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NARRATIVE REVIEW

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An analysis of clinical outcomes and essential parameters for designing effective games for upper limb rehabilitation: A scoping review

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Abstract

Background and Aims: Upper limb disabilities are one of the most common disabilities among different groups of people who always need rehabilitation. One of the important methods in helping to carry out efficient rehabilitation processes and exercises is the use of games. The aim of this study is to identify the parameters necessary to design a successful rehabilitation game and the outcomes of using these games in upper limb disabilities rehabilitation.

Methods: This scoping review was conducted by searching the Web of Science, PubMed, and Scopus. The eligibility criteria were: any form of game-based upper limb rehabilitation, published in a peer-reviewed journal, published in English, and not include articles that did not focus upper limb disabilities rehabilitation games, review, meta-analysis, or conference papers. Analysis of collected data was done using descriptive statistics (frequency and percentage).

Results: The search strategy retrieved 537 relevant articles. Finally, after removing irrelevant and repetitive articles, 21 articles were included in this study. Among the six categories of diseases or complications of upper limb disabilities, games were mostly designed for stroke patients. Smart wearables, robots and telerehabilitation were three technologies that were used for rehabilitation along with games. Sports and shooters were the most used games for upper limb disability rehabilitation. Among 99 necessary parameters for designing and implementing a successful rehabilitation game in ten categories. “Increasing the patient's motivation to perform rehabilitation exercises”, “Game difficulty levels”, “Enjoying and the attractiveness of the game for patients”, and “Providing positive or negative audiovisual feedback” were the most important parameters. “Improvement in musculoskeletal performance” and “Increasing users' enjoyment/joy of therapeutic exercises and their motivation to perform these exercises” were the most important positive outcomes,

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and "Mild discomfort such as nausea and dizziness when using games" was the only negative outcome.

Conclusions: The successful design of a game according to the parameters identified in the present study can lead to an increase in the positive outcomes of using games in the rehabilitation of disabilities. The study results indicate that upper limb therapeutic exercise augmented with virtual reality games may be highly effective in enhancing motor rehabilitation outcomes.

KEYWORDS

game, rehabilitation, Upper limb, virtual reality (VR)

1 | INTRODUCTION

Upper limb (UL) disabilities are common problems that require rehabilitation.[1] These disabilities have attracted global attention, due to the high economic costs of health care and the negative impact on the performance of daily activities and affects patients' quality of life.[2] Moreover, patients with upper limb disabilities suffer anxiety, stress, impaired cognitive capacity, and modified mood as an outcome. This can hinder their capacity to act and actively participate in society.[3] Rehabilitation of the upper limb through various therapeutic exercises is the main approach used to restore the motor function and independence of these individuals.[4] Rehabilitation in different parts of the body, such as upper or lower limbs, aims to help patients to restore movement-functional disorders that affect their mobility.[1] In addition, Rehabilitation helps reduce or minimize the debilitating outcomes of chronic diseases or disabilities by equipping people with self-management methods and assistive products they need, or by determining pain or other complications.[5]

A therapist-led face-to-face approach to providing therapeutic exercises is a common practice, but it can be very costly and inconvenient due to the need for professional and organizational resources.[4] Moreover, many individuals with upper limb disabilities report multiple barriers to full participation in rehabilitation exercises, such as fatigue, very low motivation, depression, cost, and lack of social support.[6] Over the past two decades, researchers and therapists have turned to virtual reality (VR) and gaming technologies to rehabilitation in an attempt to address cost while increasing participation.[7] Virtual reality and video games have been helped to increase the pleasure of repetitive exercise programs and thereby aid adherence to treatment.[8] The use of virtual reality-based games as a supplement or alternative to traditional physical therapy has been studied and proven to be very effective in improving the functional rehabilitation of patients.[9] Several surveys[10–13] have confirmed the feasibility and potential effectiveness of games and virtual reality in improving motor performance of the upper limb, with promising results.

To our knowledge, various systematic review studies[1,14–16] have been conducted in relation to investigating the role of games in improving upper limb disabilities; However, none of these studies specifically focused on identify the parameters necessary to design a successful upper limb rehabilitation game and the outcomes of using these games. The aim of Koutsiana et al.'s[1] study was to assess the role of serious games in upper limb rehabilitation, and to identify common ways and practice, as well as explore the technologies used for upper limb rehabilitation. The results of this study showed that despite extensive efforts to develop gamified rehabilitation systems, there is no definitive answer on whether a serious game is a desirable means to improve upper limb function or not, so more studies should be done. Cortés-Pérez et al.,[14] measured the effect of video game-based therapy with Leap Motion Controller (LMC) on the improvement of upper limb motor function in patients with central nervous system disease (CNSD). Thomson et al.'s review[15] integrated evidence of how commercial games can be used for upper extremity rehabilitation, exploring patient/therapist experience and incorporating evidence of effectiveness. The results of this study showed that commercial games can provide high-intensity upper extremity training, however, there is insufficient high-quality evidence to draw generalizable conclusions. Proença et al.,[16] also explored therapist/patient experience and incorporating evidence of effectiveness, assessment of the effect of commercial gaming and identifying the game's adverse effects. This study stated that the use of serious games and game platforms for upper extremity rehabilitation has started a new paradigm in rehabilitation, and more studies are needed to fully integrate these technologies into rehabilitation. Therefore, the aim of our study is to identify the parameters necessary to design a successful rehabilitation game and the outcomes of using these games in upper limb disabilities rehabilitation.

2 | MATERIAL AND METHODS

In this review, we followed the PRISMA scoping reviews checklist (Supporting Information Appendix A) for the information sources and search strategy, eligibility criteria, study selection, data charting process and data items, data collation process, and synthesis of results.

2.1 | Information sources and search strategy

Due to the rapid development of technologies and rehabilitation games, we identify the newest necessary parameters to design a successful rehabilitation game and the outcomes of using these games in upper limb disabilities rehabilitation. Although several systematic review[14–16] and a scoping review[1] have been published up to 2020, the number of articles published in the last 2 years was considered sufficient to answer the questions of this research, because in the author's view, very recent developments were made in this area during that period. Therefore, this scoping review included articles published from January 2021 to September 2022. Web of Science, PubMed, and Scopus databases were used to find relevant articles. Keywords and search strategies used in all three databases are listed in the additional file (Supporting Information Appendix B, Table 1). It should be noted that to access the articles whose full text we did not have access to, we emailed the corresponding authors of the articles and requested them to send us the full text.

2.2 | Eligibility criteria

Table 1 shows the inclusion and exclusion criteria.

2.3 | Study selection

Two researchers separately performed the literature search, imported articles into EndNote and excluded duplicates; Then, two other researchers also reviewed and screened the titles and abstracts of the articles for eligibility. To extract the required information from the selected articles, according to the inclusion and exclusion criteria, the remaining articles were reviewed by two researchers. Any disagreements regarding each of the articles were resolved through discussion between the authors until a final agreement was reached.

2.4 | Data charting process and data items

To obtain the data, a form created by the researchers was utilized. The validity of this form was confirmed by two experts in medical informatics and health information management. This form includes various fields such as country, publication year, the aim of the study, the disease leading to upper limb disability, the specific upper limb part affected by the disability, the technology used with games (robotics or smart wearables), the use of telerehabilitation, the name of the game, the game scenario or story, the software used for game design (as shown in Table 2, Figure 1, and Supporting Information Appendix C–E), the necessary parameters for designing and implementing a successful rehabilitation game (as shown in Table 3), and the outcomes of using upper limb rehabilitation games (as shown in Table 4).

2.5 | Data collation process

Once the articles were approved in the previous stages, the full texts were examined independently by three researchers to extract information. The extracted information was recorded in a data extraction form by the same three researchers. Next, two researchers reviewed the information extracted from the articles separately, and the third author confirmed the final results. In cases of disagreement, the research team members held a meeting to make a final decision. Finally, the extracted information was imported into an Excel spreadsheet.

2.6 | Synthesis of results

Data were qualitatively classified (frequency and percentage) after importing the Excel file. Then, the results of different sections were reported. To synthesize data, we used the progression bounding method recommended by Levac et al.,[38] Since scoping reviews do not summarize or measure evidence from studies,[38,39] in our study only descriptive analyses (such as frequency and percentage) were performed on the extracted data to describe the findings of the included studies.[40] The descriptive data and findings of all included articles were organized in the format of tables and figures based on themes to present the findings of the present study, which guided the objectives of the study. In case of disagreement by any of the authors, the final decision about each figure or table was reached through discussion.

TABLE 1 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
1. Any form of upper limb disabilities rehabilitation game (interactive computer-based game, mobile/tablet app, or platform game software) **2.** Articles published in English	**1.** Articles that did not focus upper limb disabilities rehabilitation game **2.** Upper limb rehabilitation game without any outcomes or introduction of necessary parameters for game design **3.** Books and book chapter **4.** A review and, meta-analysis **5.** Conference papers **6.** Study protocol

TABLE 2 Overview of articles included in the study.

Author(s)	Year	Country	Aim of the study	Disease leading to upper limb disability	Specific upper limb part affected by the disability	Technology used with games		Use of Telerehabilitation
						Robot	Smart wearables	
Burdea[17]	2021	USA	Design and evaluation of the usability of a virtual rehabilitation system for the training of arm disabilities	Stroke	Arms and finger	√		
Escalante-Gonzalbo[18]	2021	México	Validating the feasibility, safety and acceptability of a virtual rehabilitation platform in patients with upper limb hemiparesis after stroke	Stroke	Arm, hand, shoulder, elbow, forearm, and wrist			√
Ersoy[19]	2021	Turkey	Comparing the effect of real and virtual boxing training on neurodevelopmental therapy on upper limb, cognitive functions and balance in stroke patients	Stroke	UL			
Borrego[20]	2021	México	Evaluating the usability and user experience of using a serious video game for upper extremity motor rehabilitation and cognitive stimulation of the elderly.	Older age	UP			√
Phelan[21]	2021	United Kingdom	Exploring perceptions and impacts of a custom-made, fully immersive VR experience for children with Upper Limb Injuries (ULIs)	Injuries caused by daily activities	Shoulder, elbow and Wrist			
Rodriguez-Hernandez[22]	2021	Spain	Investigating the effects of conventional rehabilitation and virtual reality on the improvement of motor function of the upper limbs of individuals with stroke	Stroke	UL			
Tresser[23]	2021	Israel	Investigating the effectiveness of virtual games to support the rehabilitation of children with CP	cerebral palsy (CP)	UL	√		
Szturm[24]	2021	Canada	Investigating the feasibility and acceptability of a home therapeutic exercise game in upper limb rehabilitation of individuals with stroke	Stroke	Hand and arm			√
Lee[25]	2021	Taiwan	Designing an upper extremity motor training system based on virtual reality for the rehabilitation of stroke patients	Stroke	Elbows, arms, shoulders			
Hung[26]	2021	Chicago	Assessing the tolerability and feasibility of a high-dose rehabilitation game in chronic stroke survivors	Stroke	UL		√	√
Hernandez[27]	2021	Canada	Investigating the effectiveness of interactive rehabilitation game with tactile feedback in improving the arm function of children with cerebral palsy	CP	Wrist and Elbow/shoulder			
Hashim[28]	2021	Malaysia	Investigating the effects of rehabilitation video games on muscle coordination and preparation and motivation of patients with upper limb amputation	Amputation	UL		√	

TABLE 2 (Continued)

Author(s)	Year	Country	Aim of the study	Disease leading to upper limb disability	Specific upper limb part affected by the disability	Technology used with games		Use of Telerehabilitation
						Robot	Smart wearables	
Garcia-Hernandez[29]	2021	Mexico	Investigating the subjective experiences of seeing and controlling an avatar or an abstract hand representation in an immersive virtual environment for training CP children's upper limb movements	CP	UL			
Chen[30]	2021	Taiwan	Development and feasibility evaluation of a virtual reality-based rehabilitation program for children with cerebral palsy	CP	UL			
Allegue[31]	2021	Canada	Feasibility evaluation of a virtual reality-based rehabilitation system for telerehabilitation of upper limb disability of chronic stroke survivors	Stroke	UL			√
Astrakas[32]	2021	USA	Investigating the usefulness and effectiveness of a robot-assisted treatment in combination with a serious game as a rehabilitation tool in improving the movement status of chronic stroke patients.	Stroke	UL		√	
Avcil[33]	2021	Turkey	Comparing the effects of neurodevelopmental rehabilitation therapy and game-based therapy and jumping movement controller on upper limb function in patients with cerebral palsy	CP	Elbow and shoulder			√
Chau[34]	2021	China	Evaluation of acceptance, effectiveness and feasibility of virtual reality-based training among elderly people with upper limb disabilities	Older age	Arm and shoulder	√		
Baluz[35]	2022	Brazil	Design and usability evaluation of a serious game in motor rehabilitation of upper limb patients with rotator cuff syndrome and stroke	Rotator cuff syndrome and Stroke	UL			√
Baniña[36]	2022	Canada	Investigating the effect of a virtual reality program on upper extremity exercise intensity among patients with different levels of UL sensorimotor impairment	Stroke	Arm, shoulder, and elbow			
Herne[37]	2022	Australia	Investigating the effect of a serious game based on virtual reality in upper limb rehabilitation of stroke survivors	Stroke	UL			

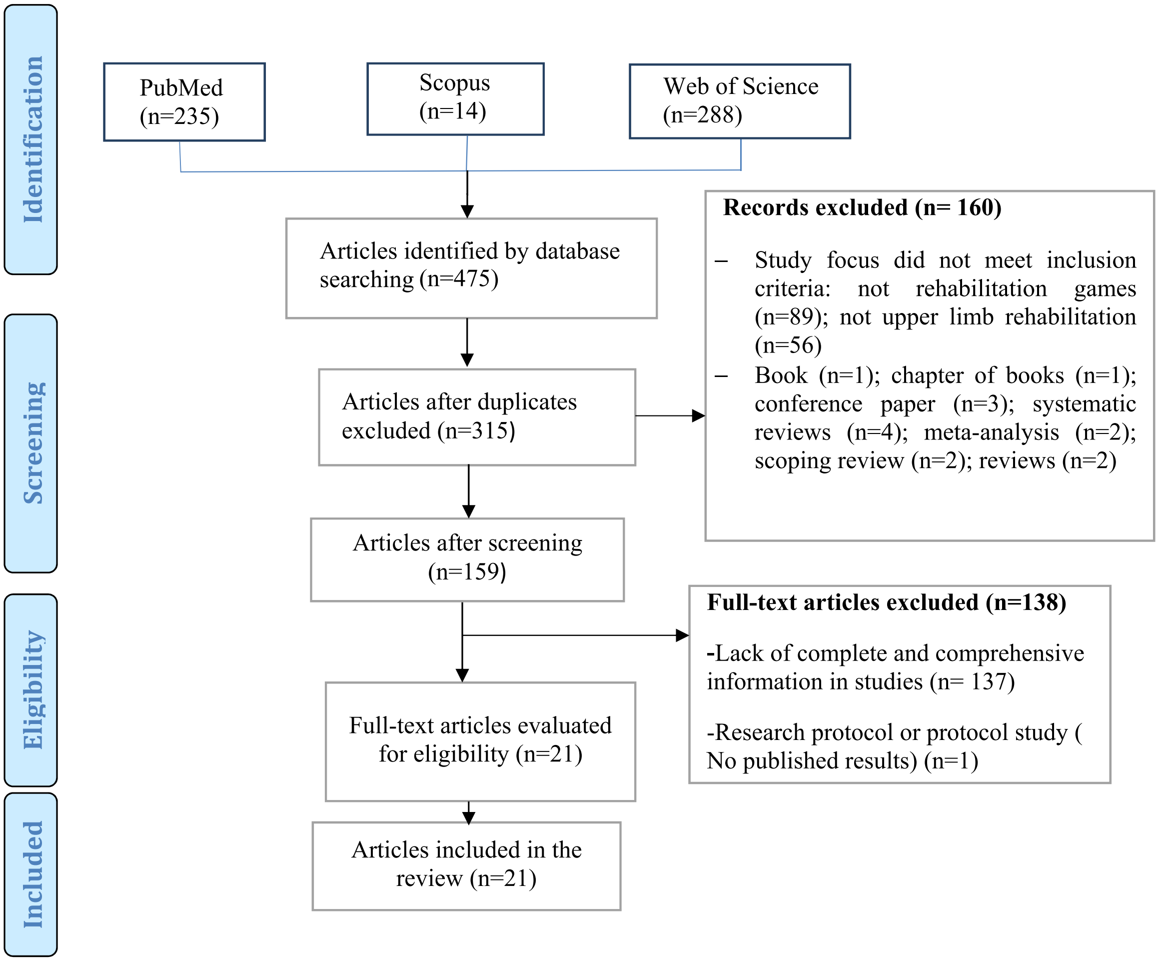

FIGURE 1 Study selection process.

2.7 | Ethical considerations

The protocol of this study was approved by ethical committee of Kerman University of Medical Sciences) IR.KMU.REC.1400.606).

3 | RESULTS

3.1 | Selection of sources of evidence

After searching, 537 related articles were retrieved. After excluding the duplicates, the remaining 475 articles were carefully reviewed and evaluated based on the inclusion and exclusion criteria.

Most of the studies were done in Canada ($n = 4$, 19%)[24,27,31,36] and México (n = 3, 14%),[18,20,29] respectively. Turkey,[19,33] Taiwan,[25,30] Malaysia,[28] and China[34] were the only Asian countries that focused on upper limb disabilities rehabilitation games.

According to Figure 2, games was used to six categories of diseases or complications leading to upper limb disabilities. Games were mostly used to rehabilitate upper limb disabilities caused by strokes ($n = 12$)[17–19,22,24–26,31,32,35–37] and cerebral palsy ($n = 5$).[23,27,29,30,33] The frequencies and percentages of other diseases and injuries leading to upper limb disabilities are shown in Figure 2.

Robots ($n = 3$)[17,23,34] and smart wearables ($n = 3$)[26,28,32] were two types of technology that were used for the rehabilitation of upper limb disabilities along with games. Moreover, seven studies[18,20,24,26,31,33,35] provided their rehabilitation services as telerehabilitation.

Most of the games were designed using Unity software ($n = 6$).[18,20,23,25,29,30] Unreal Engine 4.20, 3ds Max, Substance Designer,[21] Blender,[26] and Microsoft Visual C++[32] were other software used to design rehabilitation games. Some studies also used pre-designed games ($n = 4$).[22,27,28,35]

Supporting Information Appendix E shows different types of games for the rehabilitation of upper limb disabilities. The most types of games that were designed for rehabilitation of upper limb disabilities were sports games ($n = 14$) and shooters ($n = 7$). The studies mostly focused on the design of games such as balloons rescuer, soccer, and boxing.

Supporting Information Appendix D shows the frequency of games based on the type of illness or injury. Most of the games were designed for stroke and cerebral palsy patients. Only one type of

TABLE 3 Necessary parameters for designing and implementing a successful rehabilitation game.

Design dimensions of a game	Required parameters for each dimension	References	Parameters frequency based on the number of references
Emotional entailment and motivation	Increasing the patient's motivation to perform rehabilitation exercises (e.g., using attractive and serious challenges in the game to maximize the effort and motivation of the patient)	14	17–19,21,26–32,34,35,37
	Enjoying and the attractiveness of the game for patients (e.g., encouraging patients with emojis and cartoons)	8	19–21,24,26,28,30,37
	Not discouraging users when they are unable to do a certain task in the game	2	17,20
	Game entertaining for users	2	18,35
	Increasing the patient's effort to perform therapeutic exercises	1	26
	Perspicuity and clarity of the game for users	1	35
	Psychological absorption of the user by adding music or humor etc. to the game	1	37
Aesthetic aspects and effects	Fantasy and attractive background music and soundtrack in the game	5	23,31,32,34,35
	Esthetics and sensory appeal of the game for users	2	20,35
	Using attractive colors in games	2	20,31
	Attractive visual effects or adding humor for psychological absorption of the user	1	37
	Using interactive and playful components	1	35
Feedback	Providing positive or negative audiovisual feedback	8	17,20,26,30–32,34,37
	Presenting the total score to the user at the end of the game	2	30,37
	Presenting the obstacles and rewards in each game (e.g., providing visual and audio congratulatory messages when the user succeeds in the game)	2	17,32
	Providing the result charts to show patient progress during different treatment sessions	1	22
	Providing game scores to users in different stages of the game	1	37
	Repeated comparison of scores in each stage of the game and presenting the results to users	1	37
	Provide a warning or message for each failed user attempt	1	31
	Visualization of user progress (It is determined by the therapist by changing the size of the target after a certain number of hits or misses.)	1	23
	Providing feedback to users about errors and their reasons	1	17
Game elements and content	Game difficulty levels	12	17–25,30,34,36
	Game components and flow or mechanisms (including the shape of game objects (line, circle, triangle and square), speed, supporting sounds and images)	5	31–33,36,37
	Sound effects and background graphics	5	23,31,32,34,35
	Failures and successes in the game	4	22,23,25,36
	Aims of games	4	17,20,23,37
	Story and scenario of the game	2	32,37
	The number of objects in the game	2	18,36

(Continues)

TABLE 3 (Continued)

Design dimensions of a game	Required parameters for each dimension	References	Parameters frequency based on the number of references
	Challenges used in the game	2	17,37
	Size of the target object	2	23,33
	Target size reduction as patient progresses	2	23,26
	Competitive/cooperative feature of game	2	20,30
	Repetitive exercises and tasks in games	2	30,33
	Number of distractors and visual aids (arrows indicating whether the obstacle appears on one side of the screen or not.)	1	22
	Game characters	1	34
	Number of game inputs (eg, wrist extension in case of wrist games)	1	27
	Amount of change in target size or dwell time on it	1	23
	Minimizing costs such as mechanical energy expenditure	1	29
	Game accuracy	1	24
	Game precision	1	24
	Initial target size	1	23
	Intensity of training to users	1	30
	Guide the player or user to the goal	1	30
	Number of repetitions of each exercise in the game	1	19
	Efficiency (doing tasks without unnecessary effort)	1	35
	Dependability (Feeling in control)	1	35
	Novelty of the game	1	35
	Provide a guide in the form of images, words and sounds as guides to help users understand the game easily	1	34
	Instructions on hand movement rhythms, how to sit and breathe while playing	1	37
	Instructions on how to use healthy hands	1	37
	Endurability (It is specified by the therapist by changing the target size after a definite number of hits or misses)	1	20
Game times and speeds	Duration of Game	4	17,19,22,27
	Intensity of play as repetitions/minute	3	17,31,36
	Game speed	3	18,24,32
	Initial target delay time (i.e., time between successive appearances, target movement (moving/static, background color)	2	23,36
	Display time, and the speed of the target (if the target moves on the screen)	1	23
	Speed of the game's reaction to the actions of the patient	1	19
	Necessary time to perform and complete an exercise	1	31
	Determining the exact time of the patient's reaction to each action (e.g., from when the patient successfully catches the ball to when he has to hit the target)	1	25
	Start point of the game's difficulty level	1	22

TABLE 3 (Continued)

Design dimensions of a game	Required parameters for each dimension	References	Parameters frequency based on the number of references
	Timing of the game and its stages	1	17
	Appearing speed of objects in the game	1	18
	Duration of each practice in the games	1	35
Ease of use	Convenience and ease of gam for players	4	18,20,21,37
	Customization of the game and setting of its parameters by patients and therapists for its comfortable use	4	18,20,22,23
	Game design according to users' needs and preferences	3	24,33,36
	Perspicuity and simplicity of the game (It is very easy for users to understand the proposed game.)	1	35
	Set guidelines for progress in the game	2	36,37
	Lowering the difficulty level of the game after improving the patient's performance	1	26
	Increase and/or decrease the difficulty level of the game based on how far the user is from the target	1	26
	Selection of various difficulty levels in a game by the therapist for the patient	2	17,30
Game player or user	Having different levels in the game for different age groups	2	20,30
	User profile	1	23
	Adapting the game to different parts of the patient's upper limb to move left and right	1	25
	Adapting the game to different parts of the patient's upper limb to move up and down	1	25
	Game design based on the used or dominant hand of the player (right or left)	1	35
	Type of interaction between players and the game	1	29
	Considering the needs and abilities of patients or players in game design	1	27
	Reducing pressure or tension in players	1	28
	Player safety	1	30
	Perceived choice by patient	1	28
	Muscle preparation of the players	1	28
	Increasing participant's autonomy	1	31
	Display the player's skeleton on the screen during the game to increase awareness, feedback, and better patient interaction with the game	1	37
	Providing game information to users	1	32
	Reduce users' dizziness and nausea while playing by eliminating or minimizing agile body and head movements	1	34
	Playback of a game for the therapist to see a patient play again	1	23
Movements, angles and paths	Determining the range of motion of each joint and different parts of the upper limb	2	22,24
	Side and height of target objects in game	2	35,36

(Continues)

TABLE 3 (Continued)

Design dimensions of a game	Required parameters for each dimension	References	Parameters frequency based on the number of references
	Angles of rotation and movement of different parts of the upper body	1	25
	Viewing angle of the virtual environment	1	29
	Precision of object s movement	1	36
	Predicting the next moves in the game after every move by the user	1	18
	Direction of movements in the game in the form of horizontal, vertical, diagonal or combined lines	1	18
	Number of repetitions of moving different parts of the upper limb	1	17
	Location of objects drop (center, left, right)	1	36
	Kinetic measures (such as forces and energy consumption)	1	29
Game help	Providing a document of frequently asked questions (FAQ) in the game to help solve problems	1	37
	Providing professional advice on illness or disability in game	1	37

game was designed for rotator cuff syndrome (shooters game) and injuries caused by daily activities (sport game).

As Table 3 shows, a total of 99 necessary parameters for designing and implementing a successful rehabilitation game in 10 categories: “Emotional entailment and motivation,” “Aesthetic aspects and effects,” “Feedback,” “Game elements and content,” “Game times and speeds,” “Ease of use,” “Game rules,” “Game player or user,” “Movements, angles and paths,” and “Game help” were detected. “Increasing the patient's motivation to perform rehabilitation exercises,” “Game difficulty levels,” “Enjoying and the attractiveness of the game for patients,” and “Providing positive or negative audiovisual feedback” were the most frequent.

Thirteen different outcomes (positive and negative) were identified in relation to the use of games for the rehabilitation of upper limb disabilities (Table 4). “Improvement in musculoskeletal performance” and “Increasing users' enjoyment/joy of therapeutic exercises and their motivation to perform these exercises” were the most important positive outcomes. “Mild discomfort such as nausea and dizziness when using games” was also the only negative outcome identified.

Patients with stroke had mostly experienced positive outcomes. The only negative outcome was for disabilities due to old age and the use of robot technology. The least positive outcomes were related to individuals whose disabilities were caused by injuries caused by daily activities. Furthermore, patients who used telerehabilitation services and robot technology had the most positive outcomes compared to those who used wearables. Also, according to the last column of the table, it can be said that most of the outcomes have been caused by the use of technologies along with games and not only the use of games.

4 | DISCUSSION

In this study, necessary parameters to design a successful rehabilitation game and the outcomes of using these games in upper limb disabilities rehabilitation were identified. Smart wearables, robots, and telerehabilitation were used alongside games to rehabilitate upper limb disabilities. Ninety-nine necessary parameters for designing and implementing a successful rehabilitation game in 10 categories were identified. The most important positive outcomes were “Improvement in musculoskeletal performance” and “Increasing users' enjoyment/joy of therapeutic exercises and their motivation to perform these exercises.” “Mild discomfort such as nausea and dizziness when using games” was also the only negative outcome.

In this review, “Increasing the patient's motivation to perform rehabilitation exercises,” “Game difficulty levels,” “Enjoying and the attractiveness of the game for patients,” and “Providing positive or negative audiovisual feedback” were the most important parameters identified. Various studies[41,42] have shown that designing a successful game for rehabilitation requires careful consideration of several key parameters. Increasing the patient's motivation to perform rehabilitation exercises is essential, as patients who are motivated to engage in rehabilitation are more likely to comply with their treatment regimen.[43] One way to achieve this is by making the game fun and engaging, which can be achieved through various means such as adding rewards or incentives, making the game competitive or collaborative, and incorporating social interaction elements.[2] Neuroscience research has shown that the release of dopamine and activity in the nucleus accumbens, a region of the brain associated with reward-based learning and motivation, can be increased by the efficient and successful design of a game.[43] In addition, it is essential to ensure that the game is challenging but not too difficult for the

TABLE 4 Outcomes of using upper limb rehabilitation games.

Positive outcomes	References	Outcomes frequency based on the number of references	Positive outcomes based on the type of illness or injury: Stroke (frequency of included studies = 12)	Cerebral palsy (frequency of included studies = 5)	Older age (fequency of included studies = 2)	Rotator cuff syndrome (frequency of included studies = 1)	Amputation (frequency of included studies = 1)	Injuries caused by daily activities (frequency of included studies = 1)	Outcomes frequency based on technologies used with games: Robots (frequency of included studies = 3)	Smart wearables (frequency of included studies = 3)	Telerehabilitation (frequency of included studies = 7)	Frequency of games without using technologies
Improvement in musculoskeletal performance (musculoskeletal strength and coordination, balance, sensation, perception, flexibility and range of motion)	17–19,21–28,30–33	15	✓ 17–19,22,24–26,31,32 (*n* = 9)	✓ 23,27,30,33 (*n* = 4)	✓ 20 (*n* = 1)		✓ 28 (*n* = 1)	✓ 21 (*n* = 1)	✓ 17,23 (*n* = 1)	✓ 26,28,32 (*n* = 3)	✓ 18,24,33 (*n* = 3)	8
Increasing users' enjoyment/joy of therapeutic exercises and their motivation to perform these exercises	17,18,20,21,24,26,28–30,35,37	11	✓ 17,18,24,26,37 (*n* = 5)	✓ 30 (*n* = 1)	✓ 20,29 (*n* = 2)	✓ 35 (*n* = 1)	✓ 28 (*n* = 1)	✓ 21 (*n* = 1)	✓ 17 (*n* = 1)	✓ 26,28 (*n* = 2)	✓ 18,20,24,26,35 (*n* = 5)	3
Usefulness	17,27,28	3	✓ 17 (*n* = 1)	✓ 27 (*n* = 1)	-	-	✓ 28 (*n* = 1)	-	✓ 17 (*n* = 1)	✓ 28 (*n* = 1)	-	1
Ease of use or usability and ease of learning	17,20,23	3	✓ 17 (*n* = 1)	✓ 23 (*n* = 1)	✓ 20 (*n* = 1)	-	-	-	✓ 17,23 (*n* = 1)	-	✓ 20 (*n* = 1)	1
Therapy compliance and acceptability by patients	20,30,34	3	✓ 26 (*n* = 1)	✓ 30 (*n* = 1)	✓ 20,34 (*n* = 1)	-	-	-	✓ 34 (*n* = 1)	-	✓ 20 (*n* = 1)	1
Increasing adherence to treatment and performing rehabilitation exercises	24,26,28	3	✓ 24,26 (*n* = 2)	-	-	-	✓ 28 (*n* = 1)	-	✓ 26 (*n* = 1)	✓ 28 (*n* = 1)	✓ 24,26 (*n* = 2)	0

(Continues)

TABLE 4 (Continued)

Positive outcomes	References	Outcomes frequency based on the number of refer-ences	Positive outcomes based on the type of illness or injury						Outcomes frequency based on technologies used with games			Frequency of games without using technologies
			Stroke (frequency of included studies = 12)	Cerebral palsy (frequency of included studies = 5)	Older age (fequency of included studies = 2)	Rotator cuff syndrome (frequency of included studies = 1)	Amputation (frequency of included studies = 1)	Injuries caused by daily activities (frequency of included studies = 1)	Robots (frequency of included studies = 3)	Smart wearables (frequency of included studies = 3)	Telerehabilitation (frequency of included studies = 7)	
High user satisfaction with the system	[17,27,35]	3	✓ [22] ($n = 1$)	✓ [27] ($n = 1$)	-	✓ [35] ($n = 1$)	-	-	✓ [17] ($n = 1$)	-	✓ [35] ($n = 1$)	1
Increasing patients' autonomy in daily life activities	[22,31]	2	✓ [22,31] ($n = 2$)	-	-		-	-	-	-	✓ [31] ($n = 1$)	1
Feasibility and acceptability of the home tele-rehab program	[24]	1	✓ [24] ($n = 1$)	-	-	--	-	-	-	-	✓ [24] ($n = 1$)	1
Low scores for pressure and tension of patients	[27]	1	-	✓ [27] ($n = 1$)	-	-	-	-	-	-	-	0
Reduction of treatment-rehabilitation sessions for patients	[34]	1	-	-	✓ [34] ($n = 1$)	-	-	-	✓ [34] ($n = 1$)	-	-	1
No adverse or side effect on patients	[35]	1	-	-	-	✓ [35] ($n = 1$)	-	-	-	-	-	0
Negative outcomes	**References**	**Outcomes frequency based on the number of refer-ences**	**Negative outcomes based on the type of illness or injury**						**Outcomes frequency based on technologies used with games**			**Frequency of games without using technologies**
			Stroke (Frequency of included studies = 12)	**Cerebral palsy (Frequency of included studies = 5)**	**Older age (Frequency of included studies = 2)**	**Rotator cuff syndrome (Frequency of included studies = 1)**	**Amputation (Frequency of included studies = 1)**	**Injuries caused by daily activities (Frequency of included studies = 1)**	**Robots (Frequency of included studies = 3)**	**Smart wearables (Frequency of included studies = 3)**	**Telerehabilitation (Frequency of included studies = 7)**	
Mild discomfort such as nausea and dizziness when using games	[34]	1	-	-	✓ [34] ($n = 1$)	-	-	-	✓ [34] ($n = 1$)	-	-	1

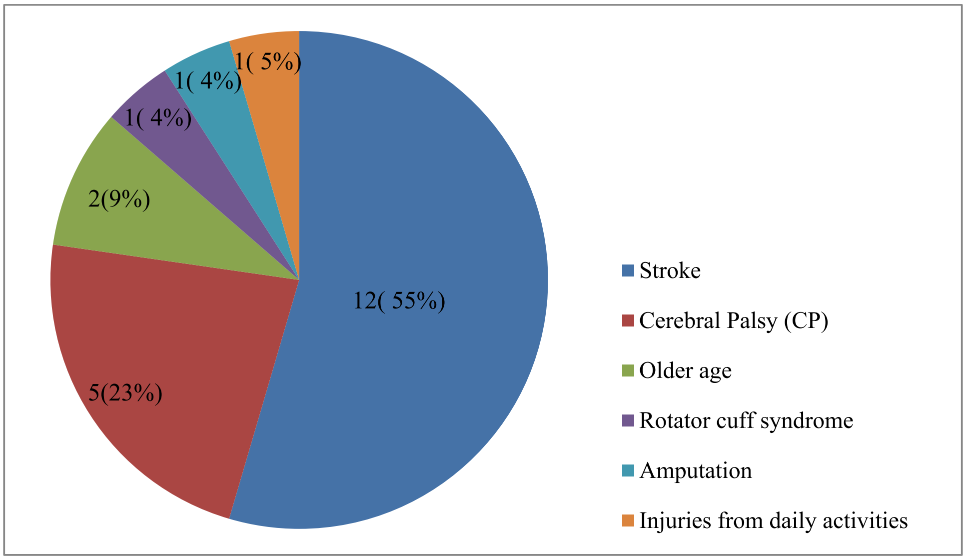

FIGURE 2 Diseases and injuries leading to upper limb disabilities.

patient's level of ability. Game difficulty levels can be adjusted based on the patient's progress and abilities, making the game adaptive and personalized.[43] This will help the patient feel a sense of accomplishment and progress while also keeping them engaged in the game. In addition to motivation and difficulty levels, enjoyment and the attractiveness of the game for patients are crucial parameters. The game's design, graphics, and audio should be visually appealing and immersive, creating a pleasant experience for the patient.[44] This can include incorporating themes and characters that appeal to the patient's interests, making the game engaging and enjoyable.[45]

As mentioned in this review, providing positive or negative audiovisual feedback was another key parameter in designing a successful rehabilitation game. The feedback can be provided in real-time to the patient, indicating their progress or areas that need improvement. This can help the patient understand their progress and keep them motivated to continue playing the game and working towards their rehabilitation goals.[46] Likewise, Kim et al.,[47] emphasized that a rehabilitation game should provide patients with transparent feedback, such as verbal and emotional encouragement from the therapies and a clear objective during therapy. Feedback can be auditory, visual, or haptic, and should promote motor learning through reinforcement of visual errors, task variability, and manipulation of task physics to guide implicit behavior.[46] Providing feedback can help prevent anxiety and maximize the patient's efforts to improve their performance.[43] Richards et al.,[48] also pointed out that repetitive movements associated with specific skills, if intensive and able to provide feedback, can promote neural plasticity and motor improvement. One method, restriction-induced movement therapy, encourages the use of the more affected limb by restricting the less affected limb and is effective in facilitating immediate and long-term functional improvements.[49]

Other necessary parameters for designing a successful game in this scoping review were: "Fantasy and attractive background music and soundtrack," "Sound effects and background graphics," "Failures and successes in the game," and "aims of the game." The music and sound effects can evoke emotions and create a sense of tension, excitement, or relaxation depending on the theme of the game. For example, a fantasy game may require a mystical and enchanting soundtrack to transport players to a magical world.[50] On the other hand, an action game may require a fast-paced and energetic soundtrack to increase the adrenaline of the players. Furthermore, the visual and auditory elements of a game can create a unique atmosphere that is essential to the player's overall experience.[51] High-quality graphics and realistic sound effects can enhance the player's immersion and sense of presence in the game world.[52]

As mentioned in this review, another crucial parameter was the inclusion of failures and successes in the game. A game that is too easy can quickly become boring, while a game that is too challenging can become frustrating. It is essential to strike the right balance between failures and successes. Including failures and successes in the game can create a sense of accomplishment and motivation for the players to keep playing and improving their skills.[53] Previous studies[54–56] have shown that adjusting the level of challenge or difficulty according to the patient's ability can facilitate meaningful gameplay and deal with failures, ultimately resulting in increased engagement in rehabilitation exercises. Likewise, the aims of the game are also an essential parameter. The game's aims must be clear and achievable for players to feel a sense of accomplishment when they achieve them.[57] The aims can also motivate players to continue playing the game and discovering new challenges and rewards.[58]

Overall, it should be said that in this scoping review, many parameters for designing a successful game were identified and introduced. Considering these parameters can help designers tailor their games to the preferences and needs of the target audience, leading to higher user engagement and better overall performance.[43]

Our review found games can cause "Improvement in musculoskeletal performance," "Increasing users' enjoyment/joy of therapeutic exercises and their motivation to perform these exercises," "Therapy compliance and acceptability by patients," and "Increasing adherence to treatment and performing rehabilitation exercises." Some review studies[4,40] also showed that virtual reality and rehabilitation games can increase the patient's motivation to perform exercises, improve upper limb function, improve independence in day-to-day activities, and improve upper limb range of motion, as well as strengthen neural connections and cause reorganization in different areas of the cerebral cortex related to the injured limb, leading to improved motor performance.[59] Virtual reality-based games boost motor learning. These games enhance motor learning and improve access to therapeutic exercises. Virtual reality can be applied to real-life environments, providing a tool for individuals to perform therapeutic tasks that may not be possible in the real world due to resource limitations or safety concerns.[59] On the other hand, games based on virtual reality can provide auditory, visual or haptic feedback and facilitate the learning of motor skills for patients. Such feedback can inform individuals of their success or failure in performing therapeutic exercises and tasks.[59,60] Linking positive feedback to good or successful therapeutic exercise can also motivate and encourage patients to participate more in rehabilitation therapy.[4] The ability to customize the methods of interaction with the virtual environment of the game and at the same time motivate people, has shown VR as a potential rehabilitation tool in these patients.[3]

Furthermore, games can help perform repetitive and intensive therapeutic exercises. Intensive rehabilitation exercises can facilitate the muscle contraction involved in exercise and strengthen muscle coordination.[61,62] Different types of game features can be included in the protocols of rehabilitation exercises with the support of virtual reality, and this can be very useful to increase the motivation of patients to perform therapeutic tasks.[4] For instance, games can include rewards (e.g., credits), the pursuit and experience of which engage and motivates users to perform certain behaviors.[63] Increased motivation is associated with better focus on therapeutic exercises, higher-dose rehabilitation exercise intensity, and treatment adherence.[64,65] Likewise, if the games are combined with telerehabilitation technologies, robots and/or smart wearables, they can increase the motivation and tendency of patients to perform therapeutic exercises, easily perform repetitive, boring and long-term exercises, increase the patient's independence in performing therapeutic exercises, increasing adherence to rehabilitation exercises and ultimately improving the quality of life of patients with upper limb disability.[2]

Other outcomes identified in this review were "High user satisfaction with the system," and "Increasing patients' autonomy in daily life activities." Some studies[66–68] have shown that rehabilitation games are useful and effective for people with upper limb disabilities, and these individuals and therapists have also reported a high level of satisfaction and acceptance of these games. Therefore, it should be said that satisfaction is an important indicator for efficiency and effectiveness, and its high-level increases individual's motivation and improves their compliance with treatment.[69] The concept of satisfaction includes both a person's legitimate expectations of the fulfillment of their desires and a person's perception of real experiences.[70] Therefore, when designing games, designers should consider the concept of satisfaction to design a customer-friendly game. In addition, to increase customer satisfaction, designers can focus on factors such as ease of use of the game, reduction of disconnection problems, adequacy of audio/video quality, absence of side effects, and increased adherence to exercise training.[70] On the other hand, when a game is properly designed, in addition to increasing patients' satisfaction, it can increase their independence in daily life activities. The findings of Chen et al., study[4] showed that game-assisted exercise therapy can improve people's independence in performing daily and self-care activities that require good upper limb function. For example, self-care activities can include bathing, eating, and dressing, usually involving the use of both sides of the upper limb. As mentioned, rehabilitation exercises supported by virtual reality-based games can help improve motor function of the upper limb, enabling individuals to participate more actively in daily activities and require less assist from healthcare providers after receiving game-supported exercise therapy.

Other findings of this review showed that games can cause low scores for pressure and tension of patients. Furthermore, some reviewed studies showed that rehabilitation games do not have adverse or side effects on patients. According to Østlie et al., study,[71] disability or limb loss is phenomenologically similar to the death of a loved one, and it is known that both upper and lower limb amputation or disability often obvious emotional reactions such as grief, shock, denial, depression, and anxiety. In addition to helping to easily perform rehabilitation exercises, rehabilitation games can also reduce the intensity of these nervous tensions.[27] Games can improve upper limb function, mental health and participation in therapeutic activities due to psychological absorption of the user by adding music or humor and providing rehabilitation exercises in the form of fun and entertaining.[37,72,73] However, the findings of a study[34] showed that games can cause mild discomfort such as nausea and dizziness when using games. Hung et al.,[74] compared Kinect2Scratch game-based training with therapist-based training. The results of their study showed that Kinect2Scratch game-based training did not cause any serious side effects for patients with upper limb disability, and none of the patients required further treatment. Laver et al,.[75] also showed in their review that in 24 studies no side effects were reported for the rehabilitation of stroke patients through games and virtual reality and only in four studies on side effects such as transient dizziness, headache, and hypertonicity. Laver et al.,[75] believed that these side effects vary depending on the characteristics of the person, the virtual reality software and hardware, and the task. Regarding the adverse or side effect identified in the current review, we can also claim that mild discomfort such as nausea and dizziness may not be the result of using the game and may have happened due to the advanced age of the participants or the use of the robot. Elderly people may experience common mild discomforts such as dizziness, hand/leg pain, eyestrain, blurred vision, hand tremors, eye redness, and cramps.[76] In a study on children with CP, the use of games reduced their pressure and tension.[27]

4.1 | Limitations of the study

There were several limitations in this scoping review. In this review, only articles published in English language were examined and analyzed. In other studies, it is better to examine articles published in languages other than English. In addition, we used only three databases, Scopus, PubMed, and Web of Science, to retrieve articles. In future studies, it is better to consider more databases to retrieve articles. Also, we did not do critical appraisal of individual sources of evidence. Although this is an optional part according to the PRISMA scoping reviews checklist, other studies can focus on this limitation. In addition, only articles published from January 2021 to September 2022 were included in our study. It is suggested not to apply the time limit in other studies.

5 | CONCLUSION

In this paper, we identified the necessary parameters to design a successful rehabilitation game and the outcomes of using these games. This study showed that game-based rehabilitation is a noninvasive approach and a promising tool to increase the active participation of patients in rehabilitation programs and exercise. Therefore, one should be very careful about the very precise and flawless design of these games. The identified parameters for the design of a game, in addition to helping to design a successful and flawless rehabilitation game, can facilitate the acceptance of a game by patients and therapists and increase their continuous use of such games.

The parameters of a successful game design were identified and introduced in this study, and they can be considered by other researchers when designing and developing rehabilitation games. Subsequently, the effectiveness of these games in improving disabilities and usability can be evaluated. Likewise, this review showed that rehabilitation games have the potential to improvement in musculoskeletal performance, increase users' enjoyment of therapeutic exercises and their motivation to perform these exercises, increase adherence to treatment and performing rehabilitation exercises, increase patients' autonomy in daily life activities, and reduction of rehabilitation sessions.

AUTHOR CONTRIBUTIONS

Khadijeh Moulaei: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing—original draft; writing—review & editing. **Kambiz Bahaadinbeigy**: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; supervision; validation; visualization; writing—original draft; writing—review & editing. **AliAkbar Haghdoostd**: Data curation; formal analysis; funding acquisition; investigation; methodology; writing—review & editing. **Mansour Shahabi Nezhad**: Data curation; formal analysis; validation; writing—review & editing. **Mohammad Gheysari**: Formal analysis; investigation; visualization. **Abbas Sheikhtaheri**: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; supervision; validation; visualization; writing—original draft; writing—review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

All data relevant to the study are included in the article.

ETHICS STATEMENT

The protocol of this study was approved by ethical committee of Kerman University of Medical Sciences (IR.KMU.REC.1400.606). All methods of the present study were performed following the relevant guidelines and regulations of the ethical committee of Kerman University of Medical Sciences.

TRANSPARENCY STATEMENT

The lead author Abbas Sheikhtaheri affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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REFERENCES

1. Koutsiana E, Ladakis I, Fotopoulos D, Chytas A, Kilintzis V, Chouvarda I. Serious gaming technology in upper extremity rehabilitation: scoping review. *JMIR Serious Games*. 2020;8(4):e19071.
2. Moulaei K, Sheikhtaheri A, Nezhad MS, Haghdoost A, Gheysari M, Bahaadinbeigy K. Telerehabilitation for upper limb disabilities: a scoping review on functions, outcomes, and evaluation methods. *Arch Public Health*. 2022;80(1):196.
3. Sahu RK, Gugnani A, Ahluwalia R. Short-term effectiveness of trunk and bimanual hand training on upper limb motor recovery and

function in stroke patients. *Int J Health Sci*. 2022;6(S1):10058-10071.

4. Chen J, Or CK, Chen T. Effectiveness of using virtual reality-supported exercise therapy for upper extremity motor rehabilitation in patients with stroke: systematic review and meta-analysis of randomized controlled trials. *J Med Internet Res*. 2022;24(6):e24111.
5. WHO. Rehabilitation. Accessed, 2023. https://www.who.int/news-room/fact-sheets/detail/rehabilitation
6. Karamians R, Proffitt R, Kline D, Gauthier LV. Effectiveness of virtual reality- and gaming-based interventions for upper extremity rehabilitation poststroke: a meta-analysis. *Arch Phys Med Rehabil*. 2020;101(5):885-896.
7. Laver KE, Lange B, George S, Deutsch JE, Saposnik G, Crotty MJ. Virtual reality for stroke rehabilitation. *Cochrane Database Syst Rev*. 2017;11(11):CD008349.
8. Donoso Brown EV, Dudgeon BJ, Gutman K, Moritz CT, McCoy SW. Understanding upper extremity home programs and the use of gaming technology for persons after stroke. *Disabil Health J* 2015;8(4):507-513.
9. Miclaus R, Roman N, Caloian S, et al. Non-immersive virtual reality for post-stroke upper extremity rehabilitation: a small cohort randomized trial. *Brain Sci*. 2020;10(9):655.
10. Hijmans JM, Hale LA, Satherley JA, McMillan NJ, King MJ. Bilateral upper-limb rehabilitation after stroke using a movement-based game controller. *J Rehabil Res Dev*. 2011;48(8):1005.
11. Mouawad MR, Doust CG, Max MD, McNulty PA. Wii-based movement therapy to promote improved upper extremity function post-stroke: a pilot study. *J Rehabil Med*. 2011;43(6):527-533.
12. Combs SA, Finley MA, Henss M, Himmler S, Lapota K, Stillwell D. Effects of a repetitive gaming intervention on upper extremity impairments and function in persons with chronic stroke: a preliminary study. *Disabil Rehabil*. 2012;34(15):1291-1298.
13. Schuck SO, Whetstone A, Hill V, Levine P, Page SJ. Game-based, portable, upper extremity rehabilitation in chronic stroke. *Top Stroke Rehabil*. 2011;18(6):720-727.
14. Cortés-Pérez I, Zagalaz-Anula N, Montoro-Cárdenas D, Lomas-Vega R, Obrero-Gaitán E, Osuna-Pérez MC. Leap motion controller video game-based therapy for upper extremity motor recovery in patients with central nervous system diseases: a systematic review with meta-analysis. *Sensors*. 2021;21(6):2065.
15. Thomson K, Pollock A, Bugge C, Brady M. Commercial gaming devices for stroke upper limb rehabilitation: a systematic review. *Int J Stroke*. 2014;9(4):479-488.
16. Proença JP, Quaresma C, Vieira P. Serious games for upper limb rehabilitation: a systematic review. *Disabil Rehabil Assist Technol*. 2018;13(1):95-100.
17. Burdea G, Kim N, Polistico K, Kadaru A, Roll D, Grampurohit N. Novel integrative rehabilitation system for the upper extremity: design and usability evaluation. *J Rehabil Assist Technol Eng*. 2021;8:205566832110128.
18. Escalante-Gonzalbo AM, Ramírez-Graullera YS, Pasantes H, et al. Safety, feasibility, and acceptability of a new virtual rehabilitation platform: a supervised pilot study. *Rehabil Process Outcome*. 2021;10:117957272110332.
19. Ersoy C, Iyigun G. Boxing training in patients with stroke causes improvement of upper extremity, balance, and cognitive functions but should it be applied as virtual or real? *Top Stroke Rehabil*. 2021;28(2):112-126.
20. Borrego G, Moran AL, Meza V, Orihuela-Espina F, Sucar LE. Key factors that influence the UX of a dual-player game for the cognitive stimulation and motor rehabilitation of older adults. *Universal Access Inform Soc*. 2021;20(4):767-783.
21. Phelan I, Furness PJ, Dunn HD, et al. Immersive virtual reality in children with upper limb injuries: findings from a feasibility study. *J Pediatr Rehabil Med*. 2021;14(3):401-414.
22. Rodríguez-Hernández M, Polonio-López B, Corregidor-Sánchez AI, Martín-Conty JL, Mohedano-Moriano A, Criado-Álvarez JJ. Effects of specific virtual reality-based therapy for the rehabilitation of the upper limb motor function post-ictus: randomized controlled trial. *Brain Sci*. 2021;11(5):555.
23. Tresser S, Kuflik T, Levin I, Weiss PL. Personalized rehabilitation for children with cerebral palsy. *User Model User-adapt Interact*. 2021;31(4):829-865.
24. Szturm T, Imran Z, Pooyania S, Kanitkar A, Mahana B. Evaluation of a game based tele rehabilitation platform for in-home therapy of hand-arm function post. *PM & R*. 2021;13(1):45-54.
25. Lee SH, Cui J, Liu L, Su MC, Zheng L, Yeh SC. An evidence-based intelligent method for upper-limb motor assessment via a VR training system on stroke rehabilitation. *IEEE Access*. 2021;9:65871-65881.
26. Hung NT, Paul V, Prakash P, et al. Wearable myoelectric interface enables high-dose, home-based training in severely impaired chronic stroke survivors. *Ann Clin Transl Neurol*. 2021;8(9):1895-1905.
27. Hernandez H, Poitras I, Fay L, Khan A, Roy JS, Biddiss E. A gaming system with haptic feedback to improve upper extremity function: a prospective case series. *Technol Disabil*. 2021;33(3):195-206.
28. Hashim NA, Abd Razak NA, Gholizadeh H, Abu Osman NA. Video game–based rehabilitation approach for individuals who have undergone upper limb amputation: case-control study. *JMIR Serious Games*. 2021;9(1):e17017.
29. Garcia-Hernandez N, Guzman-Alvarado M, Parra-Vega V. Virtual body representation for rehabilitation influences on motor performance of cerebral palsy children. *Virtual Reality*. 2021;25(3):669-680.
30. Chen HL, Lin SY, Yeh CF, et al. Development and feasibility of a kinect-based constraint-induced therapy program in the home setting for children with unilateral cerebral palsy. *Front Bioeng Biotechnol*. 2021;9755506.
31. Allegue DR, Kairy D, Higgins J, et al. A personalized home-based rehabilitation program using exergames combined with a telerehabilitation app in a chronic stroke survivor: mixed methods case study. *JMIR Serious Games*. 2021;9(3):e26153.
32. Astrakas L, de Novi G, Ottensmeyer M, et al. Improving motor function after chronic stroke by interactive gaming with a redesigned MR-compatible hand training device. *Exp Ther Med*. 2021;21(3):245.
33. Avcil E, Tarakci D, Arman N, Tarakci E. Upper extremity rehabilitation using video games in cerebral palsy: a randomized clinical trial. *Acta Neurol Belg*. 2021;121(4):1053-1060.
34. Chau PH, Kwok YYJ, Chan MKM, et al. Feasibility, acceptability, and efficacy of virtual reality training for older adults and people with disabilities: single-arm pre-post study. *J Med Internet Res*. 2021;23(5):e27640.
35. Baluz R, Teles A, Fontenele JE, et al. Motor rehabilitation of upper limbs using a gesture-based serious game: evaluation of usability and user experience. *Games Health J*. 2022;11:177-185.
36. Baniña MC, Molad R, Solomon JM, et al. Exercise intensity of the upper limb can be enhanced using a virtual rehabilitation system. *Disabil Rehabil Assist Technol*. 2022;17(1):100-106.
37. Herne R, Shiratuddin MF, Rai S, Blacker D, Laga H. Improving engagement of stroke survivors using desktop virtual reality-based serious games for upper limb rehabilitation: a multiple case study. *IEEE Access*. 2022;10:46354-46371.
38. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implement Sci*. 2010;51(1):1-9.
39. Arksey H, O'Malley LJ. Scoping studies: towards a methodological framework. *Int Soc Res Methodol: Theory Pract*. 2005;8(1):19-32.
40. Murrell JE, Pisegna JL, Juckett LA. Implementation strategies and outcomes for occupational therapy in adult stroke rehabilitation: a scoping review. *Implement Sci*. 2021;16(1):105.
41. Sanchez E. *Key criteria for game design. A framework*. The Business Game Ltd Hampshire; 2011.

42. Song S, Lee J. *Retracted: Key factors of heuristic evaluation for game design: Towards massively multi-player online role-playing game*. Elsevier; 2007.
43. Barrett N, Swain I, Gatzidis C, Mecheraoui C. The use and effect of video game design theory in the creation of game-based systems for upper limb stroke rehabilitation. *J Rehabil Assist Technol Eng*. 2016;3:2055668316643644.
44. Kato PM, Beale IL. Factors affecting acceptability to young cancer patients of a psychoeducational video game about cancer. *J Pediatr Oncol Nurs*. 2006;23(5):269-275.
45. Kinzie MB, Joseph DR. Development, Gender differences in game activity preferences of middle school children: implications for educational game design. *Educ Technol Res Dev*. 2008;56:643-663.
46. Levac DE, Huber ME, Sternad D. Learning and transfer of complex motor skills in virtual reality: a perspective review. *J Neuroeng Rehabil*. 2019;16(1):121.
47. Kim WS, Cho S, Ku J, et al. Clinical application of virtual reality for upper limb motor rehabilitation in stroke: review of technologies and clinical evidence. *J Clin Med*. 2020;9(10):3369.
48. Richards LG, Stewart KC, Woodbury ML, Senesac C, Cauraugh JH. Movement-dependent stroke recovery: a systematic review and meta-analysis of TMS and fMRI evidence. *Neuropsychologia*. 2008;46(1):3-11.
49. Wolf SL. Revisiting constraint-induced movement therapy: are we too smitten with the mitten? Is all nonuse "learned"? and other quandaries. *Phys Ther*. 2007;87(9):1212-1223.
50. Dillon R. *On the way to fun: an emotion-based approach to successful game design*. CRC Press; 2010.
51. Witkowski EJG. Culture, On the digital playing field: how we "do sport" with networked computer games. *Games Culture*. 2012;7(5):349-374.
52. Gormanley SJ. Audio immersion in games—a case study using an online game with background music and sound effects. *Comput Games J*. 2013;2:103-124.
53. Gonen A, Brill E, Frank M. Learning through business games–an analysis of successes and failures. *Insight*. 2009;17(4):356-367.
54. Yates M, Kelemen A, Sik Lanyi C. Virtual reality gaming in the rehabilitation of the upper extremities post-stroke. *Brain Inj*. 2016;30(7):855-863.
55. Shin JH, Ryu H, Jang SH. A task-specific interactive game-based virtual reality rehabilitation system for patients with stroke: a usability test and two clinical experiments. *J Neuroeng Rehabil*. 2014;11:32.
56. Hocine N, Gouaïch A, Cerri SA, Mottet D, Froger J, Laffont I. Adaptation in serious games for upper-limb rehabilitation: an approach to improve training outcomes. *User Model User-adapt Interact*. 2015;25(1):65-98.
57. Quiñones JR, Fernández-Leiva AJ. Automated video game parameter tuning with XVGDL+. *J Univ Comput Sci*. 2022;28(12):1282-1311.
58. Nicholson S. A recipe for meaningful gamification. *Gamification in Education and Business*. Springer; 2015:1-20.
59. Weiss PL, Keshner EA, Levin MF. *Virtual reality for physical and motor rehabilitation*. Springer; 2014.
60. Levin MF, Demers M. Motor learning in neurological rehabilitation. *Disabil Rehabil*. 2021;43(24):3445-3453.
61. Lee G. Effects of training using video games on the muscle strength, muscle tone, and activities of daily living of chronic stroke patients. *J Phys Ther Sci*. 2013;25(5):595-597.
62. Susan P. Carr J, Edinburgh SR, eds. *Stroke Rehabilitation: Guidelines for Exercise and Training to Opfimize Motor Skill*. Butterworth-Heinemann; 2003.
63. Lohse K, Shirzad N, Verster A, Hodges N, Van der Loos HFM. Video games and rehabilitation: using design principles to enhance engagement in physical therapy. *J Neurol Phys Ther*. 2013;37(4):166-175.
64. Choi JH, Han EY, Kim BR, et al. Effectiveness of commercial gaming-based virtual reality movement therapy on functional recovery of upper extremity in subacute stroke patients. *Ann Rehabil Med*. 2014;38(4):485-493.
65. Rohrbach N, Chicklis E, Levac DE. What is the impact of user affect on motor learning in virtual environments after stroke? A scoping review. *J Neuroeng Rehabil*. 2019;16(1):79.
66. Caprì T, Fabio RA, Iannizzotto G, Nucita A. The TCTRS project: a holistic approach for telerehabilitation in Rett Syndrome. *Electronics*. 2020;9(3):491.
67. Golomb MR, McDonald BC, Warden SJ, et al. In-home virtual reality videogame telerehabilitation in adolescents with hemiplegic cerebral palsy. *Arch Phys Med Rehabil*. 2010;91(1):1-8.
68. Huber M, Rabin B, Docan C, et al. In PlayStation 3-based tele-rehabilitation for children with hemiplegia, 2008 virtual. *Rehabilitation, IEEE*. 2008:105-112.
69. Tousignant M, Boissy P, Moffet H, et al. Patients' satisfaction of healthcare services and perception with in-home telerehabilitation and physiotherapists' satisfaction toward technology for post-knee arthroplasty: an embedded study in a randomized trial. *Telemed J e-health*. 2011;17(5):376-382.
70. Moffet H, Tousignant M, Nadeau S, et al. Patient satisfaction with in-home telerehabilitation after total knee arthroplasty: results from a randomized controlled trial. *Telemed J e-health*. 2017;23(2):80-87.
71. Østlie K, Magnus P, Skjeldal OH, Garfelt B, Tambs K. Mental health and satisfaction with life among upper limb amputees: a Norwegian population-based survey comparing adult acquired major upper limb amputees with a control group. *Disabil Rehabil*. 2011;33(17-18):1594-1607.
72. Pulman J, Buckley E. Assessing the efficacy of different upper limb hemiparesis interventions on improving health-related quality of life in stroke patients: a systematic review. *Top Stroke Rehabil*. 2013;20(2):171-188.
73. Shin J-H, Bog Park S, Ho Jang S. Effects of game-based virtual reality on health-related quality of life in chronic stroke patients: a randomized, controlled study. *Comput Biol Med*. 2015;63:92-98.
74. Hung JW, Chou CX, Chang YJ, et al. Comparison of Kinect2Scratch game-based training and therapist-based training for the improvement of upper extremity functions of patients with chronic stroke: a randomized controlled single-blinded trial. *Eur J Phys Rehabil Med*. 2019;55(5):542-550.
75. Laver KE, Lange B, George S, Deutsch JE, Saposnik G, Crotty M. Virtual reality for stroke rehabilitation. *Cochrane Database Syst Rev*. 2017;11(11):Cd008349.
76. Chan JYC, Chan TK, Wong MPF, Cheung RSM, Yiu KKL, Tsoi KKF. Effects of virtual reality on moods in community older adults. A multicenter randomized controlled trial. *Int J Geriatr Psychiatry*. 2020;35(8):926-933.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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