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REVIEW

A systematic review of serious games used for rehabilitation of individuals with Parkinson's disease

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Abstract

Purpose This study consists of a systematic review that aims to identify and evaluate the scenario of the use of serious games in the rehabilitation of individuals with Parkinson's disease.

Methods Web searches were conducted on Web of Science, Scopus, PubMed, Bireme, ScienceDirect, IEEE Digital Library, ACM Digital Library, and Google Scholar databases, using the keywords "serious game" and "Parkinson". The following variables were evaluated: type of game, interface, device, protocol used for rehabilitation, method used for assessing the effectiveness of the game, symptoms treated, and application in real patients. A total of 169 studies were identified and 38 were selected.

Results The majority of studies propose the development of exergames, used virtual reality as the interface technology, used Leap Motion and Microsoft Kinect to capture body movements, included a doctor or therapist to accompany the serious games development, used more than one tool to evaluate the game and patient outcomes, treated bradykinesia and gait impairments, and took into account experiments with patients.

Conclusion The results suggest that it is important that the solutions developed have high methodological rigor and that they extend the instrument to a clinical practice. Serious games for individuals with Parkinson's disease must be customizable, simple, and smart.

Keywords Human–computer interaction · Parkinson's disease · Rehabilitation · Serious game · Virtual reality

Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disease in individuals over 60 years old (Alves et al. 2008). Recent studies suggest that by about 2050 the number of patients with PD will be 12 million worldwide (Rocca 2018). PD is typically diagnosed from a combination of motor symptoms that include bradykinesia, rigidity, tremor, and postural instability (Teive et al. 2016). These symptoms cause functional limitations and dependence in the affected individual, which can lead to depression and isolation. Consequently, there is a need to

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carry out research that promotes quality of life of patients with PD, providing them with greater independence when performing activities of daily living (Opara et al. 2012).

Despite scientific advances, PD remains incurable and progressive and its cause is still unknown. However, it is considered that PD should be treated, not only by reducing its symptoms but also by delaying the effects caused through its advance. Thus, the treatment of PD is based on the use of medications and surgical procedures, in addition to rehabilitation through physiotherapy and occupational therapy (Ramji et al. 2017).

On the other hand, serious games (SGs) and virtual reality (VR) have been extensively investigated for rehabilitation of individuals with motor disabilities and who suffer from a wide range of diseases (Bégel et al. 2017). An SG can be defined as a pleasant or recreational video game that combines serious intentions with educational, professional, or medical purposes (i.e., purposes that are not primarily for entertainment), capable of generating specific knowledge or skills (Annetta 2010). An SG can also be understood as the relationship between the experimental and emotional freedom provided by the game and the seriousness of thought required for fulfilling the goals of the game (Mitgutsch and Alvarado 2012).

The advantages of applying SGs as motor rehabilitation activities are diverse. The exercises proposed by traditional therapy programs can be tiring and repetitive, and are only effective when these are performed on a daily and intensive basis (Tannous et al. 2018). In contrast, the user perceives the game-based exercise as playful fun and not as therapy. In this way, SGs allow the patient to be more immersed in the proposed activity, combined with a feeling of joy and satisfaction, and for this reason, they are able to strengthen patient adherence to the rehabilitation program (Assad et al. 2011). Therefore, an SG is considered a very promising tool that can be used to improve or train movement and cognition, generating greater patient motivation and engagement (Bégel et al. 2017).

VR is considered as a high-end computer 3D interface that involves real-time simulation and interactions, through multiple sensorial channels (Burdea 2003; Mirelman et al. 2011). Virtual reality is able to provide interactive feedback on patient performance, while giving to the patient a more stimulating and motivating experience than a traditional rehabilitation session (Bruin et al. 2010). Physical rehabilitation performed with the aid of VR has presented a number of advantages over conventional physical rehabilitation (Holden 2005). Studies that compared systems with VR and systems without VR for rehabilitation have shown, typically, that versions with VR produce better results when compared to versions without VR (Elor et al. 2018). This occurs as this technology facilitates motor learning and neuroplasticity by increasing the intensity of the task during guided training (Bruin et al. 2010).

More recently, a deeper interest has been noted in developing alternative methods based on SGs for evaluation and monitoring of PD. However, the incorporation of this type of technology into the clinical scenario needs to be implemented more effectively. The hypothesis of this study is that the lack of standardization in the presentation of results and the low methodological rigor in the studies already performed have hindered the incorporation of these technologies into the clinical routine. As a result, this review aims to identify and evaluate the scenario of the use of SGs in the motor rehabilitation of people with PD.

Materials and methods

In order to develop this study, the methodology defined in Kitchenham (2007) was adopted, which proposes comprehensive guidelines for creating a systematic literature review in software engineering.

Planning the systematic literature review.

The main research question in this study was "How have serious games contributed towards helping to treat the symptoms in individuals who suffer from Parkinson's disease?".

The specific research questions to guide the selection of primary studies analyzed in this review, were:

- [RQ01]—What types of games were implemented to help in the treatment of symptoms associated with Parkinson's disease?
- [RQ02]—What types of technologies (virtual reality, VR; augmented reality, AR; 3D; 2D) were identified in the games?
- [RQ03]—Are the identified games currently used in conjunction with any multimodal device? Which one(s)?
- [RQ04]—Were the identified games based on any protocol or treatment? Which one(s)?
- [RQ05]—Did the proposed solutions present any instrument for assessing the game and monitoring the results obtained by the patient with Parkinson's disease? Which one(s)?
- [RQ06]—Did the games help in the treatment of any specific symptom presented by individuals with Parkinson's disease? Which one(s)?
- [RQ07]—Did the assessment of the technologies take into account experiments with patients?

  Systematic literature review.

  The main stages involved in conducting the systematic review carried out in this study, were:
- Stage 1: Identification of keywords

The keywords were defined based on the guiding question of the study, namely, "Serious Game" and "Parkinson".

- Stage 2: Definition of the search string

The search strings were assembled through the association of keywords in English.
String: ("Serious Game" and "Parkinson").

- Stage 3: Publication period

The searches for scientific studies were carried out between February 2020 and February 2021. The publication period of the papers was from 2010 to 2021, i.e., over the past 10 years.

- Stage 4: Databases

The review was performed considering papers belonging to the following indexed databases: Web of Science, Scopus, PubMed, Bireme, ScienceDirect, IEEE Digital Library, ACM Digital Library, and Google Scholar.

- Stage 5: Selection of primary studies

For the selection of primary studies, inclusion and exclusion criteria were defined, as described below:

Inclusion criteria (IC):

[IC01]—Studies that addressed the development and/or use of a serious game capable of assisting people in the treatment of any symptoms caused by Parkinson's disease.

Exclusion criteria (EC):

[EC01]—Studies that were not in English.
[EC02]—Studies that presented only commercial aspects of the developed game.
[EC03]—Studies that did not answer any of the research questions specific to this study.
[EC04]—Duplicate or redundant papers (for studies of the same authorship or related to the same solution, only the most recent and/or most complete was included, unless it presented some complementary information).
[EC05]—Studies that presented the development of games for entertainment only.
[EC06]—Studies that did not have the full text available with open access.
[EC07]—Studies that did not address the development or use of a serious game as an aid in the treatment of symptoms of Parkinson's disease.
[EC08]—Studies that did not correspond to the publication of a full article (poster, book, technical note, patent, etc.).

The selection process of the studies included in this review is described below:

1 After database searches for the identification of potential primary studies, those considered not relevant to the issues under investigation were excluded. This first stage of exclusion was accomplished by reading the titles and keywords of the studies. The studies that were excluded in this stage were not kept in any list. If there existed any persisting doubts regarding inclusion or exclusion of any study at this stage, the decision was made that it should be maintained.
2 Successively, the abstract, introduction, and conclusion of the selected studies in stage 1 were read, performing a second filtering of the studies.
3 In this stage, the studies were read thoroughly to filter those that were considered in this review.
4 Finally, data extraction and quality evaluation of the studies were performed.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) tool was used for identification, selection, eligibility, and inclusion of studies. It presents preferred reporting items for systematic reviews and meta-analysis. As an initial result of the search, 169 studies were obtained by applying the inclusion criteria, and after applying the exclusion criteria, this number was reduced to 38. The systematic process for excluding papers at each stage is represented in Figure 1.

- Stage 6: Studies quality evaluation

In addition to the inclusion and exclusion criteria, it is also important to consider the quality of the selected papers in a systematic literature review. This measure was obtained following the recommendations indicated in Dybå and Dingsøyr (2008), which suggests the following criteria to obtain a qualitative evaluation:

A Is the article based on research (or is it merely a lesson extracted based on expert opinion)?
B Is there a clear statement of the research objectives?
C Is there an adequate description of the context in which the research was conducted?
D Was the methodology used adequate in terms of meeting the research objectives?
E Was the participant recruitment strategy adequate for the research objectives?
F Was there a control group for comparing the results?

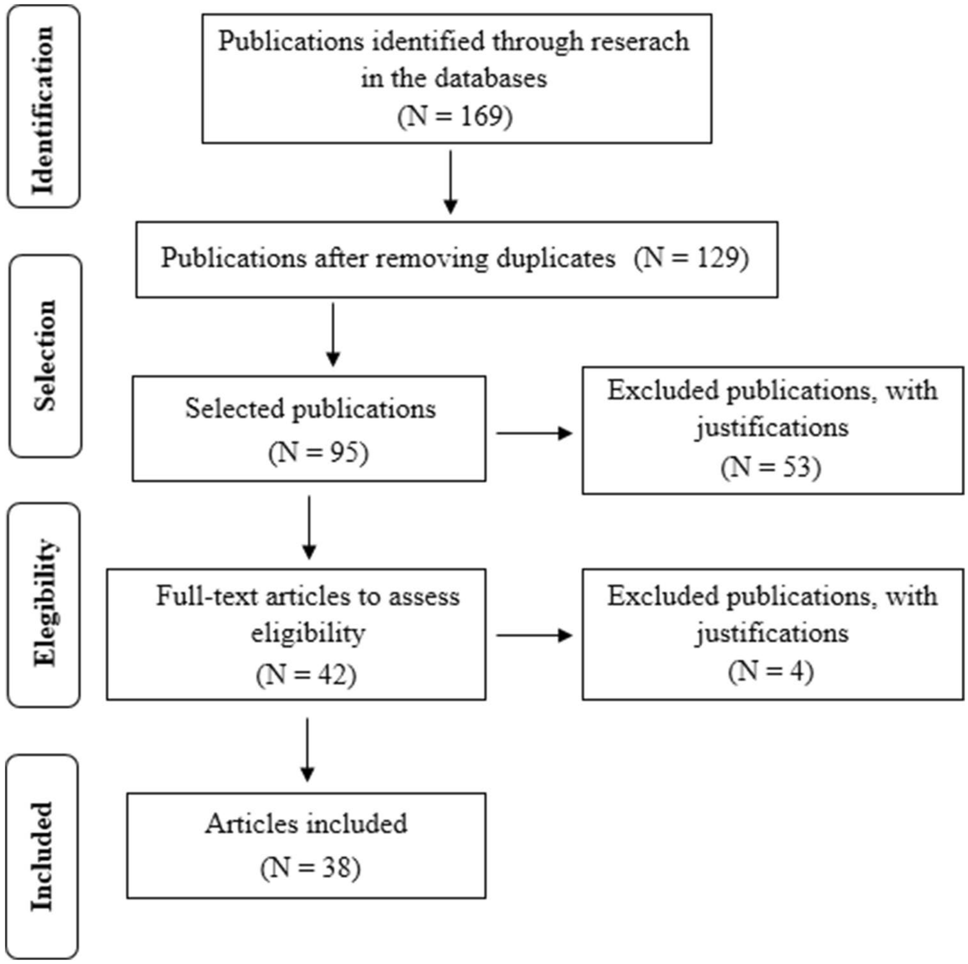


Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which shows the number of articles in each exclusion step

G Was data collected to address the research question?
H Was the data analysis sufficiently rigorous?
I Was the relationship between researcher and participants considered to an appropriate degree?
J Was there a clear statement of the results?
K What was developed in the study that can be applied in clinical practice?

The quality criteria were scored as follows:

YES = 1 point
NO = 0 point
PARTIALLY = 0.5 point

Profile of selected studies

After conducting the database searches and reading the titles and keywords, 169 studies were selected. Of these, after reading the abstract, introduction, and conclusion, and applying the exclusion criteria, 38 papers were selected and the full texts were read in order to answer the research questions and evaluate the quality of the studies.

The majority of the studies analyzed in this review presented the development and evaluation of SGs as an auxiliary tool in the treatment of some symptoms caused by PD. These symptoms included difficulties in speech (Krause et al. 2013); gait with some disability (Imbeault-Nepton and Otis 2014 and Silva et al. 2017); motor weakness in the upper limbs (Fernández-González et al. 2019; Sánchez-Herrera-Baeza et al. 2020) and lower limbs (Assad et al. 2011); loss of balance (Leblong et al. 2017; Pompeu et al. 2014; Silva et al. 2017, Yuan et al. 2020); impairment of fine movements of the fingers and hands (Chen et al. 2020, Oña et al. 2018); cognitive problems (Andrade Ferreira et al. 2020, Silva et al. 2017, van de Weijer et al. 2019); and low range of motion (Siegel and Smeddinck 2012).

Some studies described projects that include more than one SG, as in Morando et al. (2017), a paper that presents the ReMoVes platform (Remote Monitoring Validation Engineering System) with 60 variations of available games; and in Vieira et al. (2017), a study that applies four different games of Nintendo Wii Sports Resort, as well as Super

Monkey Bool®, Wii Play®, Deca Sports®, and Sports Resort® games. Consequently, several of the above-mentioned problems are evaluated. On the other hand, although the study presented in Pachoulakis and Papadopoulos (2016) proposes the application of only one game, its objective is based on rehabilitation of the upper and lower limbs at the same time, while the study developed by Sáenz-De-urturi et al. (2014) deals with physical and mental rehabilitation. The other papers, in general, explore only the treatment of one symptom.

Some papers addressed specifically the development of one SG. These studies pointed out development guidelines (Paraskevopoulos et al. 2014), design elements (Dias et al. 2018), and framework (Foletto et al. 2017) for creating SGs that assist in the rehabilitation process of individuals with PD.

Other themes explored by the analyzed studies were analysis of commercial music/rhythmic games in order to evaluate adjustments for training purposes (Bégel et al. 2017); evaluation of a music-based SG for rehabilitation of rhythmic abilities (Dauvergne et al. 2018); comparison between technological approaches of two projects belonging to the largest research and innovation program in the European Union (Solachidis et al. 2018); development and evaluation of the relationship between therapist and patient (Palacios-Navarro et al. 2014); evaluation of motor functions (Oña et al. 2019); evaluation of patients to measure the degree of motor dysfunction suffered (Van Der Meulen et al. 2016); systematic review to gather and critically analyze recent evidence on the potential for exergames (games commanded by body movements, such as exercise) for PD rehabilitation (Garcia-Agundez et al. 2019); systematic review on the use of vision-based SGs and VR systems in motor rehabilitation programs (Ayed et al. 2019); proposal of a fully immersive SG system to provide an interactive virtual environment in rehabilitation process (Avola et al. 2018); proposal of a new classification for SGs used in health (Wattanasoontorn et al. 2013); and mapping the use of SGs for neuropsychological evaluation (Valladares-Rodríguez et al. 2016).

Finally, there were studies not aimed directly at individuals with PD; however, the symptoms addressed in these studies affect also individuals with PD (Cai et al. 2021; Da Silva et al. 2017; Elor et al. 2018; Noveletto et al. 2018; Robert et al. 2020; Shah et al. 2019). Thus, several studies address the use of SGs as an aid in the treatment of individuals with PD.

Figure 2 shows the number of published studies, which were included in this review. The majority of studies encountered were published between 2017 and 2020 (approximately 68.42%). This suggests a current and growing interest in research related to the development and/or use of SGs to assist in the treatment of people with PD.

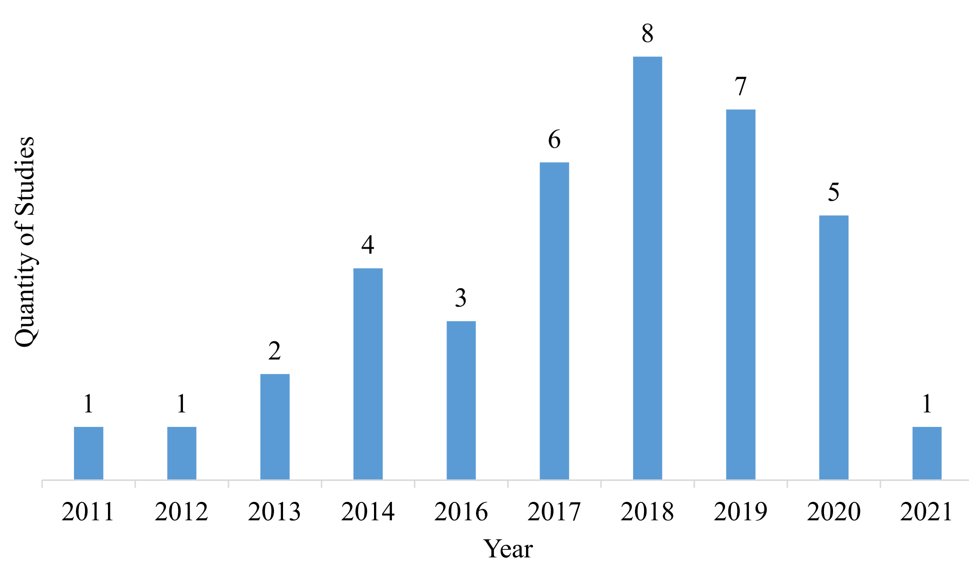
Furthermore, Fig. 3 presents the distribution of studies found in the databases. The studies selected from the Web of Science database were all excluded by the exclusion criteria EC04; i.e., they were duplicated in other databases.

Results

Classification of studies regarding specific research questions

Each study was evaluated by the seven different defined research questions. For each one, a table listing the characteristic addressed by the question and the study reference was created. Papers included in the study but do not appear in the tables indicate that these did not present or use that specific characteristic or that they were not mentioned in the study.

Fig. 2 Quantity of studies included in each year, ranging from 2011 to 2021



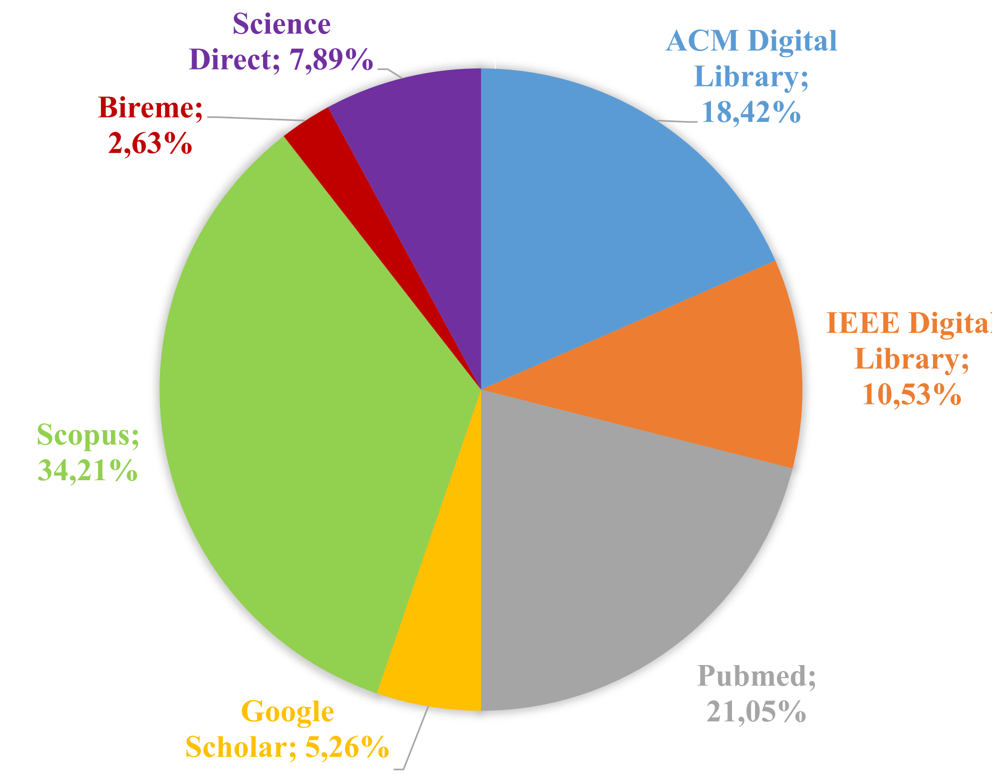


Fig. 3 Distribution of studies by database

RQ01—What types of games were implemented to help in the treatment of Parkinson's disease symptoms?

The authors of the analyzed studies, generally speaking, did not classify the developed games. They only described the mechanics of the game. Thus, through this information, the games were classified, as shown in Table 1.

Table 1 shows that some studies are classified in more than one type of game. This fact occurs as the developed game presents phases, levels, or approaches that fit in more than one classification. There is, for example, the study (Assad et al. 2011), which is classified as exergame, musical/rhythmic, and memory. The study by Silva et al. (2017) is classified as exergame and reasoning; the study by Fernández-González et al. (2019) memory, simulation, and reasoning games; the study by Sánchez-Herrera-Baeza et al. (2020) simulation, reasoning, and haptic games; the study by Yuan et al. (2020) exergame and balance; the study by van de Weijer et al. (2019)

Table 1 Types of games implemented

Type of game	Study
Exergame	(Avola et al. 2018); (Assad et al. 2011); (Cai et al. 2021); (Chen et al. 2020); (Dias et al. 2018); (Elor et al. 2018); (Foletto et al. 2017); (Leblong et al. 2017); (Morando et al. 2017); (Oña et al. 2018); (Oña et al. 2019); (Pachoulakis and Papadopoulos 2016); (Paraskevopoulos et al. 2014); (Pompeu et al. 2014); (Sáenz-De-urturi et al. 2014); (Siegel and Smeddinck 2012); (Silva et al. 2017); (Van Der Meulen et al. 2016); (Vieira et al. 2017); (Yuan et al. 2020)
Musical/rhythmic	(Assad et al. 2011); (Bégel et al. 2017); (Dauvergne et al. 2018); (Krause et al. 2013); (Shah et al. 2019)
Memory	(Assad et al. 2011); (Fernández-González et al. 2019); (Oña et al. 2018); (Palacios-Navarro et al. 2014); (Robert et al. 2020); (Sáenz-De-urturi et al. 2014); (van de Weijer et al. 2019)
Simulation	(Andrade Ferreira et al. 2020); (Da Silva et al. 2017); (Fernández-González et al. 2019); (Sánchez-Herrera-Baeza et al. 2020); (van de Weijer et al. 2019)
Reasoning	(Fernández-González et al. 2019); (Palacios-Navarro et al. 2014); (Sánchez-Herrera-Baeza et al. 2020); (Silva et al. 2017); (Vieira et al. 2017)
Haptic	(Sánchez-Herrera-Baeza et al. 2020)
Balance	(Noveletto et al. 2018); (Yuan et al. 2020)
Race	(van de Weijer et al. 2019)

memory, simulation, and race; the study by Vieira et al. (2017) exergame and reasoning; the study by Sáenz-De-urturi et al. (2014) exergame and memory; and finally, the study by Palacios-Navarro et al. (2014) memory and reasoning.

On the other hand, the studies presented in Solachidis et al. (2018), Garcia-Agundez et al. (2019), Ayed et al. (2019), Wattanasoontorn et al. (2013), and Valladares-Rodríguez et al. (2016) did not address the development of a game or did not present sufficient information about the games, and therefore, it is not possible to classify these as to the type of game implemented.

RQ02—What types of technologies (virtual reality, VR; augmented reality, AR; 3D; 2D) were identified in the games?

Table 2 presents the interfaces used in the games included in this review.

The studies Bégel et al. (2017), Imbeault-Nepton and Otis (2014), Leblong et al. (2017), Dauvergne et al. (2018), Solachidis et al. (2018), Garcia-Agundez et al. (2019), Wattanasoontorn et al. (2013), and Valladares-Rodríguez et al. (2016) did not present the development of an SG. Although the study in Solachidis et al. (2018) also did not approach the development of an SG, it does appear in Table 2 classified as VR, since this study presents a literature review concerning the use of SGs that use VR.

RQ03—Are the identified games currently used in conjunction with any multimodal device? Which one(s)?

The studies used several multimodal devices, as shown in Table 3.

Some studies are present in more than one row of the table, as these studies used more than one device. For example, in Sánchez-Herrera-Baeza et al. (2020) and Oña et al. (2019), Leap Motion and Oculus Rift were used. In Andrade Ferreira et al. (2020), Leap Motion and HMD; in Morando et al. (2017), Leap Motion, Microsoft Kinect, Microsoft Band, and Nintendo Wii; in Vieira et al. 2017), Nintendo Wii and inertial sensors; in Solachidis et al. 2018), Microsoft Kinect, RGB 360 cameras, smart bracelets, binary sensors, and WSN sensors; in Van Der Meulen et al. (2016), RGB 360 cameras and optical see-through head-mounted display (OST-HMD) with haptic controller; and, finally, in Avola et al. (2018), Leap Motion, Microsoft Kinect, and HMD.

Other studies used only traditional devices, such as notebook and projector (Krause et al. 2013) (Robert et al. 2020); tablet (Dauvergne et al. 2018) (Palacios-Navarro et al. 2014); and mouse and keyboard (van de Weijer et al. 2019). Alternatively, in some studies, specific devices were created, such as in Imbeault-Nepton and Otis (2014), Da Silva et al. (2017), and Noveletto et al. (2018). The studies Leblong et al. (2017) and Dias et al. (2018) did not mention the multimodal devices used. Finally, all studies that performed a systematic review of literature (Bégel et al. 2017, Garcia-Agundez et al. 2019, Ayed et al. 2019, Wattanasoontorn et al. 2013, and Valladares-Rodríguez et al. 2016) did not report or use multimodal devices.

RQ04—Were the identified games based on any protocol or treatment? Which one(s)?

Table 4 presents the treatment protocols used in the studies.

A number of studies, although not reporting the use of a protocol, stated that the exercises proposed by the games were recommended/accompanied by doctors/therapists (Morando et al. 2017, Sáenz-De-urturi et al. 2014, Foletto et al. 2017, and Avola et al. 2018). Moreover, the studies by Fernández-González et al. (2019), Sánchez-Herrera-Baeza et al. (2020), Oña et al. (2018), Chen et al. (2020), Robert et al. (2020), and Cai et al. (2021) reported that the games tried to imitate exercises included in traditional physiotherapy, such as palm grip, finger flexion and extension, hand supination and pronation, and gait exercises. The other studies did not

Table 2 Interfaces used in games

Type of interface	Study
2D	(Assad et al. 2011); (Dias et al. 2018); (Foletto et al. 2017); (Krause et al. 2013); (Noveletto et al. 2018); (Palacios-Navarro et al. 2014); (Shah et al. 2019); (Siegel and Smeddinck 2012); (van de Weijer et al. 2019)
3D	(Da Silva et al. 2017); (Pachoulakis and Papadopoulos 2016); (Pompeu et al. 2014); (Robert et al. 2020); (Yuan et al. 2020)
VR	(Avola et al. 2018); (Ayed et al. 2019); (Cai et al. 2021); (Chen et al. 2020); (Elor et al. 2018); (Fernández-González et al. 2019); (Morando et al. 2017); (Oña et al. 2018); (Oña et al. 2019); (Paraskevopoulos et al. 2014); (Sáenz-De-urturi et al. 2014); (Sánchez-Herrera-Baeza et al. 2020); (Silva et al. 2017); (Vieira et al. 2017)
AR	(Andrade Ferreira et al. 2020); (Van Der Meulen et al. 2016)

Table 3 Multimodal devices used by games

Multimodal devices	Study
Leap Motion	(Andrade Ferreira et al. 2020); (Avola et al. 2018); (Fernández-González et al. 2019); (Foletto et al. 2017); (Morando et al. 2017); (Oña et al. 2018); (Oña et al. 2019); (Sánchez-Herrera-Baeza et al. 2020); (Shah et al. 2019)
Microsoft Kinect	(Avola et al. 2018); (Morando et al. 2017); (Pachoulakis and Papadopoulos 2016); (Pompeu et al. 2014); (Sáenz-De-urturi et al. 2014); (Siegel and Smeddinck 2012); (Silva et al. 2017); (Solachidis et al. 2018)
Microsoft Band	(Morando et al. 2017)
Nintendo Wii	(Morando et al. 2017); (Paraskevopoulos et al. 2014); (Vieira et al. 2017)
RGB 360 cameras	(Solachidis et al. 2018); (Van Der Meulen et al. 2016)
Smart bracelet	(Solachidis et al. 2018)
Binary sensors	(Solachidis et al. 2018)
Inertial sensors	(Noveletto et al. 2018); (Vieira et al. 2017)
WSN sensors	(Da Silva et al. 2017); (Imbeault-Nepton and Otis 2014); (Solachidis et al. 2018)
HTC Vive	(Elor et al. 2018)
Optical see-through head-mounted display (OST-HMD) with haptic controller	(Van Der Meulen et al. 2016)
Oculus Rift	(Oña et al. 2019); (Sánchez-Herrera-Baeza et al. 2020)
Sony PlayStation Eye camera	(Assad et al. 2011)
Traditional devices (notebook, tablet, mouse and keyboard)	(Dauvergne et al. 2018); (Krause et al. 2013); (Palacios-Navarro et al. 2014); (Robert et al. 2020); (van de Weijer et al. 2019)
HMD	(Andrade Ferreira et al. 2020); (Avola et al. 2018); (Cai et al. 2021); (Chen et al. 2020)
XaviX (dance mat)	(Yuan et al. 2020)

Table 4 Protocols used by games

Protocol	Study
Exercises based on traditional physiotherapy tasks	(Cai et al. 2021); (Chen et al. 2020); (Fernández-González et al. 2019); (Oña et al. 2018); (Robert et al. 2020); (Sánchez-Herrera-Baeza et al. 2020)
Logopedic therapy	(Krause et al. 2013)
Multidirectional and target-directed stepping tasks	(Yuan et al. 2020)
Training of daily activities	(Andrade Ferreira et al. 2020); (Da Silva et al. 2017)
Modified constraint-induced therapy (mCIT)	(Elor et al. 2018)
Guide for exercise and Parkinson's disease by the PD Society of UK	(Paraskevopoulos et al. 2014)
Box and Blocks Test (BBT)	(Oña et al. 2019)
Train BIG to move faster	(Pachoulakis and Papadopoulos 2016)
Rhythmic training via rhythmic auditory stimulation	(Dauvergne et al. 2018)

mention whether the games were based on any protocol or treatment.

RQ05—Did the proposed solutions present any instrument for assessing the game and monitoring the results obtained by the patient with Parkinson's disease? Which one(s)?

Table 5 shows the instruments for evaluating games and monitoring patients used in the studies.

Several studies are noted as presenting more than one instrument for assessment and monitoring. This fact is quite coherent, as the assessment instrument refers to the game itself developed/applied, while the monitoring instrument refers to the assessment of clinical and psychological/psychosocial aspects of patients. The other studies did not provide information on the use of an instrument for assessing the game and monitoring the results obtained by the patient.

Table 5 Instruments for evaluation and monitoring

Instrument	Study
Game Experience Questionnaire (GEQ)	(Assad et al. 2011); (Krause et al. 2013); (Van Der Meulen et al. 2016)
VHI: 10 (Voice Handicap Index: 10)	(Krause et al. 2013)
Observation of occupational therapists	(Andrade Ferreira et al. 2020); (Chen et al. 2020); (Da Silva et al. 2017)
Recording of patients playing	(Andrade Ferreira et al. 2020); (Elor et al. 2018); (Sáenz-De-urturi et al. 2014); (Siegel and Smeddinck 2012)
Mini-Mental State Examination (MMSE)	(Andrade Ferreira et al. 2020); (Robert et al. 2020); (Sáenz-De-urturi et al. 2014)
Time Up and Go Test (TUG)	(Cai et al. 2021); (Leblong et al. 2017); (Noveletto et al. 2018); (Imbeault-Nepton and Otis 2014)
10-Meter Walk Test (10WT)	(Leblong et al. 2017); (Silva et al. 2017)
6-Minute Walk test	(Leblong et al. 2017)
Berg Balance Scale (BBS)	(Imbeault-Nepton and Otis 2014); (Noveletto et al. 2018); (Yuan et al. 2020)
Short-Form Health Survey (SF-36)	(Yuan et al. 2020)
Multi-Directional Reach Test (MDRT)	(Yuan et al. 2020)
Maximum Step Length (MSL) test	(Yuan et al. 2020)
Modified Falls Efficacy Scale (MFES)	(Yuan et al. 2020)
Nottingham Health Profile (NHP)	(Noveletto et al. 2018)
Jamar® hydraulic hand dynamometer	(Fernández-González et al. 2019); (Oña et al. 2018); (Sánchez-Herrera-Baeza et al. 2020)
Task Load Index (TLX)	(Van Der Meulen et al. 2016)
System Usability Scale (SUS)	(Assad et al. 2011); (Avola et al. 2018); (Chen et al. 2020); (Van Der Meulen et al. 2016)
Box and Blocks Test (BBT)	(Fernández-González et al. 2019); (Oña et al. 2018); (Oña et al. 2019); (Sánchez-Herrera-Baeza et al. 2020)
Purdue Pegboard Test (PPT)	(Fernández-González et al. 2019); (Oña et al. 2018); (Sánchez-Herrera-Baeza et al. 2020)
Client Satisfaction Questionnaire (CSQ-8)	(Fernández-González et al. 2019); (Sánchez-Herrera-Baeza et al. 2020)
Action Research Arm Test (ARAT)	(Sánchez-Herrera-Baeza et al. 2020)
Unified Parkinson's Disease Rating Scale (UPDRS)	(Dauvergne et al. 2018); (Vieira et al. 2017)
Suitability Evaluation Questionnaire (SEQ)	(Dauvergne et al. 2018)
Battery for the Assessment of Auditory Sensorimotor and Timing Abilities (BAASTA)	(Dauvergne et al. 2018)
Montreal Cognitive Assessment (MoCA)	(Dauvergne et al. 2018); (Silva et al. 2017)
Parkinson's Disease Questionnaire 39 (PDQ-39)	(Dauvergne et al. 2018); (Silva et al. 2017); (Vieira et al. 2017)
9 hole peg test	(Fernández-González et al. 2019); (Vieira et al. 2017)
Test d'Évaluation des Membres Supérieurs de Personnes Âgées (TEMPA)	(Vieira et al. 2017)
Functional Gait Assessment (FGA)	(Silva et al. 2017)
Dynamic Gait Index (DGI)	(Silva et al. 2017)
Mini Balance Evaluation Systems Test (Mini-BESTest)	(Silva et al. 2017)
Five times Sit-to-Stand Test (SST)	(Silva et al. 2017)
Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE)	(Robert et al. 2020)
Free and Cued Selective Reminding Test	(Robert et al. 2020)
Trial Making Test A (TMT A)	(Robert et al. 2020)
Stroop test	(Robert et al. 2020)
Digit Symbol Substitution Test (DSST)	(Robert et al. 2020)
Frontal Assessment Battery (FAB)	(Robert et al. 2020)
Neuropsychiatric Inventory (NPI)	(Robert et al. 2020)
Apathy Inventory (AI; clinician version)	(Robert et al. 2020)
Muscle Strength Grading standard (MMT)	(Cai et al. 2021)

Table 5 (continued)

Instrument	Study
Fugl-Meyer Assessment (FMA)	(Cai et al. 2021)
Motor Assessment Scale (MAS)	(Cai et al. 2021)
Barthel Index (BI)	(Cai et al. 2021)
Parameters of gait kinematics	(Cai et al. 2021)

RQ06—Did the games help in the treatment of any specific symptom presented by individuals with Parkinson's disease? Which one(s)?

Table 6 presents symptoms that affect people with PD, which the SGs helped to treat in the studies identified.

Some of the studies propose the treating of more than one symptom of PD using an SG, such as in Imbeault-Nepton and Otis (2014), which addresses symptoms associated with bradykinesia and gait impairments; in Silva et al. (2017), postural instability, gait impairments, and cognitive impairments; in Fernández-González et al. (2019) and Sánchez-Herrera-Baeza et al. (2020), bradykinesia and rigidity; in Leblong et al. (2017), Yuan et al. (2020) and Solachidis et al. (2018), postural instability and gait impairments; in Pompeu et al. (2014), postural instability and cognitive impairments; in Chen et al. (2020), bradykinesia, rest tremor, and rigidity; in Pachoulakis and Papadopoulos (2016), bradykinesia, postural instability, and gait impairments; in Sáenz-De-urturi et al. (2014), bradykinesia and cognitive impairments; and in Valladares-Rodríguez et al. (2016), cognitive impairments and visuospatial disability. The other studies did not specify which symptom the game was aimed at treating.

RQ07—Did the assessment of the technologies take into account experiments with patients?

Table 7 shows the studies that carried out experiments with real patients.

Qualitative evaluation

Table 8 shows the results of the qualitative evaluation over the selected studies, described in Stage 6 of "Systematic literature review" section. The "total" column refers to the sum of the scores for the evaluated items in each study, and the "total" row refers to the sum of scores over all studies for each evaluated item.

Principal component analysis (Abdi and Williams 2010) was employed for the identification of the variables which produced large variability in the data and for the visualization of the distance between observations, i.e., the studies in Table 8, on a lower-dimensional space. The R Package for Multivariate Analysis (Lê et al. 2008) was employed for data analysis and visualization. The variables were not standardized because their values are in the same ordinal scale. In addition, the standard deviation of variables A, B, and C is zero; hence, it is not possible to standardize them.

The scree plot shown in Fig. 4A depicts the percentage of explained variance by each principal component (i.e.,

Table 6 Symptoms treated by games

Symptom	Study
Bradykinesia	(Ayed et al. 2019); (Chen et al. 2020); (Fernández-González et al. 2019); (Foletto et al. 2017); (Imbeault-Nepton and Otis 2014); (Krause et al. 2013); (Oña et al. 2018); (Pachoulakis and Papadopoulos 2016); (Sáenz-De-urturi et al. 2014); (Sánchez-Herrera-Baeza et al. 2020); (Shah et al. 2019); (Siegel and Smeddinck 2012); (Van Der Meulen et al. 2016)
Postural instability	(Leblong et al. 2017); (Pachoulakis and Papadopoulos 2016); (Pompeu et al. 2014); (Silva et al. 2017); (Solachidis et al. 2018); (Yuan et al. 2020)
Gait impairments	(Cai et al. 2021); (Dauvergne et al. 2018); (Imbeault-Nepton and Otis 2014); (Leblong et al. 2017); (Pachoulakis and Papadopoulos 2016); (Silva et al. 2017); (Solachidis et al. 2018); (Yuan et al. 2020)
Rest tremor	(Chen et al. 2020); (Morando et al. 2017); (Vieira et al. 2017)
Rigidity	(Chen et al. 2020); (Elor et al. 2018); (Fernández-González et al. 2019); (Noveletto et al. 2018); (Sánchez-Herrera-Baeza et al. 2020)
Cognitive impairments	(Andrade Ferreira et al. 2020) (Pompeu et al. 2014); (Robert et al. 2020); (Sáenz-De-urturi et al. 2014); (Silva et al. 2017); (Valladares-Rodríguez et al. 2016); (van de Weijer et al. 2019)
Visuospatial disability	(Valladares-Rodríguez et al. 2016)

Table 7 Experiments with patients

Experiments with patients	Study
Yes	(Andrade Ferreira et al. 2020); (Assad et al. 2011); (Avola et al. 2018); (Cai et al. 2021); (Chen et al. 2020); (Da Silva et al. 2017); (Dauvergne et al. 2018); (Elor et al. 2018); (Fernández-González et al. 2019); (Foletto et al. 2017); (Imbeault-Nepton and Otis 2014); (Krause et al. 2013); (Leblong et al. 2017); (Morando et al. 2017); (Noveletto et al. 2018); (Oña et al. 2018); (Oña et al. 2019); (Palacios-Navarro et al. 2014); (Paraskevopoulos et al. 2014); (Pompeu et al. 2014); (Robert et al. 2020); (Sánchez-Herrera-Baeza et al. 2020); (Sáenz-De-urturi et al. 2014); (Shah et al. 2019); (Siegel and Smeddinck 2012); (Silva et al. 2017); (van de Weijer et al. 2019); (Van Der Meulen et al. 2016); (Vieira et al. 2017); (Yuan et al. 2020)
No/not informed	(Ayed et al. 2019); (Bégel et al. 2017); (Dias et al. 2018); (Garcia-Agundez et al. 2019); (Pachoulakis and Papadopoulos 2016); (Solachidis et al. 2018); (Valladares-Rodríguez et al. 2016); (Wattanasoontorn et al. 2013)

dimension). Most of data variability was captured by the first (39.9%) and second (22.8%) components. The contributions of variables to each principal component are presented in Fig. 4B. The larger the diameter of the circles, the more variability of the variable is represented by the component. The squared cosine (Cos2) shows the importance of a component to a variable (Abdi and Williams 2010). Figure 4C presents the cumulative importance of the first and second components to each variable.

The PCA-biplot is presented in Fig. 4D. It is a scatter plot showing the projections of the observations (i.e., studies in Table 8) onto the coordinates of the components that captured largest variability of the data. The original variables are shown in this plot as vectors. The PCA-biplot allows for the visualization of the spread of observations and the distance between data points.

Discussion

This section presents a discussion of the results obtained from this study, which will be guided and separated according to the addressed research questions.

Table 1 shows the types of games developed by the studies analyzed. The majority (52.63%) of the studies propose the development and/or use of games that promote the physical movement in the players (exergames). Keeping in mind information regarding the research questions RQ03 and RQ06 (Table 3 and Table 6, respectively), one is able to build a relationship between the type of exergame with Kinect, Nintendo Wii, and Leap Motion devices and the symptoms bradykinesia, postural instability, gait impairments, and rest tremor. The availability of devices capable of capturing body movements combined with physical problems caused by PD may be factors that contribute to the preference in developing games classified as exergames.

According to Koster (2013), games have the ability to exercise the brain, and as more patterns are learned, more novel approaches are needed to make a game attractive. Inevitably, at some point, a game can become boring and disposable. When this happens, it is necessary to change over to another game, highlighting the importance of having different games to treat a particular symptom. In this sense, by crossing the information presented in Table 1 and Table 6, one notes that by considering the type of game exergame, six studies were found that used different games for the treatment of the same symptom—bradykinesia. Thus, there is a need to have a wide variety of games with different characteristics and properties (scenarios, narratives, and mechanics) to support people with PD, when the desire or interest in a game is lost or diminished.

It is extremely important that games be developed considering some aspects related to the patients who will use them. Individuals affected by PD are, in general, elderly people. Thus, elderly people are known to be patients that are attracted by casual games that represent life experiences and not to complex games with adventure and science fiction themes. Therefore, games based on themes such as country life and nature tend to be better accepted by these individuals, increasing the efficiency the game possesses in treating symptoms (Foletto et al. 2017).

Table 8 Qualitative evaluation results

Study (reference)	Items for qualitative evaluation											
	A	B	C	D	E	F	G	H	I	J	L	**Total**
[6]	1	1	1	1	0	0	0.5	0	0	0.5	0	**5.0**
[10]	1	1	1	1	0.5	0	0.5	0.5	0	1	0.5	**7.0**
[15]	1	1	1	1	0.5	0	1	1	0	1	1	**8.5**
[18]	1	1	1	1	0.5	0	1	1	0	1	0.5	**8.0**
[19]	1	1	1	1	0.5	0	1	1	0.5	1	0.5	**8.5**
[20]	1	1	1	1	1	1	1	0.5	1	0.5	0.5	**9.5**
[21]	1	1	1	1	0.5	1	1	0.5	1	1	0.5	**9.5**
[22]	1	1	1	1	0.5	0	1	1	1	1	0.5	**9.0**
[23]	1	1	1	1	1	0	0.5	0.5	0.5	0.5	0.5	**7.5**
[24]	1	1	1	1	0.5	0.5	0.5	0	1	0.5	1	**8.0**
[25]	1	1	1	1	0.5	1	1	1	0.5	1	1	**10.0**
[26]	1	1	1	1	1	0	1	1	0	1	0.5	**8.5**
[27]	1	1	1	0.5	0.5	0	1	0.5	1	0.5	0.5	**7.5**
[28]	1	1	1	0.5	0.5	0	1	0	0	1	1	**7.0**
[29]	1	1	1	0.5	0.5	0	0.5	0.5	1	0.5	0.5	**7.0**
[30]	1	1	1	1	0.5	0	0.5	0.5	0	0.5	0	**6.0**
[31]	1	1	1	0.5	1	0	0.5	1	0	0.5	0.5	**7.0**
[32]	1	1	1	1	0.5	1	0.5	0.5	1	1	1	**9.5**
[33]	1	1	1	1	0	0	0	0	0	0.5	0.5	**5.0**
[34]	1	1	1	1	0.5	0	1	1	0	1	0.5	**8.0**
[35]	1	1	1	1	1	0	0.5	0.5	0	1	0.5	**7.5**
[36]	1	1	1	0.5	0.5	0	0.5	1	0	0.5	0.5	**6.5**
[37]	1	1	1	1	0.5	0	1	1	0	1	0.5	**8.0**
[38]	1	1	1	1	0.5	0	1	0.5	0	0.5	0.5	**7.0**
[39]	1	1	1	0.5	0	0	1	0.5	0	0.5	0.5	**6.0**
[40]	1	1	1	0.5	0.5	0	0.5	0	0	0	0	**4.5**
[41]	1	1	1	1	1	0	1	1	0	0.5	0.5	**8.0**
[42]	1	1	1	0.5	0.5	0	0.5	1	0	1	0.5	**7.0**
[43]	1	1	1	1	0	0	1	1	0	1	0	**7.0**
[44]	1	1	1	1	0.5	0	1	0.5	0	1	1	**8.0**
[45]	1	1	1	1	0.5	1	1	1	1	0.5	0.5	**9.5**
[46]	1	1	1	1	1	0.5	0.5	0.5	0.5	1	1	**9.0**
[47]	1	1	1	1	0.5	0.5	0.5	0.5	1	0.5	1	**8.5**
[48]	1	1	1	0.5	0.5	0	0.5	0	0	0.5	0.5	**5.5**
[49]	1	1	1	1	1	0.5	1	1	0	1	0.5	**9.0**
[50]	1	1	1	1	0.5	1	1	1	1	1	0.5	**10.0**
[51]	1	1	1	0.5	0.5	0.5	0.5	1	1	1	1	**9.0**
[52]	1	1	1	1	0.5	1	1	1	1	1	1	**10.5**
Total	**38**	**38**	**38**	**33**	**21**	**9.5**	**29**	**25**	**14**	**29**	**22**	

In addition, games should be created specifically for people with PD, and it is very important to keep in mind the variations in cognitive and motor ability of the patient (Vieira et al. 2017). According to Mendes et al. (2012), depending on the demands of the game, people with PD show deficits compared to healthy elderly people. Thus, these games should not be difficult or complex but rather present achievable challenges to the players.

Another important factor related to SGs for rehabilitation is the need to adapt and customize these to align with the demands of the target group (Baranyi et al. 2013). The lack of customization and the need of engagement for sustainable use are some of the main issues existing in health-oriented SGs. Different personalities are attracted to different games, and not only because of a particularly attractive problem for the brain (Elor et al. 2018, Foletto et al. 2017). Therefore, it

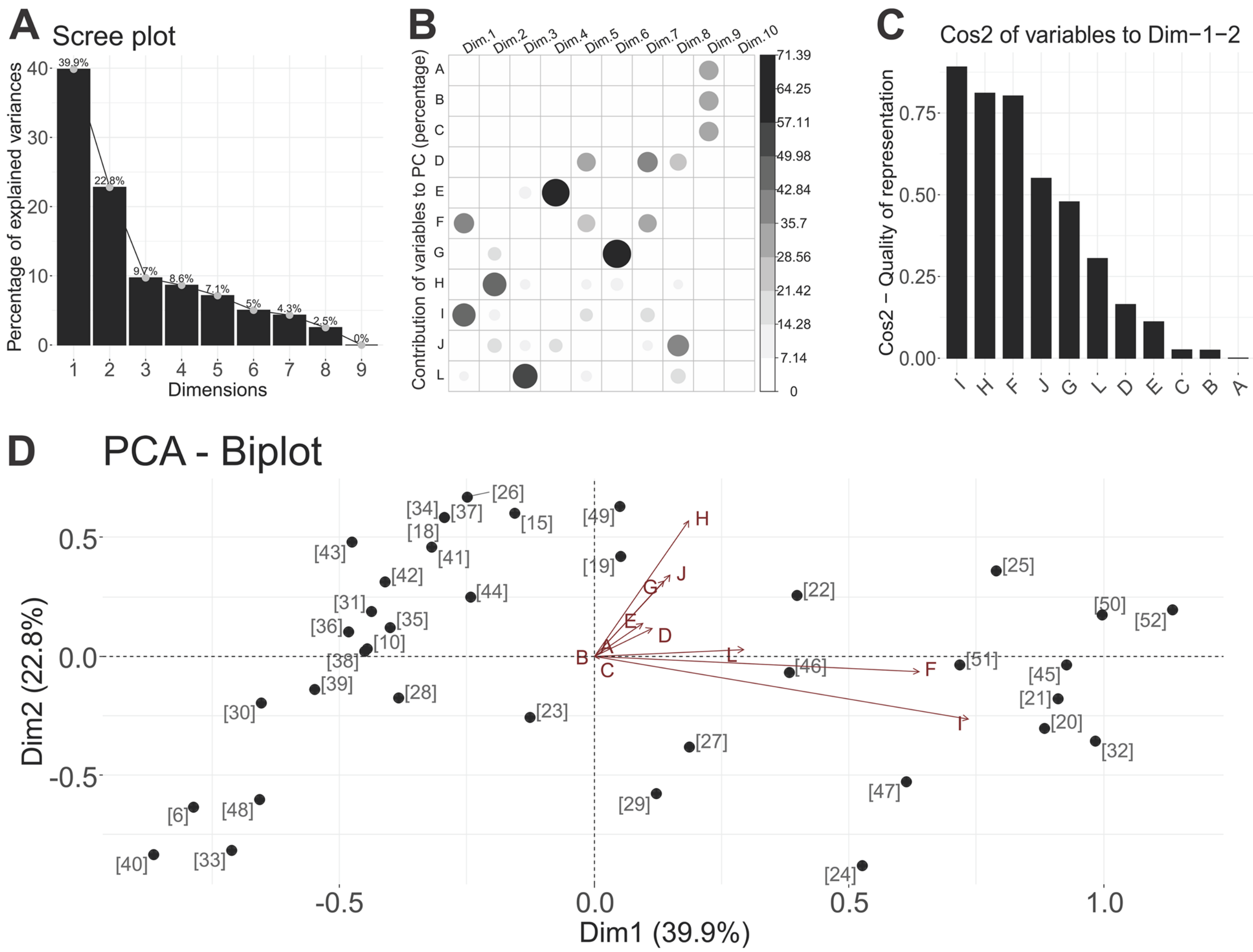


Fig. 4 Results of PCA applied to the data in Table 8. **A** Scree plot showing the data variability explained by each component (i.e., dimension). **B** The contribution of variables, i.e., items for the qualitative evaluation of studies, for each component. **C** Squared cosine (Cos2) showing the importance of each variable to components 1 (Dim 1) and 2 (Dim 2). (D) PCA-biplot depicting the projection of data points onto the lower two-dimensional space originated by Dim 1 and Dim 2. The vectors (i.e., arrows) show the representation of each variable in this space

is necessary to encourage the creation and availability of as many games as possible, in order to increase the number of people who can benefit from using the games.

Table 2 shows that studies which used VR are more numerous (36.84%) compared to other interface technologies; this is certainly due to the positive potential demonstrated in using virtual technologies that keep the player immersed and engaged in healthy activities (Elor et al. 2018, Vieira et al. 2017, and Foletto et al. 2017). According to Vieira et al. (2017), virtual reality increases the focus on tasks and requires cognitive interaction of the patient, thus contributing to the achievement of therapeutic benefits. The authors believe that with VR being an instrument that includes visual, auditory and tactile feedback, it is able to meet the demands of patients with PD and can be added to neurorehabilitation (Vieira et al. 2017). Accordingly, physiotherapy based on VR is important for exploring not only the motor skills of these patients but also cognitive skills, facilitating repetition and motor learning. Moreover, both VR and AR are seen as able to create new scenarios, narratives, and mechanics for existing games. This reutilization can decrease the time needed to make a game available, compared to the time spent developing a new game from its initial stages.

However, some negative factors may have contributed to 23.68% of the studies (a considerable proportion) presenting 2D interface technology complications, such as many patients suffering from dizziness, headaches, mental confusion, and nausea when using virtual games with immersive characteristics (Mitrousia and Giotakos 2016); the prioritization of the exercise to be performed rather than the technology used; the lack of technical knowledge for using VR or

AR; and greater simplicity in developing 2D games compared to games with virtual interfaces.

Table 3 shows different devices and sensors that can be used to capture body movements in SGs for rehabilitation, especially Leap Motion and Microsoft Kinect. The physical impairment caused by PD can prevent people from being able to handle traditional game controls, contributing to the preference for alternative types of input devices when implementing games. As discussed in RQ01, this preference may be related to the majority of games classified as exergames in this study.

Furthermore, there is an observed tendency for using traditional devices that already exist, in other words, devices that were not created considering the limitations of people who have PD. One of the factors that may explain this choice is a decrease in costs. However, affected individuals have severe limitations, especially in more advanced stages of the disease; therefore, the development of devices that improve player experience, while observing their limitations, can contribute to a better acceptance, as well as better results when using games. Only three of all the studied papers (Imbeault-Nepton and Otis 2014, Da Silva et al. 2017, and Noveletto et al. 2018) mentioned the creation of specific and adapted devices for individuals with PD.

The presence of a doctor or therapist accompanying the SGs' development process, as well as its use, is confirmed in most of studies included in this review. In contrast, the development of a game based on a rehabilitation protocol for people with PD was identified in only 15 studies (39.47%), as shown in Table 4. The use of a formal rehabilitation protocol can contribute positively towards evaluating and monitoring the results obtained by an SG in the treatment of PD symptoms.

The evaluation of the game and the monitoring of results obtained by patients are important for validating the efficiency of the developed solution. Some studies evaluate the usability and game experience, characteristics used to qualify and measure aspects related to games. However, the player can evaluate the game well, but not present a relative gain in the rehabilitation process; that is, the player does not present satisfactory results in the treatment of some specific symptom. For this reason, importance is also given to the use of instruments when evaluating the results obtained by patients, thus creating the possibility of verifying whether the game was effective in treating a certain symptom. As illustrated in Table 5, a wide variety of specific tools was identified in the studies used to evaluate patient outcomes, regarding treatment of a given symptom.

Table 6 presents the symptoms resulting from PD addressed in the included papers. The solutions used for physical rehabilitation are more numerous when compared to cognitive rehabilitation, and the two most commonly treated symptoms found in the studies were bradykinesia and gait impairments. In addition, despite a wide variety of symptoms addressed in these papers, there is a lack of solutions developed that treat more than one symptom, in fact only 12 studies treated two or more symptoms with the use of games. Among all the studies presented in this review, only the research described in Sáenz-De-urturi et al. (2014) concluded that, although the symptom (cognitive impairments) did not evolve, there was no improvement in its treatment using SG.

Although most studies performed experiments on real patients (78.95%), one notes that, due to a small number of participants, a short follow-up time and even a lack of experimental methodological rigidity, the authors of the studies did not provide any specification as to the results obtained (they described only preliminary results). As such, they only pointed out that they achieved a level of efficiency in the treatment of symptoms caused by PD. Consequently, the need for long-term tests with a statistically representative population is evident, to produce comprehensive results that can be validated with a degree of precision.

Regarding qualitative evaluations of studies, as illustrated in Table 8, the scores of each paper for the evaluated items ranged between 4.5 and 10.5 points. The mean score was 7.80 and standard deviation 1.48, showing that in general, the studies presented approximately 3.20 points less than a total of 11 points for the factor of quality. Only the studies by Bégel et al. (2017), Pachoulakis and Papadopoulos (2016), Palacios-Navarro et al. (2014), and Da Silva et al. (2017) obtained scores less than or equal to 50% of the total points distributed for quality evaluation, characterizing studies with more inconsistencies/failures, when compared to the others. However, it is important to emphasize that, among these four studies, the studies by Bégel et al. (2017) and Pachoulakis and Papadopoulos (2016) did not perform experimental procedures. This characteristic is reflected in a final quality score of the study, since items E, F, and I of the qualitative evaluation are related to the performing of an experiment.

In addition, the first three items evaluated in qualitative analysis (A, B, and C) were noted as those that received a higher score in all the included papers, presenting 38 points in the sum of the scores. However, two items (F and I) stood out for obtaining a sum of points below 50% of the total points added in relation to the other items. Therefore, in general, the studies included in this review presented two main deficiencies, a non-recruitment of people to form a control group, and a lack of care when dealing with possible bias that can affect the research regarding the relationship between researcher and participant. Two other items that obtained lower evaluation scores were those related to a recruitment strategy of individuals to perform the tests (E), and finally, the non-application of that developed in practical situations (L).

In general, it is possible to observe (Fig. 4D) a large variability of the data points, whose position on the scatter plot is influenced by the principal components and the contribution of variables to these components. A large variability is an indication of discrepancies between the quality of the studies, which may impact on the use of the results of these studies. For instance, study [40] (low-quality study) is distant and opposed on the projection space to study [52] (high-quality study).

The long length of the vector I in the direction of dimension 1 (Fig. 4D) results from the fact that this component (Dim 1) was more influenced by this variable, which is related to the relationship between researchers and participants. Studies represented on the direction of this variable took this relevant factor into account, whereas data points in the opposite direction disregarded it.

Considering study [52] as a nearly ideal reference in terms of quality, it is possible to visualize on the PCA-biplot that data points representing most of studies are far from it, suggesting the need of improving methodological aspects of the research related to variables I, F, and H, which measure the quality of data analysis and the participation of experimental groups in the research. The relatively large length of the vectors representing these variables on the PCA-biplot is related to the large variability of these variables, which was explained by the first and second principal components.

Conclusion

This study evaluated the use of SGs for rehabilitation of individuals with symptoms caused by PD. According to the selected studies, several research initiatives propose the use of SGs as a tool to assist in the treatment of symptoms arising from the disease.

Exergame was the most common types of game identified. This fact demonstrates some preferences of the researchers in two aspects. The first, using games to treat physical symptoms in detriment of cognitive symptoms, since the symptoms that appeared most in the studies were bradykinesia and gait impairments, and the second, using devices that capture patient body movements, such as Leap Motion and Microsoft Kinect. Moreover, VR is regularly applied, although not unanimously, to the solutions found, and some studies concluded that its use leads to better results compared to systems that do not use it. Therefore, it is expected that VR is increasingly incorporated into the development of SGs for health, due to the popularization of technology and the benefits that it delivers in terms of the involvement, motivation and engagement of the player.

Despite the monitoring by a doctor/therapist in most of the studies, few games were found as being developed and guided by an existing treatment protocol. It is important to emphasize that validating the efficiency of games, along with the monitoring of patient results, can be improved by using formal procedures. In addition, there was seen a need for long-term studies with a statistically representative population for the validation and generalization of the results obtained.

Designing SGs for health is a challenging process, because they need to meet the demands of players, which are often complex and diverse. Furthermore, for a game to be successful, it must be both enjoyable and effective at the same time, and reconciling these two characteristics is very difficult.

There are some weaknesses/topics still unanswered that can motivate new research into the subject, namely:

1 Conduct investigations with a statistically representative number of patients and for a sufficient length of time that allows for the correct representativeness of the results obtained.
2 Verify if there is some profile of ideal patients (e.g., in relation to the age of the individual, or stage of the disease, use or not of an antiparkinsonian drugs), who could benefit more with interventions based on SGs.
3 To make and test devices that are specifically developed to deliver the treatment, through SGs, for a particular symptom, being able to bring gains in terms of efficiency and adaptation of its use by the patient.
4 Develop SGs based on clinical protocols to help identify the effectiveness of using these solutions.
5 Develop relatively simple SGs, with little requirement for more complex cognitive capabilities, coherent and easy to understand, as well as execute.
6 Develop SGs with the ability to customize the levels of difficulty according to patient health status.

In short, although there are currently a variety of studies that address the use of SGs for rehabilitation of patients with PD, it is important that the technologies have higher methodological rigor, while extending the instrument to the clinical practice. Furthermore, an SG for individuals with PD must be customizable, simple, and smart.

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Declarations

Conflicts of interest The authors declare no conflict of interest.

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