Review

Gamification Integration in Technological Devices for Motor Rehabilitation in Parkinson Disease: Scoping Review

Pere Bosch-Barceló[1,2,3], MSc; Oriol Martínez-Navarro[1,2,4], PhD; Maria Masbernat-Almenara[1,2,4], PhD; Carlos Tersa-Miralles[1,2,4], PhD; Anni Pakarinen[3], PhD; Helena Fernández-Lago[1,2,4], PhD

[1]Department of Nursing and Physiotherapy, Universitat de Lleida, Lleida, Spain

[2]Health Care Research Group (GReCS), Lleida Institute for Biomedical Research Dr Pifarré Foundation (IRBLleida), Lleida, Spain

[3]Department of Nursing Science, University of Turku, Turku, Finland

[4]Consolidated Research Group: Society, Health, Education and Culture (GESEC), Department of Nursing and Physiotherapy, Universitat de Lleida, Lleida, Spain

Corresponding Author:

Oriol Martínez-Navarro, PhD
Department of Nursing and Physiotherapy
Universitat de Lleida
C/ Montserrat Roig, nº2
Lleida, 25198
Spain
Phone: 34 973702430
Email: oriol.martinez@udl.cat

Abstract

Background: Parkinson disease (PD) is a rapidly growing neurological condition worldwide. While physiotherapy and exercise are effective interventions, the addition of motivational aspects that improve adherence could be beneficial for people with PD. Incorporating technological devices into motor rehabilitation, coupled with gamification elements, could enhance the relevance of rehabilitation and alleviate motor symptoms.

Objective: The aim of this scoping review was to identify and classify the technological devices that integrate gamification elements used in motor rehabilitation in PD, and to describe the justification behind the use of these devices and elements in this context.

Methods: We conducted a scoping review following the framework proposed by Joanna Briggs Institute, along with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines. Major health science databases (MEDLINE, EMBASE, Scopus, Cochrane, Web of Science, PsycINFO, and Epistemonikos) were systematically searched. Relevant studies were included if they used technological interventions with gamification elements for motor symptom rehabilitation in PD. Gamification elements were extracted and categorized based on established frameworks, and content analysis was used to review the justifications for the use of technologies integrating gamification.

Results: A total of 4451 studies were retrieved from the search. After the abstract and full-text screening, 81 studies were eligible for data extraction. The analysis identified 453 gamification elements across studies, with development and accomplishment being the most prominent core drive. Progress/feedback was the most frequently used element (79/81, 98% of studies), followed by points (70/81, 86%) and levels/progression (66/81, 81%). Other notable elements included badges, leaderboards, and customization, while several core drives, like ownership and possession, lacked reported elements. Most interventions were delivered through commercial video game consoles (33/81, 41%), followed by computer-based systems (32/81, 40%). Tablet-based applications and integrated rehabilitation platforms were used in 11% (9/81) and 10% (8/81) of the studies, respectively. The expected roles of technology were clear, but intentional use of gamification was scarce.

Conclusions: This scoping review highlights the widespread adoption of technologies integrating gamification elements for motor symptom rehabilitation in individuals with PD. However, it also underscores a critical gap in understanding and justifying gamification mechanics. The current landscape relies heavily on commercial video games and emphasizes performance-based experiences, lacking theoretical grounding.

Trial Registration: OSF Registries tx3d9; https://osf.io/tx3d9

Introduction

Parkinson disease (PD) is the second most prevalent neurodegenerative disease in the world, as well as the fastest-growing one [1,2]. Over the last 20 years, the global impact of PD in terms of deaths and disability has increased by more than twofold [3]. As of 2021, nearly 12 million people around the world were living with PD, and this number is expected to increase by approximately 50% by 2035 [4].

PD is mainly characterized by the presence of several cardinal motor symptoms, mainly stiffness, bradykinesia, tremor, and postural instability [5]. The progression of these symptoms heavily impacts the ability of people with PD to manage daily activities [6]. Pharmacological treatment options for PD motor symptoms are mainly comprised of dopamine-based options: levodopa, dopamine agonists, and monoamine oxidase-B inhibitors [7]. However, these pharmacological choices come with their own array of issues, for example, Levodopa is known to eventually cause undesirable and involuntary movements known as dyskinesias in over half of patients after 6 years [8]. Due to these secondary effects, other treatment options are needed for people with PD. Physical therapy and exercise training have proven capable of inducing long-term improvements in motor symptoms and physical function among individuals with PD [9]. These interventions may also enhance the efficacy of pharmacological treatments, and help delay disease progression and age-related decline, with certain modalities additionally improving quality of life, thus becoming a crucial component in the management of people with PD [9,10].

In the last decades, a wide array of technological devices has been incorporated into the rehabilitation of neurological conditions to assist training. In this context, options such as virtual reality (VR) [11,12], robotics [13], smartphone apps [14], telerehabilitation options [15], and videogames and exergames [16] have been studied and shown positive effects on people with PD. This massive implementation of technological solutions often follows the implication that, in trying to affect and improve the users' experience and behavior, mechanics reminiscent of games are used. This concept of "the use of game design elements in non-game contexts" is widely known as gamification [17]. In the context of rehabilitation, the integration of gamification elements into technological devices is designed to create a more engaging and challenging experience for users. This approach is anticipated to enhance adherence and motivation among participants [18]. The combination of gamification and VR could even add benefits for older people in physical and cognitive domains while allowing complex training scenarios such as dual task training to be performed [19,20].

To effectively incorporate gamification elements across various intervention designs, it is essential to thoroughly understand gamification principles and their interaction with human motivation. Frameworks play a pivotal role in organizing available gamification elements into coherent categories, thereby guiding developers in selecting the most appropriate elements to achieve the desired user experience. Common frameworks include the Octalysis Framework by Kai [21], which identifies 8 core drives of human motivation, such as epic meaning and social influence; and the Marczewski 52 Gamification Mechanics and Elements [22], which classify elements based on the type of player they best cater to. However, the decision of which gamification elements to apply in interventions is often not thoroughly considered, in a context where treatment options should cater to the needs of end users [23]. Recent studies point to most VR rehabilitation options for PD being administered through commercial videogames, which are designed for entertainment in healthy individuals, far away from the context of rehabilitation for people with PD [24-26].

In PD, where apathy and depression are often present, long-term adherence to exercise and rehabilitation is concerning [27,28]. Previous research has shown that the implementation of VR does not warrant a higher adherence to treatment [11]. Strategies to promote motivation to stay involved in the rehabilitation process are key to long-term success in a population with a tendency to drop out [29]. Gamification, by integrating elements like feedback, rewards, and goal setting, may help sustain engagement and counteract the apathy and depression common in PD, thereby supporting long-term adherence to rehabilitation. However, current literature lacks information on the implementation of gamification in technological devices aimed at rehabilitating motor conditions in PD. Understanding which elements are currently used and the types of technological solutions they are integrated into is essential for developing further interventions that address the specific needs of individuals with PD. Therefore, the aim of this scoping review is to identify and classify the gamification elements and technologies used in motor rehabilitation in PD and to describe the justification behind the use of gamification and technology in this context. Specifically, this review focuses on the classification of gamification mechanics available, the types of technological devices used, and the motor symptoms these interventions target. Additionally, it explores the justifications used by each study for the inclusion of gamification elements and technological devices for motor rehabilitation in PD.

Methods

Registration and Framework

This Scoping Review is registered at the Open Science Framework database (OSF.IO/tx3d9). This review followed the Joanna Briggs Institute methodology for scoping reviews [30] and also adhered to the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Extension for Scoping Reviews) to ensure quality, transparency and reproducibility [31].

Objective

The objective of this study is to explore the use of technological devices integrating gamification in the rehabilitation of motor symptoms for individuals with PD. Specifically, it aims to identify the gamification elements and technological devices used in this context, classify the gamification elements based on the core motivational drives they target and the devices according to the motor symptoms they address, and describe the rationale behind their application in enhancing motor symptom rehabilitation for people with PD.

Eligibility Criteria

All peer-reviewed articles and peer-reviewed conference papers published in English or Spanish were included. Gray literature sources were excluded to maintain methodological consistency, ensuring all included studies underwent formal peer evaluation and were fully accessible. To guide the eligibility criteria, the Population, Concept, and Context framework was used, in which population, concept, and context are defined to guide study selection [30]. Population refers to people with PD, with no restrictions applied regarding specific subpopulations, gender, disease stage, or geographical location. The Concept covered intervention studies that described motor rehabilitation through technological solutions incorporating clearly identifiable gamification elements. Studies that used commercial video games originally developed for entertainment were also included. While Deterding's [17] definition of gamification refers to the use of game elements in nongame contexts, implying the exclusion of full video games aimed at entertainment, the therapeutic application of these games in rehabilitation effectively shifts their context. As a result, built-in motivational features such as points, progression systems, and feedback mechanics can be considered relevant gamification elements when used for rehabilitation in PD. In situations where not enough details were given regarding the intervention to chart its gamification elements, the studies were excluded. No restrictions regarding Context or year of publication were established. Articles that met the selection criteria were incorporated without assessing their quality, as the objective of scoping reviews is to chart the pertinent works in a particular area and pinpoint areas lacking research [30].

Information Sources and Search Strategy

The search strategy was developed and conducted by a librarian on November 23, 2023, across 7 electronic databases: MEDLINE, EMBASE, Scopus, Cochrane, Web of Science, PsycINFO, and Epistemonikos. A combination of controlled vocabulary and free-text keywords was used to ensure retrieval of all potentially relevant studies. The search focused on terms related to PD, gamification, rehabilitation, motor symptoms, and various technological rehabilitation strategies, such as VR, videogames, and exergames. Boolean operators were applied to refine the search, and search strings were adapted to match the indexing structures of each database. The search strategy used for each database is detailed in Multimedia Appendix 1. No systematic or scoping reviews on the specified topic were identified in the Joanna Briggs Institute Systematic Review Register, PROSPERO, or biomedical and nursing databases.

Study Selection and Data Extraction

All articles extracted from databases were imported to Covidence [32] and checked for duplicates by using its duplicate detection system. Given the large volume of references obtained, the initial title and abstract screening were independently conducted by 3 reviewers (PBB, OMN, and MMA) rather than 2, as initially proposed in the registered protocol. Any disagreements during this screening stage were resolved through consensus discussions involving all 3 reviewers. In the next step, full-text screening was independently performed by the same 3 reviewers, and inconsistencies were again resolved by consensus. Data extraction of all included articles was conducted by PBB.

A total of 4451 articles were retrieved from all databases. After duplicates were removed, both by Covidence and manually, 48.48% (2158/4451) of all articles underwent title and abstract reviewing. After this first title and abstract screening, 87.62% (1891/2158) of articles were excluded. A total of 267 articles were left for full-text screening, 69.66% (186/267) of which were excluded.

Synthesis of Results

General study information such as location, sample size, age, disease duration, gender, year, and study design were collected. Specific data pertinent to the review's objectives was also collected.

In order to identify and name the gamification elements found in each study, the Marczewski 52 Gamification Mechanics [22] nomenclature was used due to its clear terminology and ease of use. All gamification elements identified were then classified using the Kai Octalysis Framework [21] due to its focus on motivation and end user interaction with the system. The Octalysis framework delineates human motivation into 8 different core drives: epic meaning and calling, development and accomplishment, empowerment of creativity and feedback, ownership and possession, social influence and relatedness, scarcity and impatience, unpredictability and curiosity, and loss and avoidance. All gamification elements identified using Marczewski's framework [22] were classified with the core drive they most effectively addressed.

Technological devices integrating gamification were classified based on the type of platform they were used with and also based on which symptoms they intended to address.

Finally, a qualitative content analysis using an inductive approach was conducted to identify the justifications used by each study for the inclusion of gamification elements and technological devices for motor rehabilitation in PD [33]. Data from all included studies were coded and organized into categories, which were then clustered into broader themes

with the support of a hierarchical tree diagram. Definitions were developed for each code, category, and subcategory. Two reviewers (PBB and HFL) carried out the analysis independently using Excel, and then discussed how to group codes, align interpretations, and resolve discrepancies. Final themes were reviewed and refined through team-based triangulation to ensure consistency and credibility.

Results

General Information

Altogether 81 studies were included in the final review (Multimedia Appendix 2) [34-114]. The PRISMA flow diagram (Figure 1) [115] details the steps followed during the screening process and data on number of excluded studies as well as reasons for exclusion in the full-text step. Of the 81 articles included, over 50% (41/81) were published in

the year 2019 or later. Italy and Brazil were the 2 countries where most research was produced, with 18.5% (14/81) and 17.3% (13/81), respectively. The most frequent study design consisted of randomized controlled trials, which accounted for 49% (40/81) of all studies, followed by quasi-experimental studies, which accounted for 46% (37/81) of all studies. Sample sizes from the studies included ranged from 2 to 302 participants, with an average sample size of 32.2 participants. The mean age for participants was 66.64 (SD 5.05) years, with a mean of 2.29 (SD 0.57) on the Hoehn and Yahr [116] scale for disease severity and a mean disease duration of 7.35 (SD 2.70) years. A total of 39.39% of all participants were female. Most studies (62/81, 77%) implemented their interventions in an in-person format, while 23% (19/81) used telerehabilitation. Additionally, 1% (1/81) of studies used a hybrid approach, combining both in-person and remote intervention formats.

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.
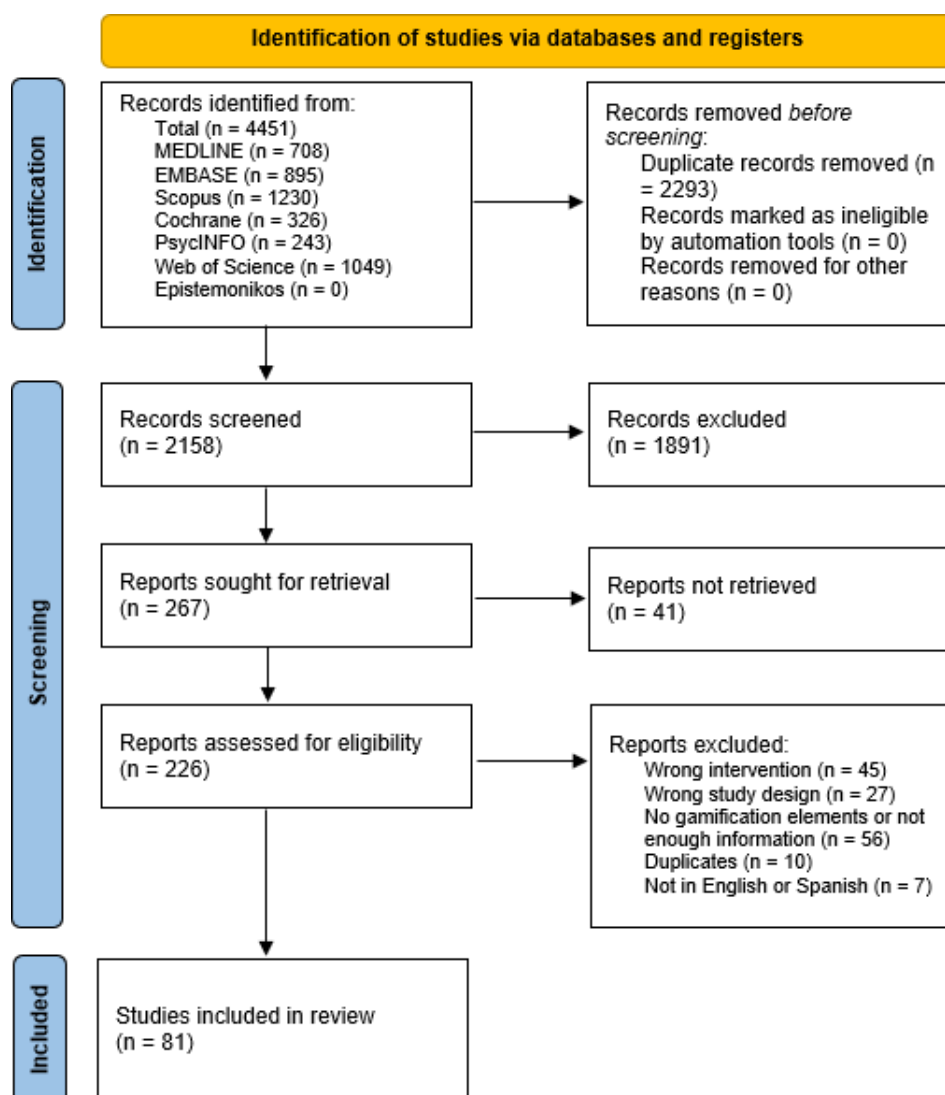
Identification and Classification of Gamification Elements and Technological Devices

Gamification Elements

Detailed data on the frequency and distribution of the identified gamification elements and their association with the

Octalysis Framework's 8 Core Drives of motivation can be found in Table 1.

Table 1. Distribution of use of gamification elements and classification according to the Octalysis Framework.

Octalysis' core drive and gamification elements	Times used (out of 81 studies)	Percentage of total studies where used	Percentage of total used elements
Epic meaning and calling			
Quests [59,60]	2	2	<1
Development and accomplishment			
Progress/Feedback [34-86,88-110,112-114]	79	98	17
Points [34-40,42-44,47,50-52,54-58,62-71,73-107,109-114]	70	86	15
Levels/Progression [34-39,41-45,47,50-52,54,56,58, 61-80,82-84,86-89,91-97,99-103,106-114]	66	81	15
Badges [35-38,51,52,54,56,58,62,64,66, 67,70,71,73,77-79,82,86,90,92,93,96,97,99-101,114]	30	37	7
Leaderboards [36-38,51,52,54,56,58,62,64,66, 67,70,71,73-75,77-79,82,88,91,95-97,99-101,114]	29	36	6
Challenges [36-38,51,52,54,56,58,62,64,66, 67,70,71,73,77-79,82,91,96,97,99-101,114]	26	32	6
Empowerment of creativity and feedback			
Customization [36-38,45,51,52,54,56,58,62,64, 66,67,70,71,73-75,77-79,82,86,91-93,96,97,99-101,114]	32	40	7
Ownership and possession			
—[a]	—	—	—
Social influence and relatedness			
Competition [36-38,51,52,54,56,58,62,64,66, 67,70,71,73,77-79,82,86,91-93,96,97,99-101,114]	29	36	6
Knowledge share [59,60]	2	2	<1
Guilds/Teams [59,60]	2	2	<1
Scarcity and impatience			
Unlockables [50]	1	1	<1
Unpredictability and curiosity			
—	—	—	—
Loss and avoidance			
Consequences [36-38,47,52,54,56,58,62,64,66,	30	37	7

Octalysis' core drive and gamification elements	Times used (out of 81 studies)	Percentage of total studies where used	Percentage of total used elements
67,70,71,73,77,79,82,88,91,96,97,99,101,107,109,110,113,114]			
Time Pressure [35-38,46,48,49,51,52,54,56,58,62,64-67,70-73,77-79,82,86,91-93,96,97,99-101,109,110,114]	37	46	8

aNot available.

A total of 453 gamification elements were identified across all included studies, categorized into 14 distinct types based on the Marczewski classification of gamification mechanics [22]. For the epic meaning and calling core drive, only quests were identified as a relevant gamification element, appearing 2 times across studies. This element was used in 2.47% (2/81) of the studies, accounting for 0.44% (2/4453) of the total gamification elements used. The development and accomplishment core drive was the most prominent category, containing a variety of gamification elements and showing extensive use across the studies. Progress/feedback mechanics were the most frequently used element, appearing in 79 studies (97.53% of studies) and representing 17.44% (80/453) of the total gamification elements used. Other commonly used elements included points, which appeared in 86.42% (70/81) of studies and accounted for 15.45% (70/453) of total elements; levels/progression, which appeared in 81.48% (66/81) of studies and represented 14.57% (66/453) of total elements; badges, used in 37.04% (30/81) of studies, accounting for 6.62% (30/453) of total elements; leaderboards, used in 35.80% (29/81) of studies, making up 6.40% (29/453) of total elements; and challenges, which appeared in 32.09% (26/81) of studies and represented 5.72% (26/453) of total elements. The empowerment of creativity and feedback core drive included only one gamification element, customization, which was used in 32 studies (39.51% of studies) and accounted for 7.06% (32/453) of total elements. Neither the ownership and possession core drive nor the unpredictability and curiosity drive showed any specific

gamification elements reported across the studies. Under the social influence and relatedness core drive, elements like competition, knowledge share, and guilds/teams were identified. Competition was used in 35.80% (29/81) of studies, contributing 6.40% (29/81) to the total elements, while both knowledge share and guilds/teams appeared only in 2.47% (2/81) of studies, accounting for a mere 0.44% (2/453) of total elements each. The scarcity and impatience drive included only one element, unlockables, which was used in just one study, appearing in 1.23% (1/81) of studies and making up only 0.22% (1/453) of the total gamification elements. Last, the loss and avoidance core drive included the elements "consequences" and "time pressure". Consequences were used in 37.04% (30/81) of studies, contributing 6.62% (30/453) to the total elements, while time pressure appeared in 45.68% (37/81) of studies, making up 8.14% (37/453) of the total elements used.

Technological Devices Integrating Gamification

Overview

The technological devices integrating gamification identified across 81 studies were categorized into 4 groups based on the platforms they were used with: video game consoles, computer-based systems, tablet-based systems, and integrated rehabilitation platforms. Detailed information on each category and the specific motor symptoms in PD they address can be found in Figure 2.

Figure 2. Symptoms addressed by each type of technological device used in rehabilitation. UE: upper extremity.
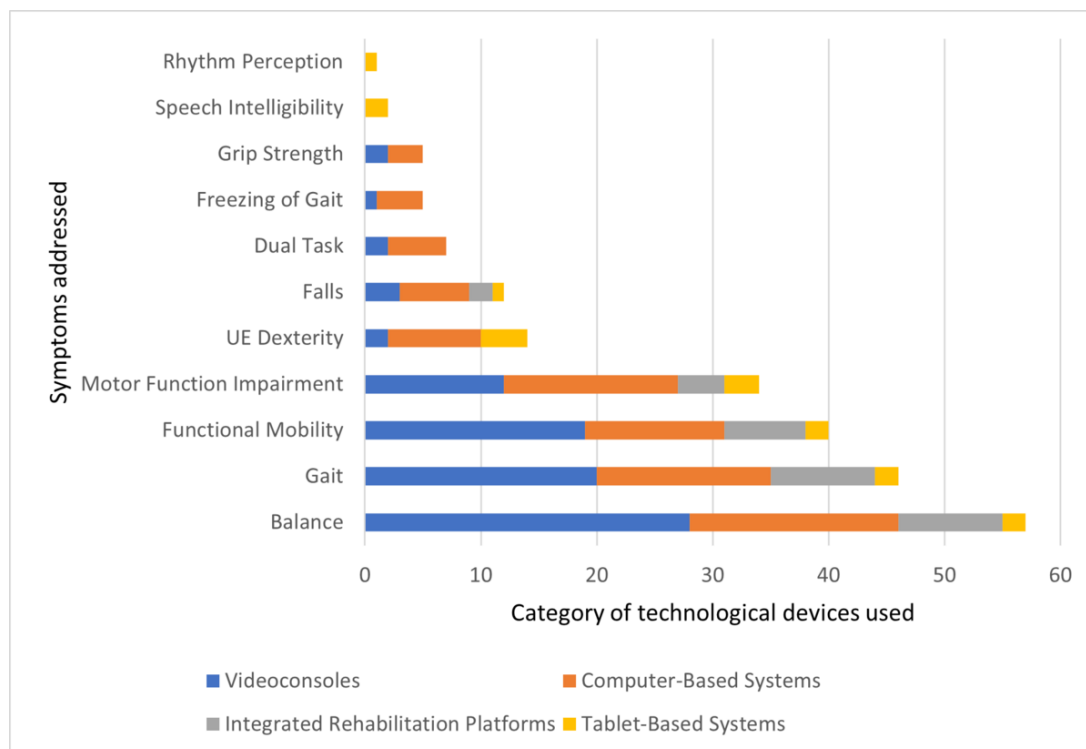
Video Game Consoles

Video game consoles like the Nintendo Wii and Microsoft Xbox, originally designed for entertainment, were frequently repurposed for rehabilitation. The Nintendo Wii was the most used device, appearing in 27% (22/81) of all studies, almost exclusively in combination with the Wii Balance Board (20/22, 91% of all Nintendo Wii studies). Most studies with this video game console addressed balance (18/22, 82% of studies), gait (12/22, 55%), functional mobility (11/22, 50%), and motor function impairment (9/22, 41%). The Microsoft Xbox, used with the Kinect motion sensor in 14% (11/81) of studies, was similarly focused on balance (10/11, 91% of studies), gait (8/11, 73%), functional mobility (7/11, 73%), and motor function impairment (3/11, 28%). None of the video game consoles were created with rehabilitation as their primary goal. A total of 85% (28/33) of studies using video game consoles delivered their interventions in an in-person format, while 13% (4/33) used telerehabilitation and 3% (1/33) combined both formats.

Computer-Based Systems

Computer-based systems were used in 40% (32/81) of studies, often in combination with motion-sensing devices like Kinect (12/32, 37.5% of computer-based systems), Leap Motion Controller (7/32, 22%), and balance boards or force plates (7/32, 22%). Kinect was applied mainly to improve balance (8/12, 67%), gait (7/12, 58%), and motor function impairment (5/12, 42%), while balance boards and force plates focused on balance (7/7, 100%), gait (4/7, 57%), and functional mobility (4/7, 57%), and the Leap Motion Controller targeted upper extremity dexterity (7/7, 100%), motor function impairment (4/7, 57%), and grip strength (3/7, 43%). The HTC Vive Pro VR device was used (2/32,

6%), enhancing immersion for balance (2/2, 100%), gait (2/2, 100%), and functional mobility (2/2, 100%) training. Additionally, some studies combined treadmills with Kinect (3/32, 9%), mainly to focus on falls (3/3, 100%). A total of 91% (29/32) of all computer-based systems were created with rehabilitation as their primary goal, and 78% (25/32) of studies using computer-based systems delivered their interventions in an in-person format, while 22% (7/32) used telerehabilitation.

Tablet-Based Systems

Tablet-based systems appeared in 11% (9/81) of all studies, either as standalone devices (6/9, 67% of all tablet-based systems) or combined with motion-sensing devices such as the Leap Motion Controller (1/9, 11%) or handheld tools like GripAble (1/9, 11%). These tablet-based systems mainly targeted upper extremity dexterity (4/9, 44%) and motor function impairment (3/9, 33%). A total of 100% (9/9) of tablet-based systems were created for rehabilitation as their primary goal and 22% (2/2) of tablet-based systems delivered their interventions in an in-person format, while 78% (7/9) used telerehabilitation.

Integrated Rehabilitation Platforms

Integrated rehabilitation platforms appeared in 10% (8/81) of all studies, testing systems explicitly designed for comprehensive rehabilitation. These platforms were used to rehabilitate balance (8/8, 100%), gait (8/8, 100%), functional mobility (5/8, 63%), and motor function impairment (2/8, 25%). All integrated rehabilitation platforms were created for rehabilitation as their primary goal. A total of 100% of interventions using integrated rehabilitation platforms were delivered in an in-person format.

Justification Behind the Use of Technological Devices Integrating Gamification

Overview

In order to determine the justifications used by each study for the inclusion of gamification elements and technological devices for motor rehabilitation in PD, four key categories were identified: (1) gamification as a benefit for therapeutic interventions, (2) evidence of effectiveness of technology in rehabilitation for PD, (3) evidence of effectiveness of technology in rehabilitation across populations, and (4) specific properties of technological solutions in rehabilitation.

Gamification as a Benefit for Therapeutic Interventions

Gamification was described as a means to support adaptive and individualized rehabilitation [45,47]. Systems were used to monitor user performance, adjust task difficulty based on scoring, and provide real-time feedback throughout the intervention. Some interventions also allowed for the customization of the experience to better match user needs and progression.

Evidence of Effectiveness of Technology in Rehabilitation for PD

Improvement of Motor Symptoms in PD

Technological devices were frequently described as effective [34,44,47,51,57,61,62,69-71,74-76,79,83,85-87,91,93,96,102, 104-106,112-114], promising [38, 48, 52, 64, 67, 68, 79, 81, 88, 102, 111], or feasible [61,72,88,114] tools for addressing motor symptoms in individuals with PD. Studies emphasized their role in improving key functions such as balance, gait, and postural control, while others framed them as having strong potential for rehabilitation, even when not yet fully established through outcomes. Articles also pointed to their feasibility as motor rehabilitation strategies, highlighting aspects like affordability and accessibility to support their use in both clinical and home-based settings.

Improvement of Nonmotor Symptoms in PD

Technological devices were described as having a supportive role in addressing cognitive function and emotional well-being in people with PD. Studies reported improvements in areas such as cognition, executive functioning, self-esteem, pain, and mental health [43,48,61,69,71,75,81,87,92,96,97,105,106,109]. Other aspects such as the potential of these technologies to create controlled, structured environments that can enhance the delivery of cognitive therapies and provide emotional support were also highlighted [64,81,100,105].

Positive Influence on Brain Activity Networks in PD

Studies discussed the role of technology in supporting underlying neurological processes relevant to rehabilitation [37,40,43,55,58,64,65,69-71,83,94,98,102]. VR and exergames were noted for their potential to promote neuroplasticity, motor learning, and motor-cognitive integration. These interventions were often associated with repetitive, goal-directed tasks designed to engage and optimize brain networks involved in movement and coordination.

Evidence of Effectiveness of Technology in Rehabilitation Across Populations

General Evidence for Physiotherapy

Studies highlighted that technology could offer rehabilitation outcomes comparable to, and in some cases exceeding, those of traditional physiotherapy [39,47,71,77,84,101]. Articles specifically noted the effectiveness of VR and exergames in enhancing therapy for both older adults and individuals with PD, supporting their use as a valid approach across different populations.

Evidence for Non-PD Populations

Technology was also supported through evidence drawn from broader populations, including stroke patients and older adults [53,54,74,75,77,91,102,112,113]. In these contexts, VR and video game–based interventions were associated with improvements in key rehabilitation outcomes such as balance, mobility, and fall reduction. These findings were used to justify the applicability of similar technological approaches in the context of PD rehabilitation.

Improvement of Clinical Parameters

Some studies pointed to the broader clinical value of technology in rehabilitation, highlighting its role in improving quality of life, physical function, daily activity performance, and pain management [48,51,52,74,86,97]. These outcomes were observed across a range of populations, including children, adults, and individuals with PD.

Specific Properties of Technological Solutions in Rehabilitation

Enhances Motivation Through an Engaging Experience

Technology was described as a tool to make rehabilitation more engaging and enjoyable [36,39,42,43,45,48,50,56,59,60,64,65,67,69-71,83,85,87-89,91,94,96-100,102,103,105,107-109,111,113,114]. By offering interactive and rewarding experiences, these interventions were seen as helpful in encouraging active participation and supporting long-term adherence to therapy programs.

Provides Quality Biofeedback

Real-time feedback was noted as a valuable feature in many interventions [37,38,41-45,51,54,55,63,65,66,73-75,77,80,81,83,84,91,92,94,98,100,102,103,106,107,109-112,114]. These feedback mechanisms were associated with enhanced motor learning,

improved performance, and greater awareness during rehabilitation tasks.

Customization of Training Parameters

The ability to tailor exercises to individual needs emerged as a key strength of technological solutions [39-41,45,48,51,53,57,63,65,70,72,73,76,84,91,94,97,100,101,105,107,111]. Customizable settings enabled repeated practice in varied contexts, supporting motor skill development and encouraging problem-solving during rehabilitation.

Enriched or Ecological Environment

Some technologies were highlighted for their capacity to simulate real-world environments, helping users practice tasks in settings that reflect daily life [48,54,55,60,63,72,74,76,78,81,84,92,97,98,101,109,112,113]. These ecologically valid scenarios were viewed as beneficial for promoting skill transfer beyond the therapeutic setting.

Supports Dual-Task Integration

Studies mentioned that technological interventions incorporated features that combined physical and cognitive tasks, making it possible to train complex dual-task scenarios [62,66,76,81,83,92,93,95,97,100,106,111]. This was particularly relevant for engaging users both mentally and physically within a single rehabilitation activity.

Enables Telerehabilitation

Technology was presented as a practical solution for home-based rehabilitation [36,58,61,83,97,100,103,106]. Devices described as user-friendly and affordable were positioned as a means of extending therapy beyond clinical settings while maintaining effectiveness.

Accessible and Cost-Effective

Portability and low cost were mentioned as noted advantages, especially in tools designed for home use [36,61,74,79,82,87,97,104]. These features lead to an easier integration into daily routines, which may contribute to better consistency and accessibility in rehabilitation.

Safe Intervention

Studies emphasized the safety of technological interventions, particularly in controlled environments [50,89,98,112,113]. This was considered relevant for tasks that carry a higher risk of falls or injury, offering a secure space for functional improvement.

Discussion

Principal Findings

This scoping review aimed to identify and classify the technological devices integrating gamification used in motor rehabilitation for PD, as well as to describe the rationale behind their application. This review is particularly relevant as it addresses a growing interest in leveraging innovative, technology-driven approaches to manage PD's motor symptoms, a field where gamification has been suggested to enhance patient engagement and therapeutic outcomes [20]. Despite this potential, the integration of gamification into PD rehabilitation interventions remains underexplored, with a limited understanding of how these elements are being applied in practice or their theoretical justifications.

Findings reveal that while technological devices integrating rehabilitation are widely used, the range of gamification mechanics is narrow, with a strong focus on the development and accomplishment core drive. This result aligns with statements by Kai [21], according to which the core drive of development and accomplishment is the easiest to design and the one drawing the most focus from developers. Commonly used elements like feedback mechanisms, points, and progression systems dominate interventions, reflecting an emphasis on monitoring and improving performance. This aligns closely with the most targeted motor symptoms—balance, gait, and functional mobility—which significantly benefit from feedback-driven adjustments offered by motion-sensing technologies, aiding postural control in individuals with PD [117]. Gamification mechanics such as time pressure and consequences from the loss and avoidance core drive are used less frequently with the goal of instilling urgency and accountability, improving speed and efficiency. Elements from this core drive should be carefully considered in designing future interventions, since different motor phenotypes of PD appear to respond differently to reward or punishment-based systems [118]. Similarly, competition mechanics foster motivation and social interaction, aiding long-term engagement. However, more intrinsic motivational pathways, such as those tied to unpredictability and curiosity or ownership and possession, remain underused. Notably absent are complex gamification features like narratives or exploratory elements, highlighting a gap in current approaches.

Out of all the studies included in this review, only 2 [45,47] explicitly refer to the concept or use of gamification when describing their interventions, and none used a theoretical framework to justify their use. Additionally, 37 out of the 81 included studies used technological devices originally designed for entertainment in healthy populations rather than as rehabilitation tools tailored to individuals with health conditions. These findings underline clear research gaps in applying gamification to its full potential in the rehabilitation of people with PD, as well as highlighting an overreliance on video game consoles and other devices designed for entertainment purposes (ie, Nintendo Wii and Microsoft Kinect) rather than rehabilitation-specific technologies. The high presence of interventions based on commercial video consoles and video games for rehabilitation presents an intriguing landscape within this context. On the one hand, leveraging refined, off-the-shelf commercial software offers distinct advantages, eliminating the need for costly development efforts and providing products inherently designed for entertainment, which may enhance participant engagement. However, it is essential to recognize that these interventions lack tailored considerations for populations affected by neurodegenerative conditions, such

as PD. Furthermore, the feedback mechanisms embedded in these software options are geared toward game performance rather than exercise and motor learning, potentially rendering them less relevant for the rehabilitation of individuals with PD. As a result, gamification elements, digital environments, and gameplay patterns may not align optimally with the requirements and objectives of this specific population [119]. User-centered design would be an essential part of development in this context, incorporating the needs and preferences of individuals with PD into the interventions [120]. Notably, people with PD exhibit distinct differences from the younger populations typically targeted by commercial video games, which could lead to unintended outcomes when using them to apply rehabilitation interventions [121].

The delivery format of interventions varied by technology type. Video game consoles and computer-based systems were primarily used in in-person settings (85% [28/33] and 78% [25/32], respectively), while tablet-based systems were predominantly used in telerehabilitation (7/9, 78%). Despite most devices being designed for at-home use, researchers tended to implement interventions in supervised settings, likely to ensure safety, adherence, and standardized assessments. This preference aligns with findings suggesting that motion-sensing and immersive rehabilitation technologies often require clinical oversight for effective implementation, particularly in neurodegenerative conditions such as PD [122].

This review identified 4 distinct categories through content analysis of the justifications provided by studies for using technological devices integrating gamification for rehabilitation. Collectively, these categories underscore expectations of such solutions as being safe, motivational, and engaging tools for addressing diverse conditions. They are bolstered by extensive evidence of potential and proven effectiveness and offer innovative training opportunities, including telerehabilitation, dual-task integration, and advanced biofeedback. Despite these well-defined expectations, articles give minimal or no attention to the gamification elements that significantly contribute to their interventions. Current evidence of gaming interventions is unclear, with no studies isolating the effects of gamification used in interventions on people with PD [123]. These findings suggest that while technological solutions show great promise for advancing rehabilitation for individuals with PD, greater emphasis on thoughtfully integrating gamification elements could enhance outcomes by providing more tailored and effective interventions for this population [24].

Implications for Future Research and Clinical Practice

Many of the interventions in this review relied on commercial entertainment video games, which are not inherently designed for rehabilitation. Their built-in feedback systems and progression mechanics are primarily meant to enhance gameplay rather than support motor learning or therapeutic outcomes for individuals with PD. However, these games remain widely used because they are engaging, cost-effective, and easily accessible. Rather than focusing solely on developing new rehabilitation-specific games, a practical approach could involve evaluating existing commercial games to determine their suitability for therapy. Establishing clear assessment criteria, such as a standardized checklist, could help clinicians identify which games align best with rehabilitation goals and patient needs.

Future research should also explore how well these technologies adapt to the specific challenges faced by individuals with PD, particularly in terms of usability and accessibility. Additionally, a deeper understanding of how different gamification elements influence engagement and adherence, especially when grounded in motivational theories, could help refine rehabilitation strategies. Identifying the most effective elements for sustaining participation and improving outcomes would allow clinicians to make better-informed choices and develop interventions that truly meet the needs of people with PD. To advance this field, research should also prioritize a structured, evidence-based approach to gamification, ensuring that technological solutions are designed with both therapeutic effectiveness and user experience in mind. Integrating User-Centered Design principles with established motivational frameworks could help create interventions that are both engaging and clinically relevant, thus optimizing their impact in neurorehabilitation settings.

Limitations

This scoping review adhered to the PRISMA-ScR [31] recommendations to ensure methodological rigor. However, several limitations warrant acknowledgment:

Due to the substantial volume of retrieved studies, an initial screening was conducted using only titles and abstracts. This step involved 3 different reviewers who reached a consensus in cases of disagreement. Despite this method, there remains a risk of inadvertently excluding relevant papers.

Another limitation consists of the review's scope being bound by the search date at which it was performed. Consequently, any studies published after this date were not considered. There is also a limitation in that gray literature, which may contain valuable insights, was not included in the search. As a result, some relevant research might have been overlooked. Articles published in languages other than English and Spanish were also not included, which may also omit relevant information from this review.

This review did not systematically analyze the usability, accessibility, or adaptability of the interventions, as these factors were not part of the predefined data extraction criteria. While these aspects are important for the success of rehabilitation technologies, more research is needed to understand how well gamified interventions address the unique motor and cognitive challenges of individuals with PD.

Finally, there is also a limitation in how the selection of gamification elements for this study was performed. While efforts were made to identify gamification elements in all included studies based on manuscript information and

web-based sources, certain custom-made software options and commercial games were inaccessible or had limited available information. Consequently, some gamification elements may not have been fully accounted for.

Conclusions

This scoping review sheds light on the widespread adoption of technologies integrating gamification elements for motor symptom rehabilitation in individuals with PD. However, it also reveals a notable gap in understanding and acknowledging gamification mechanics among researchers and developers. The current landscape of gamification elements within the reviewed interventions predominantly emphasizes performance-based experiences, focusing on straightforward elements like scoring and feedback. Expectations of technological devices integrating gamification applied in rehabilitation contexts are clear, but there is a notable absence of justification for the specific inclusion of gamification through the application of relevant theories or frameworks, indicating a lack of standardization or rationale for the design of these interventions. Further studies in this field should focus on the importance of user-centered design for the inclusion of gamification mechanics that could modify the experience of users, so as to optimize the development efforts to optimally reach the needs of people with PD. There is also a clear need for the development of studies that report on the effects of gamification itself, which would allow developers to precisely deploy elements according to the expected role of these mechanics within their interventions.

Data Availability

All data generated and analyzed during this study will be made available upon reasonable request.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Search strategy for each database.
[DOCX File (Microsoft Word File), 26 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Details of all included studies.
[XLSX File (Microsoft Excel File), 38 KB-Multimedia Appendix 2]

Checklist 1

PRISMA-ScR checklist.
[PDF File (Adobe File), 113 KB-Checklist 1]

References

1. Poewe W, Seppi K, Tanner CM, et al. Parkinson disease. Nat Rev Dis Primers. Mar 23, 2017;3(1–21):17013. [doi: 10.1038/nrdp.2017.13] [Medline: 28332488]
2. Feigin VL, Abajobir AA, Abate KH, et al. Global, regional, and national burden of neurological disorders during 1990–2015: a systematic analysis for the global burden of disease study 2015. Lancet Neurol. Nov 2017;16(11):877-897. [doi: 10.1016/S1474-4422(17)30299-5]
3. Deuschl G, Beghi E, Fazekas F, et al. The burden of neurological diseases in Europe: an analysis for the global burden of disease study 2017. Lancet Public Health. Oct 2020;5(10):e551-e567. [doi: 10.1016/S2468-2667(20)30190-0] [Medline: 33007212]
4. Luo Y, Qiao L, Li M, Wen X, Zhang W, Li X. Global, regional, national epidemiology and trends of Parkinson's disease from 1990 to 2021: findings from the global burden of disease study 2021. Front Aging Neurosci. 2024;16:1498756. [doi: 10.3389/fnagi.2024.1498756] [Medline: 39868382]
5. Leite Silva ABR, Gonçalves de Oliveira RW, Diógenes GP, et al. Premotor, nonmotor and motor symptoms of Parkinson's disease: a new clinical state of the art. Ageing Res Rev. Feb 2023;84:101834. [doi: 10.1016/j.arr.2022.101834] [Medline: 36581178]
6. Shulman LM, Gruber-Baldini AL, Anderson KE, et al. The evolution of disability in Parkinson disease. Mov Disord. Apr 30, 2008;23(6):790-796. [doi: 10.1002/mds.21879] [Medline: 18361474]
7. Armstrong MJ, Okun MS. Diagnosis and treatment of Parkinson disease. JAMA. Feb 11, 2020;323(6):548. [doi: 10.1001/jama.2019.22360]

8. Manson A, Stirpe P, Schrag A. Levodopa-induced-dyskinesias clinical features, incidence, risk factors, management and impact on quality of life. J Parkinsons Dis. 2012;2(3):189-198. [doi: 10.3233/JPD-2012-120103] [Medline: 23938226]

9. Tomlinson CL, Patel S, Meek C, et al. Physiotherapy versus placebo or no intervention in Parkinson's disease. Cochrane Database Syst Rev. Sep 10, 2013;2013(9):CD002817. [doi: 10.1002/14651858.CD002817.pub4] [Medline: 24018704]

10. Mak MK, Wong-Yu IS, Shen X, Chung CL. Long-term effects of exercise and physical therapy in people with Parkinson disease. Nat Rev Neurol. Nov 2017;13(11):689-703. [doi: 10.1038/nrneurol.2017.128] [Medline: 29027544]

11. Dockx K, Bekkers EM, Van den Bergh V, et al. Virtual reality for rehabilitation in Parkinson's disease. Cochrane Database Syst Rev. Dec 21, 2016;12(12):CD010760. [doi: 10.1002/14651858.CD010760.pub2] [Medline: 28000926]

12. Truijen S, Abdullahi A, Bijsterbosch D, et al. Effect of home-based virtual reality training and telerehabilitation on balance in individuals with Parkinson disease, multiple sclerosis, and stroke: a systematic review and meta-analysis. Neurol Sci. May 2022;43(5):2995-3006. [doi: 10.1007/s10072-021-05855-2] [Medline: 35175439]

13. Picelli A, Capecci M, Filippetti M, et al. Effects of robot-assisted gait training on postural instability in Parkinson's disease: a systematic review. Eur J Phys Rehabil Med. Jun 2021;57(3):472-477. [doi: 10.23736/S1973-9087.21.06939-2] [Medline: 33826278]

14. Putzolu M, Manzini V, Gambaro M, et al. Home-based exercise training by using a smartphone app in patients with Parkinson's disease: a feasibility study. Front Neurol. 2023;14:1205386. [doi: 10.3389/fneur.2023.1205386] [Medline: 37448748]

15. Vellata C, Belli S, Balsamo F, Giordano A, Colombo R, Maggioni G. Effectiveness of telerehabilitation on motor impairments, non-motor symptoms and compliance in patients with Parkinson's disease: a systematic review. Front Neurol. 2021;12:627999. [doi: 10.3389/fneur.2021.627999] [Medline: 34512495]

16. Chuang CS, Chen YW, Zeng BY, et al. Effects of modern technology (exergame and virtual reality) assisted rehabilitation vs conventional rehabilitation in patients with Parkinson's disease: a network meta-analysis of randomised controlled trials. Physiotherapy. Dec 2022;117:35-42. [doi: 10.1016/j.physio.2022.07.001] [Medline: 36242929]

17. Deterding S, Khaled R, Nacke LE, Dixon D. Gamification: toward a definition. Presented at: CHI 2011 Gamification Workshop Proceedings; May 7-12, 2011; Vancouver, BC, Canada. URL: http://gamification-research.org/wp-content/uploads/2011/04/02-Deterding-Khaled-Nacke-Dixon.pdf [Accessed 2025-06-30]

18. Alfieri FM, da Silva Dias C, de Oliveira NC, Battistella LR. Gamification in musculoskeletal rehabilitation. Curr Rev Musculoskelet Med. Dec 2022;15(6):629-636. [doi: 10.1007/s12178-022-09797-w] [Medline: 36301514]

19. Adlakha S, Chhabra D, Shukla P. Effectiveness of gamification for the rehabilitation of neurodegenerative disorders. Chaos Solit Fractals. Nov 2020;140:110192. [doi: 10.1016/j.chaos.2020.110192]

20. De Freitas TB, Leite PHW, Doná F, Pompeu JE, Swarowsky A, Torriani-Pasin C. The effects of dual task gait and balance training in Parkinson's disease: a systematic review. Physiother Theory Pract. Oct 2020;36(10):1088-1096. [doi: 10.1080/09593985.2018.1551455] [Medline: 30501424]

21. Kai CY. Actionable Gamification: Beyond Points, Badges, and Leaderboards. Packt Publishing Ltd; 2019. URL: https://yukaichou.com/gamification-book/ [Accessed 2025-06-30]

22. Marczewski A. The periodic table of gamification elements - gamified UK - gamification expert. gamified.uk; 2017. URL: https://www.gamified.uk/2017/04/03/periodic-table-gamification-elements/ [Accessed 2025-06-26]

23. Sevcenko K, Lindgren I. The effects of virtual reality training in stroke and Parkinson's disease rehabilitation: a systematic review and a perspective on usability. Eur Rev Aging Phys Act. Jan 25, 2022;19(1):4. [doi: 10.1186/s11556-022-00283-3] [Medline: 35078401]

24. Rodríguez-Mansilla J, Bedmar-Vargas C, Garrido-Ardila EM, et al. Effects of virtual reality in the rehabilitation of Parkinson's disease: a systematic review. J Clin Med. Jul 26, 2023;12(15):10419374. [doi: 10.3390/jcm12154896] [Medline: 37568298]

25. Zhang J, Luximon Y, Pang MYC, Wang H. Effectiveness of exergaming-based interventions for mobility and balance performance in older adults with Parkinson's disease: systematic review and meta-analysis of randomised controlled trials. Age Ageing. Aug 2, 2022;51(8):afac175. [doi: 10.1093/ageing/afac175] [Medline: 35930726]

26. Cano Porras D, Siemonsma P, Inzelberg R, Zeilig G, Plotnik M. Advantages of virtual reality in the rehabilitation of balance and gait: systematic review. Neurology (ECronicon). May 29, 2018;90(22):1017-1025. [doi: 10.1212/WNL.0000000000005603] [Medline: 29720544]

27. den Brok M, van Dalen JW, van Gool WA, Moll van Charante EP, de Bie RMA, Richard E. Apathy in Parkinson's disease: a systematic review and meta-analysis. Mov Disord. May 2015;30(6):759-769. [doi: 10.1002/mds.26208] [Medline: 25787145]

28. Aarsland D, Larsen JP, Lim NG, et al. Range of neuropsychiatric disturbances in patients with Parkinson's disease. J Neurol Neurosurg Psychiatry. Oct 1999;67(4):492-496. [doi: 10.1136/jnnp.67.4.492] [Medline: 10486397]

29.   van Nimwegen M, Speelman AD, Overeem S, et al. Promotion of physical activity and fitness in sedentary patients with Parkinson's disease: randomised controlled trial. BMJ. Mar 1, 2013;346(7898):f576. [doi: 10.1136/bmj.f576] [Medline: 23457213]

30.   Edoardo A, Zachary M, Joanna Briggs Institute. JBI manual for evidence synthesis. Joanna Briggs Institute; 2020. URL: https://tinyurl.com/47tcykxd [Accessed 2025-06-26]

31.   Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. Oct 2, 2018;169(7):467-473. [doi: 10.7326/M18-0850] [Medline: 30178033]

32.   Covidence systematic review software. 2023. URL: www.covidence.org [Accessed 2025-06-26]

33.   Hsieh HF, Shannon SE. Three approaches to qualitative content analysis. Qual Health Res. Nov 2005;15(9):1277-1288. [doi: 10.1177/1049732305276687] [Medline: 16204405]

34.   Albiol-Pérez S, Gil-Gómez JA, Muñoz-Tomás MT, Gil-Gómez H, Vial-Escolano R, Lozano-Quilis JA. The effect of balance training on postural control in patients with Parkinson's disease using a virtual rehabilitation system. Methods Inf Med. Mar 23, 2017;56(2):138-144. [doi: 10.3414/ME16-02-0004] [Medline: 28244545]

35.   Allen NE, Song J, Paul SS, et al. An interactive videogame for arm and hand exercise in people with Parkinson's disease: a randomized controlled trial. Parkinsonism Relat Disord. Aug 2017;41:66-72. [doi: 10.1016/j.parkreldis.2017.05.011] [Medline: 28528804]

36.   Alves MLM, Mesquita BS, Morais WS, Leal JC, Satler CE, Dos Santos Mendes FA. Nintendo WiiTM versus Xbox KinectTM for assisting people with Parkinson's disease. Percept Mot Skills. Jun 2018;125(3):546-565. [doi: 10.1177/0031512518769204] [Medline: 29665760]

37.   Anwar N, Akram S, Ilyas A, Khalid K, Munir M, Khizer Hayar M. Comparison of virtual reality and conventional balance training to improve balance and walking in Parkinson's disease patients. Med Forum Mon. 2021;32(7):129-133.

38.   Bacha JMR, Cunha MCC, Freitas TB, et al. Effects of virtual rehabilitation on postural control of individuals with Parkinson disease. Motricidade. 2021;17(3):220-227.

39.   Barth M, Möbius R, Themann P, et al. Functional improvement of patients with Parkinson syndromes using a rehabilitation training software. Front Neurol. 2023;14:1210926. [doi: 10.3389/fneur.2023.1210926] [Medline: 37645604]

40.   Bekkers EMJ, Mirelman A, Alcock L, et al. Do patients with Parkinson's disease with freezing of gait respond differently than those without to treadmill training augmented by virtual reality? Neurorehabil Neural Repair. May 2020;34(5):440-449. [doi: 10.1177/1545968320912756] [Medline: 32202203]

41.   Bevilacqua R, Benadduci M, Renato Riccardi G, et al. SI-ROBOTICS system: a preliminary study on usability of a rehabilitation program in patients with parkinson's disease. Presented at: CEUR Workshop Proceedings; Dec 16, 2022; Florence, Italy. URL: https://ceur-ws.org/Vol-3323/paper3.pdf [Accessed 2025-06-30]

42.   Brachman A, Marszałek W, Kamieniarz A, Michalska J, Pawłowski M, Juras G. Biomechanical measures of balance after balance-based exergaming training dedicated for patients with Parkinson's disease. Gait Posture. Jun 2021;87:170-176. [doi: 10.1016/j.gaitpost.2021.04.036] [Medline: 33940308]

43.   Calabrò RS, Naro A, Cimino V, et al. Improving motor performance in Parkinson's disease: a preliminary study on the promising use of the computer assisted virtual reality environment (CAREN). Neurol Sci. Apr 2020;41(4):933-941. [doi: 10.1007/s10072-019-04194-7] [Medline: 31858331]

44.   Carpinella I, Cattaneo D, Bonora G, et al. Wearable sensor-based biofeedback training for balance and gait in Parkinson disease: a pilot randomized controlled trial. Arch Phys Med Rehabil. Apr 2017;98(4):622-630. [doi: 10.1016/j.apmr.2016.11.003] [Medline: 27965005]

45.   Chua LK, Chung YC, Bellard D, et al. Gamified dual-task training for individuals with Parkinson disease: an exploratory study on feasibility, safety, and efficacy. Int J Environ Res Public Health. Nov 25, 2021;18(23):12384. [doi: 10.3390/ijerph182312384] [Medline: 34886114]

46.   Cikajlo I, Zajc D, Dolinšek I. Precise hand movement telerehabilitation with virtual cubes for patients with parkinson's disease. Presented at: ACM International Conference Proceeding Series; Oct 13-14, 2016:17-20; Lisbon, Portugal. [doi: 10.1145/3051488.305149]

47.   Cikajlo I, Hukić A, Dolinšek I, et al. Can telerehabilitation games lead to functional improvement of upper extremities in individuals with Parkinson's disease? Int J Rehabil Res. Sep 2018;41(3):230-238. [doi: 10.1097/MRR.0000000000000291] [Medline: 29757774]

48.   Cikajlo I, Peterlin Potisk K. Advantages of using 3D virtual reality based training in persons with Parkinson's disease: a parallel study. J Neuroeng Rehabil. Oct 17, 2019;16(1):119. [doi: 10.1186/s12984-019-0601-1] [Medline: 31623622]

49.   Cikajlo I, Hukić A, Zajc D. Exergaming as part of the telerehabilitation can be adequate to the outpatient training: preliminary findings of a non-randomized pilot study in Parkinson's disease. Front Neurol. 2021;12:625225. [doi: 10.3389/fneur.2021.625225] [Medline: 33815252]

50. Dauvergne C, Bégel V, Gény C, Puyjarinet F, Laffont I, Dalla Bella S. Home-based training of rhythmic skills with a serious game in Parkinson's disease: usability and acceptability. Ann Phys Rehabil Med. Nov 2018;61(6):380-385. [doi: 10.1016/j.rehab.2018.08.002] [Medline: 30193992]

51. de Melo GEL, Kleiner AFR, Lopes JBP, et al. Effect of virtual reality training on walking distance and physical fitness in individuals with Parkinson's disease. NeuroRehabilitation. 2018;42(4):473-480. [doi: 10.3233/NRE-172355] [Medline: 29660956]

52. de Melo Cerqueira TM, de Moura JA, de Lira JO, Leal JC, D'Amelio M, do Santos Mendes FA. Cognitive and motor effects of kinect-based games training in people with and without Parkinson disease: a preliminary study. Physiother Res Int. Jan 2020;25(1):e1807. [doi: 10.1002/pri.1807] [Medline: 31468656]

53. Ellis T, Latham NK, DeAngelis TR, Thomas CA, Saint-Hilaire M, Bickmore TW. Feasibility of a virtual exercise coach to promote walking in community-dwelling persons with Parkinson disease. Am J Phys Med Rehabil. 2013;92(6):472-485. [doi: 10.1097/PHM.0b013e31828cd466]

54. Esculier JF, Vaudrin J, Bériault P, Gagnon K, Tremblay LE. Home-based balance training programme using Wii Fit with balance board for Parkinsons's disease: a pilot study. J Rehabil Med. Feb 2012;44(2):144-150. [doi: 10.2340/16501977-0922] [Medline: 22266676]

55. Fernández-González P, Carratalá-Tejada M, Monge-Pereira E, et al. Leap motion controlled video game-based therapy for upper limb rehabilitation in patients with Parkinson's disease: a feasibility study. J Neuroeng Rehabil. Nov 6, 2019;16(1):133. [doi: 10.1186/s12984-019-0593-x] [Medline: 31694653]

56. Ferraz DD, Trippo KV, Duarte GP, Neto MG, Bernardes Santos KO, Filho JO. The effects of functional training, bicycle exercise, and exergaming on walking capacity of elderly patients with Parkinson disease: a pilot randomized controlled single-blinded trial. Arch Phys Med Rehabil. May 2018;99(5):826-833. [doi: 10.1016/j.apmr.2017.12.014] [Medline: 29337023]

57. Fundarò C, Maestri R, Ferriero G, Chimento P, Taveggia G, Casale R. Self-selected speed gait training in Parkinson's disease: robot-assisted gait training with virtual reality versus gait training on the ground. Eur J Phys Rehabil Med. Aug 2019;55(4):456-462. [doi: 10.23736/S1973-9087.18.05368-6] [Medline: 30370751]

58. Gandolfi M, Geroin C, Dimitrova E, et al. Virtual reality telerehabilitation for postural instability in Parkinson's disease: a multicenter, single-blind, randomized, controlled trial. Biomed Res Int. 2017;2017:7962826. [doi: 10.1155/2017/7962826] [Medline: 29333454]

59. Ganzeboom M, Bakker M, Beijer L, Rietveld T, Strik H. Speech training for neurological patients using a serious game. Brit J Educational Tech. Jul 2018;49(4):761-774. [doi: 10.1111/bjet.12640]

60. Ganzeboom M, Bakker M, Beijer L, Strik H, Rietveld T. A serious game for speech training in dysarthric speakers with Parkinson's disease: exploring therapeutic efficacy and patient satisfaction. Int J Lang Commun Disord. Jul 2022;57(4):808-821. [doi: 10.1111/1460-6984.12722] [Medline: 35338751]

61. Goffredo M, Baglio F, DE Icco R, et al. Efficacy of non-immersive virtual reality-based telerehabilitation on postural stability in Parkinson's disease: a multicenter randomized controlled trial. Eur J Phys Rehabil Med. Dec 2023;59(6):689-696. [doi: 10.23736/S1973-9087.23.07954-6] [Medline: 37847247]

62. Gonçalves GB, Leite MAA, Orsini M, Pereira JS. Effects of using the Nintendo Wii Fit plus platform in the sensorimotor training of gait disorders in Parkinson's disease. Neurol Int. Jan 17, 2014;6(1):5048. [doi: 10.4081/ni.2014.5048] [Medline: 24744845]

63. Gulcan K, Guclu-Gunduz A, Yasar E, Ar U, Sucullu Karadag Y, Saygili F. The effects of augmented and virtual reality gait training on balance and gait in patients with Parkinson's disease. Acta Neurol Belg. Oct 2023;123(5):1917-1925. [doi: 10.1007/s13760-022-02147-0] [Medline: 36443623]

64. Hajebrahimi F, Velioglu HA, Bayraktaroglu Z, Helvaci Yilmaz N, Hanoglu L. Clinical evaluation and resting state fMRI analysis of virtual reality based training in Parkinson's disease through a randomized controlled trial. Sci Rep. May 16, 2022;12(1):8024. [doi: 10.1038/s41598-022-12061-3] [Medline: 35577874]

65. Hashemi Y, Taghizadeh G, Azad A, Behzadipour S. The effects of supervised and non-supervised upper limb virtual reality exercises on upper limb sensory-motor functions in patients with idiopathic Parkinson's disease. Hum Mov Sci. Oct 2022;85:102977. [doi: 10.1016/j.humov.2022.102977] [Medline: 35932518]

66. Herz NB, Mehta SH, Sethi KD, Jackson P, Hall P, Morgan JC. Nintendo Wii rehabilitation ("Wii-hab") provides benefits in Parkinson's disease. Parkinsonism Relat Disord. Nov 2013;19(11):1039-1042. [doi: 10.1016/j.parkreldis.2013.07.014] [Medline: 23968649]

67. Holmes JD, Gu ML, Johnson AM, Jenkins ME. The effects of a home-based virtual reality rehabilitation program on balance among individuals with Parkinson's disease. Phys Occup Ther Geriatr. Sep 2013;31(3):241-253. [doi: 10.3109/02703181.2013.814743]

68.   Imbimbo I, Coraci D, Santilli C, et al. Parkinson's disease and virtual reality rehabilitation: cognitive reserve influences the walking and balance outcome. Neurol Sci. Nov 2021;42(11):4615-4621. [doi: 10.1007/s10072-021-05123-3] [Medline: 33661481]

69.   Jäggi S, Wachter A, Adcock M, et al. Feasibility and effects of cognitive-motor exergames on fall risk factors in typical and atypical Parkinson's inpatients: a randomized controlled pilot study. Eur J Med Res. Jan 16, 2023;28(1):30. [doi: 10.1186/s40001-022-00963-x] [Medline: 36647177]

70.   Kashif M, Ahmad A, Bandpei MAM, Syed HA, Raza A, Sana V. A randomized controlled trial of motor imagery combined with virtual reality techniques in patients with Parkinson's disease. J Pers Med. Mar 12, 2022;12(3):450. [doi: 10.3390/jpm12030450] [Medline: 35330450]

71.   Kashif M, Ahmad A, Bandpei MAM, Gilani SA, Hanif A, Iram H. Combined effects of virtual reality techniques and motor imagery on balance, motor function and activities of daily living in patients with Parkinson's disease: a randomized controlled trial. BMC Geriatr. Apr 30, 2022;22(1):381. [doi: 10.1186/s12877-022-03035-1] [Medline: 35488213]

72.   Lau J, Regis C, Burke C, Kaleda MJ, McKenna R, Muratori LM. Immersive technology for cognitive-motor training in Parkinson's disease. Front Hum Neurosci. 2022;16:863930. [doi: 10.3389/fnhum.2022.863930] [Medline: 35615742]

73.   Lee NY, Lee DK, Song HS. Effect of virtual reality dance exercise on the balance, activities of daily living, and depressive disorder status of Parkinson's disease patients. J Phys Ther Sci. Jan 2015;27(1):145-147. [doi: 10.1589/jpts. 27.145] [Medline: 25642060]

74.   Liao YY, Yang YR, Cheng SJ, Wu YR, Fuh JL, Wang RY. Virtual reality-based training to improve obstacle-crossing performance and dynamic balance in patients with Parkinson's disease. Neurorehabil Neural Repair. Aug 2015;29(7):658-667. [doi: 10.1177/1545968314562111] [Medline: 25539782]

75.   Liao YY, Yang YR, Wu YR, Wang RY. Virtual reality-based Wii Fit training in improving muscle strength, sensory integration ability, and walking abilities in patients with Parkinson's disease: a randomized control trial. Int J Gerontol. Dec 2015;9(4):190-195. [doi: 10.1016/j.ijge.2014.06.007]

76.   Maranesi E, Casoni E, Baldoni R, et al. The effect of non-immersive virtual reality exergames versus traditional physiotherapy in Parkinson's disease older patients: preliminary results from a randomized-controlled trial. Int J Environ Res Public Health. Nov 10, 2022;19(22):14818. [doi: 10.3390/ijerph192214818] [Medline: 36429537]

77.   Mazur A, Pietraszko W, Krygowska-Wajs A. Visual feedback training using WII Fit improves balance in Parkinson's disease. Folia Med Cracov. 2013;LIII(1):65-78.

78.   Melo G, Kleiner AFR, Lopes J, et al. P100 - effects of virtual reality training on mobility in individuals with Parkinson's disease. Gait Posture. Sep 2018;65:394-395. [doi: 10.1016/j.gaitpost.2018.06.071]

79.   Mhatre PV, Vilares I, Stibb SM, et al. Wii Fit balance board playing improves balance and gait in Parkinson disease. PM R. Sep 2013;5(9):769-777. [doi: 10.1016/j.pmrj.2013.05.019] [Medline: 23770422]

80.   Mirelman A, Maidan I, Herman T, Deutsch JE, Giladi N, Hausdorff JM. Virtual reality for gait training: can it induce motor learning to enhance complex walking and reduce fall risk in patients with Parkinson's disease? J Gerontol A Biol Sci Med Sci. Feb 2011;66(2):234-240. [doi: 10.1093/gerona/glq201] [Medline: 21106702]

81.   Mirelman A, Rochester L, Maidan I, et al. Addition of a non-immersive virtual reality component to treadmill training to reduce fall risk in older adults (V-TIME): a randomised controlled trial. Lancet. Sep 17, 2016;388(10050):1170-1182. [doi: 10.1016/S0140-6736(16)31325-3] [Medline: 27524393]

82.   Negrini S, Bissolotti L, Ferraris A, Noro F, Bishop MD, Villafañe JH. Nintendo Wii Fit for balance rehabilitation in patients with Parkinson's disease: a comparative study. J Bodyw Mov Ther. Jan 2017;21(1):117-123. [doi: 10.1016/j. jbmt.2016.06.001] [Medline: 28167167]

83.   Nuic D, Vinti M, Karachi C, Foulon P, Van Hamme A, Welter ML. The feasibility and positive effects of a customised videogame rehabilitation programme for freezing of gait and falls in Parkinson's disease patients: a pilot study. J Neuroeng Rehabil. Apr 10, 2018;15(1):31. [doi: 10.1186/s12984-018-0375-x] [Medline: 29636105]

84.   Nuic D, van de Weijer S, Cherif S, et al. Home-based exergaming to treat gait and balance disorders in patients with Parkinson's disease: a phase II randomized controlled trial. Eur J Neurol. Jan 2024;31(1):e16055. [doi: 10.1111/ene. 16055] [Medline: 37691341]

85.   Oña ED, Balaguer C, Cano-de la Cuerda R, Collado-Vázquez S, Jardón A. Effectiveness of serious games for leap motion on the functionality of the upper limb in Parkinson's disease: a feasibility study. Comput Intell Neurosci. 2018;2018:7148427. [doi: 10.1155/2018/7148427] [Medline: 29849550]

86.   Özgönenel L, Çağırıcı S, Çabalar M, Durmuşoğlu G. Use of game console for rehabilitation of Parkinson's disease. Balkan Med J. Jul 2016;33(4):396-400. [doi: 10.5152/balkanmedj.2016.16842] [Medline: 27606134]

87.   Palacios-Navarro G, García-Magariño I, Ramos-Lorente P. A kinect-based system for lower limb rehabilitation in Parkinson's disease patients: a pilot study. J Med Syst. Sep 2015;39(9):103. [doi: 10.1007/s10916-015-0289-0] [Medline: 26265237]

88. Pastore-Wapp M, Kaufmann BC, Nyffeler T, Wapp S, Bohlhalter S, Vanbellingen T. Feasibility of a combined intermittent theta-burst stimulation and video game-based dexterity training in Parkinson's disease. J Neuroeng Rehabil. Jan 12, 2023;20(1):2. [doi: 10.1186/s12984-023-01123-w] [Medline: 36635679]

89. Pazzaglia C, Imbimbo I, Tranchita E, et al. Comparison of virtual reality rehabilitation and conventional rehabilitation in Parkinson's disease: a randomised controlled trial. Physiotherapy. Mar 2020;106:36-42. [doi: 10.1016/j.physio.2019.12.007] [Medline: 32026844]

90. Pelosin E, Ponte C, Putzolu M, et al. Motor-cognitive treadmill training with virtual reality in Parkinson's disease: the effect of training duration. Front Aging Neurosci. 2021;13:753381. [doi: 10.3389/fnagi.2021.753381] [Medline: 35069171]

91. Pompeu JE, Mendes F, Silva K da, et al. Effect of Nintendo WiiTMBased motor and cognitive training on activities of daily living in patients with Parkinson's disease: a randomised clinical trial. Physiotherapy. Sep 2012;98(3):196-204. [doi: 10.1016/j.physio.2012.06.004] [Medline: 22898575]

92. Pompeu JE, Arduini LA, Botelho AR, et al. Feasibility, safety and outcomes of playing Kinect Adventures! Physiotherapy. Jun 2014;100(2):162-168. [doi: 10.1016/j.physio.2013.10.003] [Medline: 24703891]

93. Pompeu JE, Torriani-Pasin C, Doná F, Ganança FF, da Silva KG, Ferraz HB. Effect of kinect games on postural control of patients with parkinson's disease. Presented at: REHAB '15. Association for Computing Machinery. 54-57; Lisbon Portugal. Oct 2015.URL: https://dl.acm.org/doi/proceedings/10.1145/2838944 [doi: 10.1145/2838944.2838958]

94. Pullia M, Ciatto L, Andronaco G, et al. Treadmill training plus semi-immersive virtual reality in Parkinson's disease: results from a pilot study. Brain Sci. Sep 12, 2023;13(9):37759913. [doi: 10.3390/brainsci13091312] [Medline: 37759913]

95. Puyjarinet F, Bégel V, Geny C, et al. At-home training with a rhythmic video game for improving orofacial, manual, and gait abilities in Parkinson's disease: a pilot study. Front Neurosci. 2022;16:874032. [doi: 10.3389/fnins.2022.874032] [Medline: 35769698]

96. Qayyum S, Hashmi Z, Waqas S, Tariq M, Mughal MW, Tanvir M. Effects of exer–gaming on balance and gait in Parkinson's patients. PJMHS. Dec 30, 2022;16(12):213-214. URL: https://pjmhsonline.com/index.php/pjmhs/issue/view/11 [doi: 10.53350/pjmhs20221612213]

97. Ribas CG, Alves da Silva L, Corrêa MR, Teive HG, Valderramas S. Effectiveness of exergaming in improving functional balance, fatigue and quality of life in Parkinson's disease: a pilot randomized controlled trial. Parkinsonism Relat Disord. May 2017;38:13-18. [doi: 10.1016/j.parkreldis.2017.02.006] [Medline: 28190675]

98. Sánchez-Herrera-Baeza P, Cano-de-la-Cuerda R, Oña-Simbaña ED, et al. The impact of a novel immersive virtual reality technology associated with serious games in Parkinson's disease patients on upper limb rehabilitation: a mixed methods intervention study. Sensors (Basel). Apr 11, 2020;20(8):2168. [doi: 10.3390/s20082168] [Medline: 32290517]

99. Santos P, Machado T, Santos L, Ribeiro N, Melo A. Efficacy of the Nintendo Wii combination with conventional exercises in the rehabilitation of individuals with Parkinson's disease: a randomized clinical trial. NeuroRehabilitation. 2019;45(2):255-263. [doi: 10.3233/NRE-192771] [Medline: 31498138]

100. Schaeffer E, Busch JH, Roeben B, et al. Effects of exergaming on attentional deficits and dual-tasking in Parkinson's disease. Front Neurol. 2019;10(JUN):646. [doi: 10.3389/fneur.2019.00646] [Medline: 31275234]

101. Severiano MIR, Zeigelboim BS, Teive HAG, Santos GJB, Fonseca VR. Effect of virtual reality in Parkinson's disease: a prospective observational study. Arq Neuropsiquiatr. Feb 2018;76(2):78-84. [doi: 10.1590/0004-282X20170195] [Medline: 29489960]

102. Shih MC, Wang RY, Cheng SJ, Yang YR. Effects of a balance-based exergaming intervention using the Kinect sensor on posture stability in individuals with Parkinson's disease: a single-blinded randomized controlled trial. J Neuroeng Rehabil. Aug 27, 2016;13(1):78. [doi: 10.1186/s12984-016-0185-y] [Medline: 27568011]

103. Song J, Paul SS, Caetano MJD, et al. Home-based step training using videogame technology in people with Parkinson's disease: a single-blinded randomised controlled trial. Clin Rehabil. Mar 2018;32(3):299-311. [doi: 10.1177/0269215517721593] [Medline: 28745063]

104. Summa S, Basteris A, Betti E, Sanguineti V. Adaptive training with full-body movements to reduce bradykinesia in persons with Parkinson's disease: a pilot study. J Neuroeng Rehabil. Feb 14, 2015;12(1):16. [doi: 10.1186/s12984-015-0009-5] [Medline: 25885094]

105. Syed UE, Kamal A. Video game-based and conventional therapies in patients of neurological deficits: an experimental study. Disabil Rehabil Assist Technol. Apr 2021;16(3):332-339. [doi: 10.1080/17483107.2019.1679266] [Medline: 31684776]

106. van den Heuvel MRC, Kwakkel G, Beek PJ, Berendse HW, Daffertshofer A, van Wegen EEH. Effects of augmented visual feedback during balance training in Parkinson's disease: a pilot randomized clinical trial. Parkinsonism Relat Disord. Dec 2014;20(12):1352-1358. [doi: 10.1016/j.parkreldis.2014.09.022] [Medline: 25283070]

107. van Beek JJW, van Wegen EEH, Bohlhalter S, Vanbellingen T. Exergaming-based dexterity training in persons with Parkinson disease: a pilot feasibility study. J Neurol Phys Ther. Jul 2019;43(3):168-174. [doi: 10.1097/NPT. 0000000000000278] [Medline: 31136450]

108. van der Kolk NM, de Vries NM, Kessels RPC, et al. Effectiveness of home-based and remotely supervised aerobic exercise in Parkinson's disease: a double-blind, randomised controlled trial. Lancet Neurol. Nov 2019;18(11):998-1008. [doi: 10.1016/S1474-4422(19)30285-6] [Medline: 31521532]

109. Wang YW, Chen CH, Lin YC. Balance rehabilitation system for parkinson's disease patients based on augmented reality. Presented at: 2020 IEEE Eurasia Conference on IOT, Communication and Engineering (ECICE); Oct 23-25, 2020:191-194; Yunlin, Taiwan. URL: https://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=9301908 [doi: 10. 1109/ECICE50847.2020.9302018]

110. Yang WC, Wang HK, Wu RM, Lo CS, Lin KH. Home-based virtual reality balance training and conventional balance training in Parkinson's disease: a randomized controlled trial. J Formos Med Assoc. Sep 2016;115(9):734-743. [doi: 10. 1016/j.jfma.2015.07.012] [Medline: 26279172]

111. Yen CY, Lin KH, Hu MH, Wu RM, Lu TW, Lin CH. Effects of virtual reality-augmented balance training on sensory organization and attentional demand for postural control in people with Parkinson disease: a randomized controlled trial. Phys Ther. Jun 2011;91(6):862-874. [doi: 10.2522/ptj.20100050] [Medline: 21474638]

112. Yuan RY, Chen SC, Peng CW, Lin YN, Chang YT, Lai CH. Effects of interactive video-game-based exercise on balance in older adults with mild-to-moderate Parkinson's disease. J Neuroeng Rehabil. Jul 13, 2020;17(1):91. [doi: 10. 1186/s12984-020-00725-y] [Medline: 32660512]

113. Yun SJ, Hyun SE, Oh BM, Seo HG. Fully immersive virtual reality exergames with dual-task components for patients with Parkinson's disease: a feasibility study. J Neuroeng Rehabil. Jul 18, 2023;20(1):92. [doi: 10.1186/s12984-023-01215-7] [Medline: 37464349]

114. Zeigelboim BS, José MR, Severiano MIR, et al. The use of exergames in the neurorehabilitation of people with Parkinson disease: the impact on daily life. Int Arch Otorhinolaryngol. Jan 2021;25(1):e64-e70. [doi: 10.1055/s-0040-1702973] [Medline: 33542753]

115. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. Mar 29, 2021;372:n71. [doi: 10.1136/bmj.n71] [Medline: 33782057]

116. Hoehn MM, Yahr MD. Parkinsonism: onset, progression and mortality. Neurology (ECronicon). May 1967;17(5):427-442. [doi: 10.1212/wnl.17.5.427] [Medline: 6067254]

117. Caudron S, Guerraz M, Eusebio A, Gros JP, Azulay JP, Vaugoyeau M. Evaluation of a visual biofeedback on the postural control in Parkinson's disease. Neurophysiol Clin. Jan 2014;44(1):77-86. [doi: 10.1016/j.neucli.2013.10.134] [Medline: 24502908]

118. van Nuland AJ, Helmich RC, Dirkx MF, et al. Effects of dopamine on reinforcement learning in Parkinson's disease depend on motor phenotype. Brain (Bacau). Dec 5, 2020;143(11):3422-3434. [doi: 10.1093/brain/awaa335] [Medline: 33147621]

119. Steiner B, Elgert L, Saalfeld B, Wolf KH. Gamification in rehabilitation of patients with musculoskeletal diseases of the shoulder: scoping review. JMIR Serious Games. Aug 25, 2020;8(3):e19914. [doi: 10.2196/19914] [Medline: 32840488]

120. Chen Y. Exploring design guidelines of using user-centered design in gamification development: a delphi study. Int J Hum Comput Interact. Aug 9, 2019;35(13):1170-1181. [doi: 10.1080/10447318.2018.1514823]

121. Gregor P, Newell AF, Zajicek M. Designing for dynamic diversity. Presented at: ASSETS02; Jul 8-10, 2002:151-156; Edinburgh, Scotland.

122. Cunha B, Ferreira R, Sousa ASP. Home-based rehabilitation of the shoulder using auxiliary systems and artificial intelligence: an overview. Sensors (Basel). Aug 11, 2023;23(16):7100. [doi: 10.3390/s23167100] [Medline: 37631637]

123. Ernst M, Folkerts AK, Gollan R, et al. Physical exercise for people with Parkinson's disease: a systematic review and network meta-analysis. Cochrane Database Syst Rev. Jan 5, 2023;1(1):CD013856. [doi: 10.1002/14651858.CD013856. pub2] [Medline: 36602886]

Abbreviations

PD: Parkinson disease
PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews
VR: virtual reality