Demands	Task Description
Goalkeeper	Lateral displacement, with hip abduction, bilateral head rotation, knees and hips flexion movements	Planning, Attention, Information processing	The player is a goalkeeper who has to move the head and trunk to defend balls that are kicked toward the goal
Great Header	Anteroposterior displacement of the center of gravity, weight transfer over the lower limbs	Planning, Decision making, Information processing Attention	The player must move his head back and forth, heading one ball to hit the targets
Space Dodge	Lateral and anteroposterior pelvis displacement, bilateral head rotation	Planning, Attention, Decision making, Inhibitory control, Memory	The player has to drive the spaceship with body movements, dodging obstacles
Oculus 360 Photos	Turning in place performing stationary steps	Sustained attention Working memory Spatial time organization Dual tasking	The player must turn around (360°) and verbally to describe the displayed images

The control group performed all pre-, post-, and follow-up testing evaluations over the 5-week period but received no training of any type during the 5-week VR training period. Immediately after the end of the study evaluations, the participants of the CG were referred to physiotherapy program in an university project. Participants in both groups did not undergo other therapies during the training and/or assessment periods.

Data Analysis

All analyses were performed using the statistical package SPSS 21.0 (Chicago, IL, USA). The Shapiro-Wilk test confirmed the normality of the data distribution. Both groups´ data were summarized as means and standard deviations. Unpaired T-test was applied to compare the demographic and clinical characteristics of the groups. A mixed ANOVA of repeated measures, with time (pre, post and follow-up) as within factors and the groups (VRG and CG) as between factors, was used to analyze clinical outcomes.

The Tukey test was used for post hoc analysis of specific two-way comparisons between variables, regardless of the results of the interaction effects. Within-group (pre- to post changes) effect sizes (ES) were calculated using Cohen's d for each outcome. Effect sizes were classified as small (ES ≤0.49), medium (ES 0.50–0.79), and large (ES ≥0.80). Statistical significance of 5% was adopted.

RESULTS

The demographic and clinical characteristics of the participants are presented in Table 1. Baseline features of both groups were not significantly different.

Table 1. Characteristics of participants and between-group comparisons

Characteristics	Groups				
	VRG		CG		
	Mean	Standard Deviation	Mean	Standard Deviation	p[a]
Age (years)	60.32	7.75	64.36	9.65	0.24
Sex: Male/Female	16/4		12/8		0.58
Education (years)	11.37	4.51	10.36	4.67	0.60
MMSE (score)	27.79	2.22	27.36	2.65	0.72
GDS-15 (score)	1.74	1.24	3.00	2.64	0.16
H&Y (score)	1.74	0.56	2.00	0.89	0.58

n= 20 for each group; Statistics are presented as Mean and Standard Deviation; [a]Unpaired T-test; VRG= Samsung Gear VR group; CG= Control group; MMSE= mini mental examination; GDS-15= Geriatric Depression Scale—15 items; H&Y= Hoehn and Yahr scale

Table 2 shows the performance of each group on the gait tests. No group or interaction effects were observed for the 10MWT. The VRG showed significant improvement in gait speed, measured by the 10MWT (RM ANOVA time effect - F= 8.82; df= 2; p= 0,000). The post hoc test showed that there were significant differences between the pretesting and post testing and also between the pretesting and follow-up testing, only for VRG, but there was no statistically significant difference between VRG and CG. There were no statistically significant effects for TUG and for the 30-second walk tests in any group.

Table 3 shows the performance of each group in the cognitive tests. No group or interaction effects were observed in the Forward or Backward Digit Span tests and verbal fluency. The VRG showed significant improvement in the performance of the verbal fluency test in the follow-up, compared to the baseline (RM Anova time effect - F= 7.52; df= 2; p= 0.01).

Only VRG showed significant improvements in the post-test performance that were maintained in the follow-up, compared to baseline in both of them in the Forward or Backward Digit Span tests (RM Anova time effects: F= 2.52; df= 2; p= 0.04, and F= 4.75; df= 2; p= 0.011, respectively), but there was no statistically significant difference between VRG and CG in the verbal fluency test and Forward or Backward Digit Span tests. No significant differences were found in the Stroop Color Test in any group (RM Anova time effect - p= 0,074).

In the SUS questionnaire, the VRG presented a mean score of 84.75 ± 12.32 what means "excellent" usability of the system in the user´s point of view. Most of the participants (65%) classified the usability of the system as "best imaginable", 25% of participants rated it excellent, 5% rated it good, 5% rated it OK, no patient rated the system's usability as poor and worst imaginable. Additionally, no adverse events and falls were recorded during training.

DISCUSSION

The current study aimed to evaluate the effects of training with SGVR games, on gait and cognition of people with PD, compared to a group without any intervention. In motor assessment, there was time effect for VRG in gait speed, measured by 10MWT, in the post-testing and in the follow-up, when compared to the pre-testing. In the cognitive evaluation, by means of the Forward and the Backward Digit Span tests and of the verbal fluency test, there were time effects, as well, for VRG in the post-testing performance that was maintained in the follow-up, compared to baseline. However, as there were no group or intervention effects in any test, it must be clear that there was no difference between the groups in terms of intervention effects.

Although already demonstrated in previous studies,[16,48] that the training with virtual reality, using Xbox and Nintendo Wii, could promote significant improvements in cognition, such as visuospatial abilities, attention, concentration, language, fluency and orientation,[48] working memory[16,48] and gait of people[16] with PD, our results did not demonstrate improvements on cognition and gait speed performance, using the SGVR system, even with time effects presented for VRG. Therefore, our results were not able to confirm the hypothesis of significant gait and cognition improvement, when comparing our sample and using that device.

The VRG training was not planned as an exclusive motor training, but as a motor-cognitive training, as the movements must be performed simultaneously with the execution of specific cognitive tasks required by each game. Anteroposterior displacement of the center of gravity was required in the Great Header game, in which the participants should perform head and trunk movements to direct balls toward to mobile targets, and also in the Goalkeeper game, in which it was additionally necessary to perform knees and hips flexions to defend balls kicked in different velocities and positions. In the Space Dogde game, participants performed trunk displacements and lateral steps to guide a spaceship, avoiding obstacles. In the Oculus 360 Photos game, participants were instructed to perform steps alternation to turn 360° and describe landscapes that were displayed on the screen.

In the Goalkeeper game, eg., participants should defend balls kicked quickly, requiring attention and information processing. In the Great Header game, information processing and decision making were essential for player to drive balls towards specific targets. In the Space Dogde game, attention, inhibitory control, memory, and decision making were essential to prevent the virtual spaceship of crashing into obstacles; Oculus 360 Photos task required dual tasking to carry out the stationary march, turning around and, simultaneously, to describe the images that were projected. Success in that task, therefore, depended also on working memory and sustained attention.

Although the games chosen for the study presented important motor aspects for gait training, such as the requirement for alternating stationary steps and active displacements of the center of gravity, associated to simultaneous cognitive demands, this stimulation was not enough to promote significant differences. The SGVR system seems not to be suitable to be used as gait training tool for people with PD, once that its main demand is only head movements for gaming interaction. In order to test the therapeutic potential, we tried to insert multijointed movements including trunk, pelvis and lower limbs movements in the training. Nevertheless, there was no significant effects.

Table 2. Performance of participants on the gait tests

	Pretesting Mean (SD)	Post testing Mean (SD)	Follow up testing Mean (SD)	Post x Pretesting ES (95% CI)	Follow up x Pretesting ES (95% CI)	P (Post testing)	P (Follow up testing)
10MWT (meters/seconds)							
VRG	1.6 (0. 2)	1.7 (0. 2)*	1.8 (0.2) **	0.5 (0.02 - 0.20)	1 (0.09 - 0.24)	0.01	0.001
CG	1.1 (0. 3)	1.2 (0. 3)	1.2 (0.3)	0.3 (-0.03 – 0.14)	0.3 (-0.02 – 0.13)	0.25	0.16
TUG (seconds)							
VRG	8.0 (1.3)	7.5 (1.3)	7.3 (1.3)	0. 3 (-3.00 – 2.11)	0.5 (-2.37 – 1.09)	0.72	0.46
CG	12.6 (8.3)	10.0 (2.9)	10.9 (4.9)	0.4 (-5.11 – 0.00)	0.2 (-3.40 – 0.06)	0.05	0.05
30-Seconds WTST (meters)							
VRG	50.6 (5.2)	51.2 (8.5)	52.0 (9.5)	0.0 (-2.56 – 3.73)	0.1 (-1.76 – 4.48)	0.70	0.38
CG	35.9 (10.7)	35.4 (9.2)	34.3 (10.2)	0.05 (-3.61 – 2.68)	0.1 (-4.75 – 1.49)	0.76	0.29
30-Seconds WTDT (meters)							
VRG	41.7 (8.6)	42.5 (8.3)	43.3 (7.7)	0.09 (-1.67 – 3.30)	0.1 (-1.22 – 4.48)	0.51	0.25
CG	29.1 (11.4)	29.0 (10.2)	28.7 (9.9)	0.00 (-2.59 – 2.52)	0.03 (-3.34 – 2.52)	0.97	0.77

*SD= standard deviation; CI= confidence interval; ES= effect size; *p< 0.05, **p< 0.01= Tukey´s post hoc test-comparisons related to the pre-training measure; TUG= Timed Up and Go Test; 10MWT= 10-meter walking test; WTST= walking test in single task; WTDT= walking test in dual task; VRG= Samsung Virtual Reality Group; CG= Control Group; Post testing= 7 days after Pretesting; Follow up= 30 days after Pretesting*

Table 3. Performance of participants in cognitive tests

	Pretesting Mean (SD)	Post testing Mean (SD)	Follow up testing Mean (SD)	Post x Pretesting ES (95% CI)	Follow up x Pretesting ES (95% CI)	P Post testing	P Follow up testing
Verbal Fluency Test (number of words)							
VRG	12.5 (4. 2)	11.9 (1. 7)	15.1(3.0) *	0.1 (-2.96 – 1.7)	0.7(0.82 – 4.37)	0.89	0.002
CG	14.9 (6.3)	13.1 (3.7)	14.4(5.9)	0.3 (-4.21 – 0.63)	0.08 (-2.29 – 1.34)	0.20	0.88
Forward Digit Span Test (number of right answers)							
VRG	8.3 (2. 6)	9.4(2. 5)*	9.9 (1.9) *	0.4 (0.13 – 2.06)	0.6 (0.31 – 2.78)	0.02	0.01
CG	11.4 (2.7)	11.4 (2.9)	10.8(2.7)	0 (-0.98 – 0.98)	0.2 (-1.79 – 0.73)	1.0	0.66
Backward Digit Span Test (number of right answers)							
VRG	4.8(1. 6)	6.1(1. 4)*	6.4(2. 0)*	0.8 (0.16 – 2.33)	0.8 (0.30 – 2.89)	0.01	0.01
CG	6.4(2.1)	6.9 (2.5)	6.47(2.89)	0.2 (-0.58 – 1.63)	0.02 (-1.28 – 1.38)	0.56	1.00
Stroop Color Test (seconds)							
VRG	27.0 (10.6)	23.2 (7.1)	20.9 (5.1)	0.4 (-8.90 – 1.44)	0.7 (-13.90 – 1.78)	0.22	0.17
CG	42.8 (18. 0)	38.1 (12.7)	43.5 (17.9)	0.3 (-10.12 – 0.79)	0.03 (-7.60 – 8.94)	0.11	0.99

*SD= standard deviation; CI= confidence interval; ES= effect size; * p< 0.05= Tukey´s post hoc test -comparisons related to the pre-training measure; VFT= verbal fluency test; FDS = Forward Digit Span test; BDST= Backward Digit Span test; SCT= Stroop Color Test; VRG= Samsung Virtual Reality Group; CG= Control Group; Post testing= 7 days after Pretesting; Follow up= 30 days after Pretesting*

In the author´s knowledge, this study was the first to evaluate the IVR system´s usability in people with PD. Previous studies, so far, only evaluated the usability of non-IVR systems. Lee, Shin, and Song´s[49] study found a good usability for Nintendo Wii® videogames in people with stroke. These participants scored an average of 71 points in the SUS. Lloréns et al.[50] study presented similar results when comparing the usability assessment of two groups of people with stroke (trained in a clinic or at home) after VR devices training. Participants in that study scored SUS with averages of 87.50 and 85.40 points, respectively. People with vestibular and other neurological diseases who underwent training with Nintendo Wii® Fit Plus, scored an average of 82 points.[51]

Usability was rated at least excellent by most of the patients in the current study, according to the criteria of SUS questionnaire46. It was plausible to suppose that using SGVR games could cause side effects, such as cybersickness,[52] in people with PD. However, there were no reports of vertigo, dizziness, or nausea, after using the system, even in participants in stage 3, according to H&Y, who have balance disruption.

Among the most important limitations of this study are the non-randomization of participants in the groups and the fact that the control group have maintained their usual activities, without any intervention and did not perform the same motor training involved in the VRG training. This limited our conclusions about the real effectiveness of IVR training for improving gait and cognition in people with PD.

The small sample size, which produces limited statistical power and makes it impossible to generalize the results to people with more advanced PD, the reduced number of sessions and low frequency of training and the failure to assess the performance of the participants in the trained games, which could bring more information about the learning curve, are also important limitations. In addition, the use of commercial games from the SGVR system can be a limitation and contribute to the results found, considering that they were not games created with therapeutic purposes for people with PD. Randomized clinical trials, with a greater number of participants and training sessions and that compare Immersive VR training with other therapies, are needed to better evaluate the effectiveness of immersive virtual reality training on gait and cognition of people with PD.

CONCLUSION

Our study indicated that a 10-sessions training with SGVR games was not able to promote significant improvement in gait velocity, information processing, working and long-term memory, attention, organizational skills, and response inhibition in people with PD. It was concluded, however, that the usability of the system was considered at least excellent by users, without the occurrence of adverse effects.

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