Review Article

A Systematic Review on Serious Games in Attention Rehabilitation and Their Effects

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Attention is a basic and main mental task and can play an important role in the functioning of other brain abilities such as intelligence, memory, learning, and perception, and its deficit occurs in 80% of patients with traumatic brain injury. The use of game-based tools for rehabilitation is rapidly expanding. Cognitive rehabilitation via video games is an emerging hot topic in cognitive science. Serious games serve a specific purpose in addition to entertainment. They can be more engaging than exercises since they replace reward and motivation systems with real-world motivations as a complement for rehabilitation activities. This study was aimed at identifying and categorizing serious computer games used for attention rehabilitation and evaluating their effects. Six electronic databases (Scopus, PubMed, ISI, Embase, IEEE, and Cochrane) were searched in August 2021. The search strategy consisted of three main concepts of "serious game", "cognitive deficits", and "cognitive rehabilitation". The inclusion criteria were (1) journal articles, (2) English language, (3) being published in the last 10 years, (4) human participants, and (5) game-based intervention. In the 30 included studies, 22 unique games were utilized for attention rehabilitation. Lumosity (20%), Brain Age (Dr. Kawashima’s Brain Training) (10%), and MoHRS (6.66%) were the most common games among the studies. There were (57%) casual, (23%) action, (10%) simulation, and (10%) multiple genres. Of the 47 tools used in the studies, 5 utilized cross-modal oddball attention tasks, 4 utilized game performance, 3 utilized the paced auditory serial additional test (PASAT), and the rest employed other tools. A total of 73 outcome measures were related to attention, 42 measures did not have significant results, 30 were significantly improved, 1 was significantly deteriorated, and 4 articles did not have any specific measures for attention evaluation. Thus, the results revealed the positive effect of serious games on attention. However, issues such as absence of scientific teams, the variety of the disorders that cause defects, the variety of criteria, differences in measurements, lack of long-term follow-up, insufficient RCT studies, and small sample sizes should be considered when designing, developing, and using game-based systems to prevent bias.

1. Introduction

Attention is defined as a set of complex psychological functions that include focusing or engaging with the goal, enduring, and being alert for a long time. It is a feature in the human brain that allows a limited amount of information to be actively processed. This information is taken from the vast amount of information available to the senses, stored memory, and other cognitive processes [1]. It is the basis of cognitive functions because any defect in its function can decrease cognitive efficiency [2], and its improvement can greatly contribute to the rehabilitation process of stroke patients [3]. Attention is a major mental task and can also play an important role in the functioning of other cerebral abilities such as intelligence, memory, and perception [4]. Attention deficit can be caused by various diseases and disorders such as multiple sclerosis, traumatic brain injuries, and stroke. In each of these neuropsychological situations,
there are different physical and cognitive symptoms in patients [5].

The attention control system is one of the most complex control procedures in our nervous system. Different networks distributed in the brain are involved in different aspects of the attention control system. Interactions between and within these networks of attention are mediated by various inhibitory and excitatory neurotransmitters. These neurotransmitters play a vital role in the proper functioning of the attention control system, and their interaction is essential. Any defect in neurotransmitter interactions can lead to dysfunction of attention networks and consequently dysfunction of the attention control system [6].

Attention is defined as awareness of what is happening around us [7]. Its deficit is very common and usually occurs in 80% of patients with traumatic brain injury, slowing down the patient’s reactions in daily life and increasing irritability [8]. The model of Sohlberg and Mateer [9] classifies attention into five different categories of focused, sustained, selective, alternating, and divided attention [9]. In terms of types of stimuli and due to the existence of five senses in the human body, it is divided into 5 categories: visual, auditory, tactile, olfactory, and gustatory [6]. Also, attention can be divided into two broad categories: intensive processes, such as alertness and vigilance, and selective attention processes, such as focused and divided attention. Aspects of intensity could be a prerequisite for more complex aspects, such as selective [10, 11]. In fact, lack of attention is associated with problems with balance, daily life functions, and falls [12]. Due to the high impact of attention deficit on other cognitive and physical functions, many researchers have tried to provide effective treatment options for this deficit [13].

Researchers are now well aware that the brain is a more flexible organ than previously thought and is able to significantly repair damage by reorganizing itself, which is the basis of functional rehabilitation. This feature is called neuroplasticity of the brain [14]. It is shown that the brain can repair itself after injury through repetitive, intensive, and task-oriented exercises [15]. Cognitive rehabilitation, behaviour adjustment, psychological management, education, and individual and family counselling are the primary methods of treatment in the rehabilitation of attention deficits [16]. Many researchers have emphasized the importance of cognitive rehabilitation in reducing behavioural and cognitive consequences and promoting independence and quality of life [14, 17, 18]. Cognitive rehabilitation currently generally uses one of the two approaches to treating cognitive deficits. (a) The therapeutic or restitution approach seeks to directly retrain impaired cognitive function. The basic rationale for this approach is the notion that practicing carefully selected exercises improves damaged neural circuits and restores function in the damaged attention processes themselves. (b) The alternative or compensation approach helps people with attention deficits learn or relearn how to perform specific skills. The basic rationale for this approach is that new neuropsychological processes replace the damaged areas of the brain through practice and develop individual skills [19, 20]. Most studies have pointed to the positive effect of cognitive rehabilitation on attention deficit due to various diseases in both approaches, especially in the compensation approach [21–23], but at the same time, some studies are ambiguous about this positive effect in the long term [23, 24].

Still, the most important challenge for therapists is how to encourage patients to perform rehabilitation programs frequently [25, 26]. Today, cognitive rehabilitation methods can be divided into two main categories: traditional methods and computer-based methods. Traditional methods use noncomputer neuropsychological techniques to improve attention and concentration deficits. The traditional rehabilitation is done face-to-face; that is, one or sometimes several therapists work with a patient [27]. These methods have many limitations such as lack of access in all places, high travel costs, lack of accurate monitoring, dearth of information about the patient’s performance, and being dull due to their repetitive nature [28, 29]. Computer-based methods use similar neuropsychological processes but utilize the computer for training as an adjunct to face-to-face rehabilitation that will solve the problems associated with traditional methods [29–31]. Several studies suggest that providing feedback, training strategies, and intervention control by the therapist, along with technology, can improve outcomes [31–33].

Over the past few decades, evidence has highlighted the positive impact of computer-based rehabilitation programs on a variety of deficiencies [31, 34–38]. Among these interventions, the use of game-based tools for rehabilitation is rapidly increasing [39]. Serious games are games that serve a specific purpose in addition to entertainment [40]. The use of serious games in physical rehabilitation has a long history, but this method in cognitive rehabilitation, although scientifically a hot topic, is still not practically and widely practiced [41, 42]. Serious games can be more engaging than exercises because they replace reward and motivation systems with real-world motivations as a complement to rehabilitation activities. People can be immersed in the game world, and their ability and knowledge can be improved without any danger [43]. Other features of these games are increasing the quality and effectiveness of rehabilitation, providing different levels of play to people according to the severity of defects and overcoming the limited resources and facilities of conventional rehabilitation methods [44]. Coles et al. [45] used computer games to teach safety knowledge to children with cognitive impairments, and Prang et al. [46] utilized computer games to rehabilitate disabled patients. Traditional rehabilitation exercises require repetitive and dull activities that are not completed by patients. Moreover, most people today are familiar with digital environments, especially mobile phones. Therefore, health professionals are interested in using computer games for rehabilitation purposes, which will both enhance motivation and determine the outcome of rehabilitation [47, 48].

In this qualitative literature review, we summarize findings about serious games in attention rehabilitation. The objectives of this review are as follows:
(1) To investigate and identify the existing literature on the application of serious games for attention rehabilitation

(2) To map and categorize the literature according to the study purpose, target group, measures methods, features and capabilities of games, analytical results, and interpretation

(3) To evaluate the effects of serious games in cognitive rehabilitation

2. Materials and Methods

Herein, we present a systematic literature review of serious games for attention rehabilitation based on the PRISMA checklist 2020 [49]. This review identified and classified relevant studies on serious games and summarized the findings and gaps. To be flexible in the search, we used parallel and iterative processes for screening, classification, and review phases.

2.1. Eligibility Criteria. The eligibility criteria were as follows: (1) being a journal article, (2) being written in English, (3) being published in the last 10 years, (4) human participants, and (5) providing any game-based intervention. Studies would be excluded from the study if they were (1) unrelated and (2) duplicated; (3) had unavailable full texts or were abstract-only studies; (4) were of other types, e.g., reviews, (5) involved no video games or cognitive rehabilitation; and (6) were protocols and studies only about Exergames.

2.2. Information Sources and Search Strategy. According to the AMSTAR guidelines, at least two databases have to be searched in a systematic review [50]. To obtain more accurate and exhaustive results, we increased the number of searched databases. Six electronic databases (Scopus, PubMed, ISI, Embase, IEEE, and Cochrane) were searched on 2 August 2021 for articles published from January 2011 to August 2021. In addition, to ensure the search of all related articles and reduce the possibility of bias, a manual search was performed using two methods: (1) checking the references of the related papers and (2) using the Google Scholar search engine. We adopted the PICO approach to prepare the search terms [51]. The research team jointly selected three different categories of keywords “serious game”, “cognitive deficits”, and “cognitive rehabilitation” to achieve the objectives of the study and the exhaustiveness and sensitivity of the search. Then, we used MeSH, Embtree, and other related papers to find all the keywords related to these categories. During the primary search, we found that some articles with topics and themes cognitive rehabilitation, executive function, memory, perception, problem solving, etc. also considered attention along with these topics; thus, to cover these articles as well, we used the term cognitive as the more general term instead of attention. First, a standard search was performed in PubMed; then, in other databases, this strategy was modified according to the specific symbols and search methods in that database to obtain the most relevant related results. Our search strategy was a combination of words such as computer game* OR video game* OR online game* OR applied game* OR serious game* OR gamification OR virtual game OR Mobile game* AND Cognitive Dysfunction OR Cognit* OR Attention defect* OR attention* OR perception OR concentration AND Remediat* OR Rehabilitat* OR Train* OR Therap* OR Readapt*. The search strategies for each database are listed in supplementary 1 Tables S1–S3.

2.3. Selection and Data Collection Process. After importing the citations to EndNote 20, duplicates were detected and deleted by this software. To select studies, they were read in two phases, including their title or abstract and a full-text review by two independent reviewers. Disagreements in selection were resolved by a third reviewer. Studies were eligible for data extraction if they met all the inclusion criteria and did not meet the exclusion criteria in the opinion of the reviewers. Then, a Microsoft Excel 2016 data extraction spreadsheet was designed and used by all team members to collect data. The spreadsheet items included the following: title, journal, author, year, volume, pages, abstract, keywords, objective, disease, country, setting, target group, mean age of participants, name of the game, platform, description of the game, game genre, sample size, intervention group, control group, evaluation methods, outcome measures, results, and statistical methods. In the spreadsheet, some responses were in the open-answer format and some in the closed-answer format. The reviewers could choose the not clear option if they could not find the answer. To extract more information about games that were not fully described by the included article, Internet resources and other articles were searched. We also searched the websites of the games to obtain the latest release information.

2.4. Risk of Bias Assessment. Because we aimed to provide a classification of articles and games available for attention rehabilitation and evaluate their overall effects, at this phase, we did not intend to conduct a meta-analysis on the data; therefore, we did not perform a quality assessment of the included studies.

2.5. Synthesis Methods and Analysis. According to the objectives, comparative tables and figures are presented to describe and categorize the results. With a qualitative analysis method, we combined and analysed the results and no meta-analysis was performed due to the heterogeneity of the outcome measures and differences in the populations. Prior to this step, data were checked and refined to provide better results. Excel 2016 was used to present and analyse the data.

3. Results

3.1. Selection of Studies. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the study selection process is displayed in Figure 1. Initially, 3,937 studies were obtained from six scientific databases; after removing the duplicates, the remaining 1,672 articles were screened based on the titles and abstracts. The screening process resulted in the exclusion of 1,369 articles.
based on the inclusion and exclusion criteria. Then, 303 articles were downloaded in full text for further screening. Of these, 282 were excluded after reviewing their full text for various reasons, e.g., administering the intervention to non-patients, games with physical activities, lack of gamification, noncognitive rehabilitation intervention, or being review articles. From these databases, 21 articles entered the final phase of inclusion, and 9 articles were manually searched. Finally, 30 articles were selected for data extraction. The results are visualized using the PRISMA flow diagram in Figure 1.

3.2. Study Characteristics. Of the 30 articles included in the review, all were published in English from 2012 to 2021, with most articles being published during 2013–2017 (four per year). The journals with the highest numbers of publications were *Frontiers in Aging Neuroscience* (n = 3) and *PLOS One* (n = 2), and 13 of 30 of these journals (43%) are ranked in quartile 1. All the other journals had published only one included article. Most of the studies were conducted in Europe 13 (43%), followed by 6 (20%) in North America, 5 (17%) in Asia, 3 (10%) in multiple countries, and other in Australia (1, 3%), Africa (1, 3%), and South America (1, 3%) (Figures 2 and 3).

The mean age of the participants ranged from 5.2 to 79.4 years (Table 1). The highest target group of the games was the elderly 10 (33%) and those with traumatic brain injury 6 (20%). Other target diseases include autism spectrum disorder, ADHD, at-risk children, developmental disabilities, HIV, dementia, dyslexia, neglect disorder, neurocognitive disorders, stroke, and multiple sclerosis (MS). Evidently, the target groups in the studies were very diverse. Moreover, 12 (40%) of the studies were RCTs, while the rest were of other types such as prepost (6, 20%), pilot RCT (4, 13%), quasi-experimental (3, 10%), case series (2, 6.66%), single-subject (2, 6.66%), or uncontrolled clinical trial (1, 3.33%). Most studies were conducted in Italy (4, 13%) and Spain (4, 13%), and some studies were the result of the collaboration of several countries.

All included interventions belonged to different types of computer technologies involving gamification. On the other hand, there were various types of control groups. Most
studies administered routine care to the control group (11 out of 30). However, one study compared a BCI video game (FarmerKeeper) with cartoons. Another study compared an active video game-based physical activity program with an aerobic exercise program. There was also a study comparing a popular brain training game (Brain Age) with a popular puzzle game (Tetris). One study also compared Lumosity and a simulation strategy game. In another study conducted using Lumosity for the intervention group, the control group participated in discussion sessions about general topics related to aging. A study compared Brainastic computerized cognitive training (CCT) with watching videos on history, art, literature, and science plus physical exercise as a control group. One study compared preselected games (Kinect Adventures and Kinect Sports) with a balance platform therapy (BPT) by the Biodex Medical Systems. Furthermore, one study compared the Medal of Honor: Rising Sun (MoHRS) with three control groups, including a placebo control arcade game (Tetris), a useful field of view (UFOV) training program, and routine care.

Most studies had a sample size of more than 10 (25 out of 30). Studies with a small sample were often comprised a virtual reality (VR) or augmented reality (AR) intervention group (8, 9, 29). The largest sample size was 232 and 157, respectively (24, 5), while the other sample sizes were below 60.
Table 1: Summary of the included studies.

| Num | Author (year) | Journal | Country   | Study design | Intervention (game) | Control group | Target group               | Participants | Mean age | Session number, frequency, duration | Result                                                                                     |
|-----|---------------|---------|-----------|--------------|--------------------|---------------|-----------------------------|--------------|---------|------------------------------------|--------------------------------------------------------------------------------------------|
| 1   | Mercado et al. [52] (2020) | Journal on Multimodal User Interfaces | Mexico     | Non-RCT (quasi-experimental) | A BCI video game (FarmerKeeper) | Cartoons       | Children with autism          | 26 (IG = 13; CG = 13) | 8.0 ± 3.07 | 13 sessions, 15 min, 3 blocks around 4 min each | All measures of attention, sustained attention, and attentional control in all children show improvement |
| 2   | De Giglio et al. [53] (2015) | Neurorehabilitation and Neural Repair | Italy       | Pilot RCT     | A home-based cognitive rehabilitation program (Dr. Kawashima’s Brain Training) | Waitlist (usual care) | Multiple sclerosis            | 35 (IG = 18; CG = 17) | 43.9 ± 8.4  | 40 sessions, 8 consecutive weeks, 30 min/d, 5 d/wk | Significant improvement in the effect of DKBT on ST, SDMT, and some MSQoL subscales was observed. Improvements were also observed in the cognitive subscales MFIS and PASAT, but this improvement was not significant |
| 3   | Montani et al. [42] (2014) | Frontiers in Psychology | Italy       | Uncontrolled before and after clinical trial | A new adaptive video game Labyrinth (“diamond task” and “snake task”) | —              | Traumatic brain injury (TBI)   | 20 | 20.8 ± 1.5 | 14 sessions, 40 min, 2 weeks | The results confirmed the strengthening of cognitive abilities by the game, especially the improvement of attentional control during the game Processing speed, attention, and visual recognition memory as well as two dimensions of subjective well-being showed significant improvement |
| 4   | Ballesteros et al. [54] (2015) | Frontiers in Aging Neuroscience | Spain       | RCT           | Nonaction video game training (Lumosity) | Usual care     | Elderly                      | 28 (IG = 17; CG = 11) | 69.0 ± 5.53 | 20 sessions, 1 hour, 10–12 weeks | The overall KABC-II mental processing index, knowledge, and planning improved significantly compared to passive |
| 5   | Boivin et al. [55] (2016) | AIDS Research and Human Retroviruses | Ugandan + USA | RCT           | Computerized cognitive rehabilitation training (Captain’s Log) | Usual care     | Children with HIV            | 157 (CCRT = 51; limited CCRT = 52 ; CG = 54) | 8.9 ± 1.86  | 24 sessions, 1 hour, 3 days per week |                                                                                                     |
Table 1: Continued.

| Num | Author (year) | Journal | Country | Study design | Intervention (game) | Control group | Target group | Participants | Mean age | Session number, frequency, duration | Result |
|-----|---------------|---------|---------|--------------|--------------------|----------------|--------------|--------------|----------|-------------------------------|--------|
| 6   | Franceschini et al. [56] (2013) | Current Biology | Italy | Uncontrolled before and after clinical trial | Video games | — | Dyslexia | 20 | 9.83 ± 17.25 | 9 sessions, 80 min per day | Significant improvements were seen in CogState Groton maze chasing, card detection, and learning in both CCRT arms. However, in other CogState memory or attention measures, TOVA, BRIEF, and CBCL were there any different in the arms |
| 7   | Guimaraes et al. [57] (2018) | Journal of Physical Education and Sport | Brazil | RCT | Active video game-based (AVG) physical activity program | Aerobic exercise program | Elderly | 27 (IG = 13; CG = 14) | 60.4 ± 3.8 | 36 sessions, 3 times a week, 12 weeks | The results showed that only action video games helped to increase children’s reading speed, attention abilities, and skills In the AVG group, only executive function and delayed memory improved, and in the aerobic group, visual attention, executive function, delayed memory, short-term memory, and overall cognition improved. However, we did not find significant differences between groups in the performance of cognitive tests. This suggests that the benefits of AVG exercise may be similar to those of |
| Num | Author (year)                  | Journal                       | Country     | Study design                  | Intervention (game)                  | Control group | Target group | Participants | Mean age | Session number, frequency, duration | Result                                                                 |
|-----|-------------------------------|-------------------------------|-------------|-------------------------------|---------------------------------------|---------------|--------------|--------------|----------|------------------------------------|------------------------------------------------------------------------|
| 8   | Alqithami et al. [58] (2019)  | Healthcare                    | Saudi Arabia| Single-subject design (non RCT)| Augmented reality game (AR-Therapist) | —             | ADHD         | 1            | —        | —                                  | Depend on child performance and his engagement level, 10 trials of 1 minute each, which indicates a positive performance index. |
| 9   | Boletsis et al. [59] (2016)   | International Journal of Serious Games | Norway     | Uncontrolled clinical trial   | Augmented reality cube game (CogARC system) | —             | Dementia      | 5            | 67.6 ± 5.77 | To complete two levels of each minigame approximately 25–30 minutes in total | The iGEQ test showed improvement in positive effect, immersion, and challenge. However, some values indicate specific problems in several small games. Also, the usability score by the SUS test in CogARC was higher. |
| 10  | Nouchi et al. [60] (2012)     | PloS One                      | Japan       | RCT                           | A popular brain training game (Brain Age); A popular puzzle game (Tetris) | Elderly       | 32 (IG = 16; CG = 16) | 69.08 ± 2.44 | 20 sessions, 15 minutes per day, 5 days per week, 4 weeks | The results showed that in all measures of executive function, TMT-B, and two measures of processing speed, the intervention game had a better result than the Tetris game as control. However, there is no significant difference between the effect of Brain Age and Tetris in measuring global cognitive status and all attention measures. |
| 11  |                               |                               | Spain       | RCT                           | Usual care                            | Elderly       |              | 69.0 ± 5.53 | —        | —                                  | —                                                                       |
| Num | Author. (year) | Journal | Country | Study design | Intervention (game) | Control group | Target group | Participants | Mean age | Session number, frequency, duration | Result |
|-----|----------------|---------|---------|-------------|--------------------|---------------|--------------|--------------|---------|----------------------------------|--------|
| 11  | Ballesteros et al. [61] (2014) | Frontiers in Aging Neuroscience |          |             | 20 nonaction video games (Lumosity) |          | 40 (IG = 20; CG = 20) | 20 sessions, 1 hour, 10–12 weeks |       | Attention, processing speed, immediate, delayed visual recognition memory, and the two dimensions of the well-being scale (affection and assertiveness) showed significant improvement. The intervention resulted in a significant improvement in game performance and an effect of lag in both groups showed by the attentional blink task. The detection of the second target at all-time lags showed great progress for the intervention group. Also, the attention training group showed a significant improvement in map search (2 min), but this improvement was not significant in the other two TEA methods. In contrast, a significant decrease was observed in the TAU group. No improvement was observed in the BRIEF-A (executive performance) or GSES (self-efficacy) scales. |
| 12  | Vakili et al. [62] (2016) | Cogent Psychology | Australia | RCT | Action video game (Medal of Honor: Rising Sun (MoHRS)) | Waitlist (usual care) | Traumatic brain injury (TBI) | 26 (IG = 15; CG = 11) | 28.57 ± 8.10 | 8 sessions, 2 hours, 8 weeks |        |
| Num | Author (year) | Journal | Country | Study design | Intervention (game) | Control group | Target group | Participants | Mean age | Session number, frequency, duration | Result |
|-----|---------------|---------|---------|-------------|---------------------|---------------|--------------|--------------|---------|-----------------------------------|--------|
| 13  | Gamito et al. [63] (2017) | Disability and Rehabilitation | Portugal | RCT | A virtual reality-based serious game application | Waitlist (usual care) | Stroke | 20 (IG = 10; CG = 10) | 55.0 ± 13.5 | 8-18 sessions, 2-3 sessions per week, 1 hour, 4-6 weeks | Unlike the control group, in the intervention group, a significant improvement in patients’ WMS scores and efficiency was observed. Significant interaction was also seen on work efficiency of sustained attention. Attention measurements (TOVA omissions), processing speed (TOVA response time), basic visuomotor tracking speed (GMLT chase test), and problem solving (GMLT learning test) were significantly improved. In contrast, TOVA percent commission errors and KABC-II nonverbal index composite score did not significantly improve as a result of BPG training. Peripersonal neglect on the line bisection task, MMSE, and the attentional matrices showed a significant improvement. Despite the improvement in |
| 14  | Giordani et al. [64] (2015) | Global Mental Health | Uganda | Uncontrolled before and after clinical trial | A computer-based training platform (Brain Powered Games (BPG) package) | — | At-risk African children | 33 | 8.55 ± 2.29 | 24 sessions, 45 min, 3 days per week, 2 months |
| 15  | Mainetti et al. [65] (2013) | Technology and Health Care | Italy | A case series (non-RCT) | A set of designed games (Duckneglect) | — | Neglect disorder | 1 | — | 20 sessions, 30 minutes, 5 days a week, 1 month |
| Num | Author, (year) | Journal, Country | Study design | Intervention (game) | Control group | Target group | Participants | Mean age | Session number, frequency, duration | Result |
|-----|----------------|------------------|--------------|--------------------|---------------|--------------|--------------|---------|-----------------------------------|--------|
| 16  | Chen et al. [66] (2012) | Turkish Online Journal of Educational Technology (TOJET), Taiwan + Canada | Non-RCT | Somatosensory video game trainings (three games) | Usual care | Elderly | 35 (IG: 4 weeks = 8; IG: 8 weeks = 10; CG: 4 weeks = 8; CG: 4 weeks = 9) | 79.09 ± 6.61 | 12-24 sessions, 30 min, 3 times per week, 4 and 8 weeks | postsession test performance, this improvement was not stable until the end of the rehabilitation period and a five-month follow-up showed that the patient remained stable. In most participants, after 8 weeks of follow-up, selective attention in immediate effect, carry-forward effects, and overall effect improved significantly and did not show rapid improvement overall. In the end, they concluded that the use of somatosensory video games to promote the selective attention of the elderly with disabilities is a good approach. Contrary to the measurement of selective attention and working memory, a significant improvement was seen in the performance of participants in the training sessions. While both groups |
| 17  | Ballesteros et al. [67] (2017) | Frontiers in Aging Neuroscience, Spain | RCT | Nonaction video games from Lumosity | An active control group with simulation strategy games | Elderly | 55 (IG = 30; CG = 25) | 65.46 ± 5.07 | 16 session, 40-50 min, 10-12 weeks | |

Table 1: Continued.
| Num | Author et al. | Journal                      | Country    | Study design           | Intervention (game)                           | Control group        | Target group                  | Participants | Mean age | Session number, frequency, duration | Result                                                                 |
|-----|---------------|------------------------------|------------|------------------------|-----------------------------------------------|----------------------|------------------------------|--------------|----------|---------------------------------|------------------------------------------------------------------------|
| 18  | Robert et al. [68] (2020) | *Journal of Medical Internet Research* | France     | RCT                    | MeMo (Memory Motivation) web application     | Usual care           | Neurocognitive disorders     | 46 (IG = 25; CG = 21) | 79.4 ± 6.8 | 48 session, 30 min, 4 per week, 12 and 24 weeks | progressed similarly in the Corsi block task, a marginal training effect was observed for the N-back task, and no progress was observed for the Stroop task in the experimental group. Attention tests (trial making test A and correct digit symbol substitution test items), and the apathy inventory (AI) showed significant differences between MeMo and nonactive MeMo groups. Patients' adherence to the intervention was moderate, and there was 70% patient retention |
| 19  | Sharma et al. [69] (2017) | *Disability and rehabilitation* | Canada     | A case series (non-RCT) | The cognitive training program (brain HQTM)   | —                    | Moderate-severe brain injury | 10           | 43.7 ± 16.14 | 60 sessions, 60 min, 5 days per week, 12 weeks | —                                                                 |
| 20  | Yoshida et al. [70] (2018) | *Neurorehabilitation*        | Japan      | Pilot RCT              | Two types of video game tasks: a flow task and a control task | Usual care           | Traumatic brain injury (TBI) | 20           | 41.7 ± 9.37 | 40 sessions, 20 min, 2 in a day, 4 weeks | —                                                                 |
| 21  | Zickefoose et al. [71] (2013) | *Brain injury*              | USA        | Single-subject design (non-RCT) | Two types of video game tasks: a flow task and a control task | —                    | Traumatic brain injury (TBI) | 4            | 42.75 ± 7.80 | 20 sessions, 30 min, 1 month | Although participants made significant progress in both interventions, there was a limited generalization |

**Table 1: Continued.**
Table 1: Continued.

| Num | Author. (year) | Journal | Country | Study design | Intervention (game) | Control group | Target group | Participants | Mean age | Session number, frequency, duration | Result |
|-----|----------------|---------|---------|--------------|---------------------|---------------|--------------|--------------|----------|------------------------------------|--------|
| 22  | Macoun et al. [72] (2020) | Journal of Autism and Developmental Disorders | Canada | Non-RCT | A game-based cognitive training program (Caribbean Quest) | Waitlist (usual care) | Children with autism | 20 (IG = 11; CG = 9) | 8.64 ± 1.74 | 24 sessions, 30 min, approximately 3 times per week, 8–10 weeks | Executive function or attention performance measures: the error rate in the intervention group was significantly lower compared to the control group. For KITAP “owls” (divided attention) or “ghost ball” (sustained attention) tasks and WISC-IV spatial span or digit span tasks, no differences were observed compared to before the intervention. There was a significant difference in errors between the intervention and control groups in the visual-spatial WM task of “colored boxes.” Academic fluency: fewer errors in the intervention group than the control group were significant. There was no difference in oral reading fluency in the intervention group. |
| 23  | Mayas et al. [73] (2014) | PLOS One | Spain + Australia | RCT | 10 video games selected from Lumosity | Discussion meetings about | Elderly | 27 (IG = 15; CG = 12) | 68.6 ± 5.45 | 20 sessions, 1 hour, 10–12 weeks | Significant increase in alertness and decrease in |
| Num | Author. (year) | Journal | Country | Study design | Intervention (game) | Control group | Target group | Participants | Mean age | Session number, frequency, duration | Result |
|-----|----------------|---------|---------|--------------|---------------------|----------------|--------------|--------------|----------|----------------------------------|--------|
| 24  | Yu et al. [74] (2021) | International Journal of Environmental Research and Public Health | China | RCT | Brainastic computerized cognitive training (CCT) | Video watching on history, art, literature, and science + physical exercise | Elderly | 232 (IG1: multidomain CCT + PE = 117; IG2: two-domain CCT + PE = 116; video watching + PE = 114) | 64.2 ± 6.4 | IG1, IG2: 24 sessions, 1 hour PE + 30 min Brainastic CCT session | The improvement in frailty status, learning ability, and verbal memory ability was quite visible in the participants in the intervention groups (multi-/two-domain CCT+PE) compared to the control participants. Multidomain CCT did not perform better in improving frailty status or cognitive function than two-domain CCT. Improvement due to training was seen in the baking tray task, star cancellation test, and extinction test. Fewer missed goals in Posner’s task were improved. CBS continued to show improvements in daily activities, both immediately after training and after 6 months of follow-up. |
| 25  | Fordell et al. [75] (2016) | Topics in stroke rehabilitation | Sweden | Uncontrolled before and after clinical trial | Multisensory stimulation in virtual reality (RehAtt) | — | Chronic neglect after stroke | 15 | 72.8 ± 5.7 | 15 sessions, 1 hour, 3 times per week, 5 weeks | |
| 26  | Straudi et al. [76] (2017) | BMC neurology | Italy | Exploratory, pilot RCT | Preselected games (Kinect) | A balance platform therapy | Traumatic brain injury (TBI) | 21 (IG:VGT = 11; CG:BPT = 8) | 36.0 ± 12.0 | 18 sessions, 1 hour, 3 per week, 6 weeks | CB&H scores improved in both groups, but only UBS |
| Num | Author. (year) | Journal | Country | Study design | Intervention (game) | Control group | Target group | Participants | Mean age | Session number, frequency, duration | Result |
|-----|----------------|---------|---------|-------------|---------------------|---------------|--------------|--------------|---------|-------------------------------------|--------|
| 27  | Janssen et al. [77] (2014) | Journal of Clinical and Experimental Neuropsychology | USA | Pilot RCT | Hybrid-variable priority training (HVT) program (Space Fortress game) | (BPT) by Biodex Medical Systems | Waitlist | Multiple sclerosis | 28 (IG = 14; CG = 14) | 47.18 ± 7.6 | 20 sessions, 1 hour (part task training: 10 sessions, variable priority training: 10 sessions) | Adventures and Kinect Sports) and TUG increased in the VGT group. Also, in the VGT group, selective attention was significantly improved. Except for the WTAR test, other tests (BDI-II, PASAT, SDMT, SRT, LTS, CLTR, and WLG) did not show significant improvement in the intervention group. There was evidence in improving skill acquisition and feasibility of the intervention, but there was no evidence of widespread transfer to cognitive function tasks. However, an improvement in spatial short-term memory was seen in participants. Also, attention and executive function did not show significant improvement, and verbal memory showed a higher rate in the control group. The visual memory in the intervention group showed a significant improvement. No |
| Num | Author et al. [78] (2013) | Journal/Country | Study design | Intervention (game) | Control group | Target group | Participants | Mean age | Result |
|-----|--------------------------|-----------------|--------------|--------------------|---------------|--------------|--------------|---------|--------|
| 28  | Belchior et al. [78] (2013) | Computers in Human Behaviour / Canada & USA | RCT | Medal of Honor: Rising Sun (MoHRS) | A placebo control arcade game (Tetris), useful field of view (UFOV) training program, a usual care control group | Elderly | 58 (IG: MOH = 14; CG:Tetris = 16; CG:UFOV = 15; CG:contact = 13) | 74.7 ± 6.4 | 6 sessions, 90 min, 2–3 weeks |

Significant change was seen in the transition to long-term spatial memory measurements by the 10/36 spatial recall delay version. Also, no significant results were observed for higher-order functions, which are measured by the demand for verbal fluency of the word list generation task. Significant improvement was seen in UFOV compared to game groups. On the other hand, a significant improvement was observed in all three intervention groups compared to the noncontact control group. Also, contrary to the findings observed in the younger adults, there was no difference between the two game states.

Significant improvements in specific motor skills and cognitive, social, and emotional skills were seen in children. No withdrawal of children was performed in any of
| Num | Author (year) | Journal     | Country   | Study design | Intervention (game) | Control group | Target group | Participants | Mean age  | Session number, frequency, duration | Result                                                                 |
|-----|---------------|-------------|-----------|--------------|--------------------|----------------|--------------|--------------|-----------|-------------------------------------|------------------------------------------------------------------------|
| 30  | Castro-Rojas [80] (2018) | Gerontechnology | Denmark | Uncontrolled before and after clinical trial | A web-based game application (Lumosity) | —              | Elderly      | 51           | 67.10 ± 5.40 | 3 sessions, 2.5 hours, 6 weeks | The performance of online cognitive games in participants was improved by participants with repetitive practice. Unlike factors such as age, education, and a positive attitude towards technology, the significant effect of the number of game times on performance improvement was statistically quite clear. |

ADHD: attention-deficit hyperactivity disorder; HIV: human immunodeficiency virus; RCT: randomized controlled trial; BCE: brain-computer interfaces.
3.3. Mapping Serious Games in Attention Rehabilitation. In the included studies, 22 unique games were used for attention rehabilitation. Lumosity (6, 20%), Brain Age (Dr. Kawashima’s Brain Training) (3, 10%), and MoHRS (2, 6.66%) were the most commonly used games. Moreover, 9 (40%) games were developed by the authors of the articles, 10 (45%) games by a commercial group, and 3 (13%) by other scientific groups. The included games had a variety of platforms. The PC application platform was the most frequent (9, 41%), followed by Kinect console (3, 14%), web application (3, 14%), augmented reality system (2, 9%), Nintendo console (2, 9%), PlayStation 2 (1, 5%), tablet application (1, 5%), and VR system (1, 5%).

Video game genre refers to categories of games with similar gameplay characteristics, usually not defined by the story and the setting (unlike cinema) but by how the player interacts with the game [81]. Genres cover a wide range of games and are further branched into subgenres. For example, a simulation game is classified into subgenres such as sports and process games [81]. Of all the included articles, there were 17 (57%) casual, 7 (23%) action, 3 (10%) simulation, and 3 (10%) multiple genres. Among the casual genre studies, there were 1 (6%) item with board games, 11 (65%) puzzles, and 5 (29%) multiple subgenres. In the action genre, there were 3 (43%) items with first-person shooters, 3 (43%) platformers, and 1 (14%) role-playing game (RPG) subgenre. Of the simulation genre studies, there were 1 (33%) item with process and 2 (67%) sport. All multiple genres also had multiple subgenres (3, 10%). Figure 4 illustrates the genres and subgenres of games according to the platforms used in the articles.

3.4. Brief Description of the Games Involved. In this section, we will briefly describe the features of the games included in the study. All the games along with some of their features are listed in Table 2.

FarmerKeeper is a brain-computer interface video game developed by Mercado et al. to support neurofeedback training for children with autism spectrum disorder [52]. Neurofeedback can regenerate and retrain brain activity to enhance cognitive function in healthy individuals and those with certain developmental neurological conditions [82, 83]. The game takes place on a farm. The object is to keep children’s attention above a certain threshold to control a runner who is looking for lost farm animals to bring them back to their pen.

Dr. Kawashima Brain Training for the Nintendo Switch is the fifth entry in the Brain Age puzzle video game series. It is based on research by neurologist Ryuta Kawashima whose avatar guides the player throughout the game. The Italian version of the game was used in the study by De Giglio et al. [53]. The minigames included in this game set include calculations, voice calculation, reading aloud, low to high, syllable count, head count, triangle math, and time lapse. In calculation, simple math questions appear on the screen very quickly and the player has to write the answer on the touch screen. In voice calculation, the answers must be said aloud. In reading aloud, a piece of a classic story should be read as soon as possible. In low to high, the position of numbers that appear on the screen for a short time should be memorized, and the player should demonstrate numbers from lowest to highest. In syllable count, the number of syllables in each sentence is counted. In head count, the screen above shows a group of people. After a few seconds, they are enclosed by a house and soon start coming in and out of the house. The player must count the number of people currently in the house. In triangle math, equations consist of 3 numbers and 2 operations and the player must perform operations in two modes, e.g., \(7 + 5 + 4\) and \((7 + 5) + (5 + 4)\). In time lapse, the time difference between the 2 analog hours must be calculated.

Labyrinth includes a little man moving in the maze to reach the goal. The game character is controlled with a joystick by the gamer. The level of difficulty changes according to the task. The game consists of two tasks: diamond task and snake task. Each task has eight difficulty levels on a continuum from lower (level 1) to higher levels (level 8). The purpose of the game character depends on the nature of the current task. In DT, the man must collect diamonds that are randomly distributed in the play area. In ST, he must avoid being caught by a snake and reach the shelter house which appears in a random place.

Lumosity includes 50 games, 10 of which are specifically related to attention (Assist Ants, Feel the Beat, Skyrise, Eagle Eye, Playing Koi, Trouble Brewing, Train of Thought, Lost in Migration, and Star Search). In the included studies that have used the Lumosity package, different minigames have been utilized. Here, we provide a brief description of the games related to attention only. Assist Ants is designed to challenge your divided attention. You need to ensure the safety of each ant by helping it avoid collisions. Feel the Beat practices a sense of timing and rhythm. You have to rely on audio cues and use your sense of rhythm to match the beats in each experiment. In Skyrise, the goal is to work on your field of vision. In this game, several squares with numbers inside them appear. You have to memorize all the numbers and select them in ascending numerical order. The main goal of Eagle Eye is to improve your peripheral vision. You need to focus on the white circle in the middle and memorize the symbol or number that appears there. The goal of Playing Koi is to feed all the fish in the pond only once. In Trouble Brewing, you have to prepare a certain number of coffee orders in 2 minutes. In Train of Thought, you must guide each train to the matching station by switching the route keys. In Lost in Migration, the herd stays at one point and your task is to determine the path that the middle bird is facing. In Star Search, players must quickly find a unique object among a set of items that have the same shape, color, movement, and texture.

Captain’s Log marketed by Brain Train Corporation is a comprehensive suite of computer cognitive learning games consisting of more than 2,000 computer-based exercises targeting 20 cognitive skills. Training modules are presented as games in which students’ performance is recorded and points are earned based on performance accuracy.

Rayman Raving Rabbids includes 75 minigames and has two modes of play: story mode and score mode. In the story mode, the game follows 15 days of Rayman’s imprisonment
by the Rabbids. Every day, Rayman must do at least three trials. In the score mode, players can repeat previous trials to improve their scores.

Kinect Sports Ultimate Collection simulates 13 sports: basketball, soccer, American football, bowling, beach volleyball, table tennis, boxing, golf, tennis, skiing, darts, baseball, and track and field. To improve performance, songs and comments are used to help control and play the games.

AR-Therapist is a simulated augmented reality (AR) environment using a simple game. The game simply simulates two balls in 3D; one is the target ball and the other is not. The player must hit the ball at a specified time which, if correct, will add to the value of the correct shots. Otherwise, the value is added to the errors.

CogARC uses the AR interaction technique and manipulation of tangible physical objects (cubes) for cognitive screening and training. This game includes 6 minigames. Game mechanics include challenges, competition, feedback, and rewards. The gameplay structure offers two modes: free and linear. The player can play the minigames freely (free mode), in any order and at the desired levels, or play all the minigames in a predetermined order (linear mode). The minigames include Shape Match in which similar shapes should be matched, Color Match where you have to match the meaning of one word with another word's color, Sum Tower that uses numbers to create the desired sum, Building Blocks where you should find the answer to simple arithmetic calculations, Pattern Memory where you have to memorize and recreate a 3 × 3 matrix pattern of colored tiles, and Word Game where words related to a specific topic must be found.

Medal of Honor: Rising Sun (MoHRS) is a first-person shooter video game, the fifth in a series of Medal of Honor released by EA Game. Rising Sun is set in World War II during the Pacific War and has single and multiplayer capabilities.

The VR-based serious game application comprises several daily life activities such as buying several items, finding the way to the minimarket, finding a virtual character dressed in yellow, and recognizing outdoor advertisements, devised to train cognitive functions.

The Brain Powered Games (BPG) package includes Butterfly, iSpy, Stampede, Whacky Animal, and Gone Fishing. Butterfly is a simple game in which a butterfly flies on the screen and the player must use a mouse or other input devices to move the butterfly when it stops moving at a random location. iSpy is a memory game that works based on a common learning and memory pattern. The player is asked to watch a scene. After a brief display, the image is removed with a short delay and then represented, and the player is asked to click on the new item(s) that were absent in the previous image. In Stampede, the player sees a special animal to be memorized. Then, a group of animals appear spinning on a computer screen, and the player has to click only on the animal that was originally presented. The Whacky Animal training program, the player is shown animals that must be memorized; as the animals appear randomly on the screen, they must be clicked or touched before disappearing behind the screen. In Gone Fishing, the player has to fish by following the bobber and clicking on it.

In Duckneglect, the player is told to tap one or more objects belonging to a particular class (targets) that appear...
| Game                        | Genre                     | Developer                  | Released date | Platform                  | Language  | Description                                                                                                                                                                                                                                                                                                                                 |
|-----------------------------|---------------------------|----------------------------|----------------|---------------------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FarmerKeeper                | Action (platformers)      | Mercado et al.             | 2018           | PC based                  | English   | The game story unfolds on a farm. The goal of the game is to maintain children’s attention above a threshold to control a runner who is seeking for lost farm animals to take them back to their pens. In the game, the player’s memory and concentration skills are tested. |
| Brain Age (Dr. Kawashima’s Brain Training) | Casual (puzzle)          | Commercial (Nintendo)      | 2020           | Wii U, Nintendo DS        | Italian   | Puzzles and minigames to strengthen the player’s memory and concentration skills. |
| Labyrinth                   | Casual (board game)       | Montani et al.             | 2014           | PC based                  | English   | A little man moves along a maze to reach a goal. The game character is controlled by the gamer through a joystick. |
| Lumosity                    | Casual (puzzle)           | Commercial (Lomus Lab)     | 2021           | Web based                 | Italian   | These video games include 50 games, 10 of which are specifically related to attention (Assist Ants, Feel the Beat, Skyrise, Eagle Eye, Playing Koi, Trouble Breeding, Train of Thought, Lost in Migration, Star Search). |
| Captain’s Log               | Action (platformers)      | Sanford et al.             | 1988           | PC based                  | English   | BrainTrain’s software products are designed for decision support, education, research, and maintaining a healthy lifestyle purpose. |
| Rayman Raving Rabbids       | Action role-playing game (RPG) | Commercial (Ubisoft)       | 2006           | PlayStation, Microsoft 2, Windows, Xbox 360 | English   | The game features two different modes of play: story mode and score mode. In the story mode, the game follows fifteen days of Rayman’s imprisonment by the Rabbids. Each day, Rayman must complete at least three trials, followed by one special “boss trial” such as a first-person rail shooter using plungers or a racing game in which the player controls a racing car. Minigames fall into one of four categories: Bunny Hunt, Sports, Challenges, and “Shake your Booty!” |
| Kinect Sports Ultimate Collection | Simulation (sport)     | Commercial (Rare)           | 2010           | Xbox 360, Kinect          | English   | Includes 13 sports: basketball, soccer, bowling, tennis, table tennis and minigames. |
| AR-Therapist               | Simulation (sport)        | Alqithami et al.           | 2019           | English                  | English   | Includes 3 sports: ultimate frisbee, volleyball, table tennis, boxing, golf, tennis, skiing, darts, and baseball. |
| Game                                      | Genre                      | Developer                  | Released date | Platform              | Language       | Description                                                                                                                                                                                                 | Paper number |
|-------------------------------------------|----------------------------|----------------------------|---------------|-----------------------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| CogARC system                             | Casual (puzzle, word game) | Boletsis et al.            | 2016          | AR on a tablet PC     | English        | A simulated augmented reality environment using a simple game. CogARC is a serious game for cognitive training and screening, utilizing an interaction technique based on augmented reality (AR) and the manipulation of tangible, physical objects (cubes). The game is a collection of cognitive minigames of preventative nature. | 9            |
| Medal of Honor: Rising Sun (MoHRS)        | Action (first-person shooters) | Commercial (EA Games)      | 2003          | GameCube, PlayStation 2, Xbox | English        | Rising Sun is set in World War II during the Pacific War. Comprised several daily life activities that were devised to train cognitive functions such as buying several items, finding the way to the minimarket, finding a virtual character dressed in yellow, and recognition of outdoor advertisements. | 12, 28       |
| A virtual reality-based serious game application | Simulation (process)       | Gamito et al.              | 2015          | VR on PC              | English        | Comprised several daily life activities that were devised to train cognitive functions such as buying several items, finding the way to the minimarket, finding a virtual character dressed in yellow, and recognition of outdoor advertisements. | 13            |
| Brain Powered Games (BPG) package          | Casual (puzzle, word game) | Giordani et al.            | 2015          | PC and smartphone with multiple platforms | English        | A computer-based training platform                                                                                                                                                                       | 14            |
| Duckneglect                                | Casual (puzzle, word game) | Mainetti et al.            | 2013          | PC based              | English        | A set of specifically designed games that is based on three key elements: games to guide rehabilitation, hands-free motion tracking, and the display of mirror images. MeMo is divided into two parts. The first part involves memory, which includes the following three activities: “recognition” for visual memory training, “MeMo quiz” for working memory training, and “faces” for associative memory training. The second part involves mental flexibility/attention, which includes the following three activities: “Arrows” for processing speed, inhibitory control, and mental flexibility training; “Tricky Cards” for working memory training; and “Jumping Squares” | 15            |
| MeMo (Memory Motivation) web app           | Action (platform)          | Scientific group           | 2015          | Web based, mobile application | French, English, Italian | MeMo is divided into two parts. The first part involves memory, which includes the following three activities: “recognition” for visual memory training, “MeMo quiz” for working memory training, and “faces” for associative memory training. The second part involves mental flexibility/attention, which includes the following three activities: “Arrows” for processing speed, inhibitory control, and mental flexibility training; “Tricky Cards” for working memory training; and “Jumping Squares” | 18            |
| Game | Genre | Developer | Released date | Platform | Language | Description | Paper number |
|------|-------|-----------|---------------|----------|----------|-------------|--------------|
| BrainHQ | Casual (puzzle, word game) | Scientific group & commercial (Posit Science) | 2017 | Web based, mobile application | Multiple languages: English, German, Japanese, etc. | for reaction anticipation and inhibitory control training | 19 |
| A video game task | Casual (puzzle, word game) | Yoshida et al. | 2014 | PC based | English | Two types of video game tasks for attentional training; one is a flow task and the other a control task. The task includes Square, Click Number, and Tower | 20 |
| Caribbean Quest (CQ) | Multiple genre: Scuba: platformers, Pirate Deli: simulation (cooking), Submarine: casual (puzzle), Wave: action (platformers), Squidditch: casual (puzzle)) | Scientific group (University of Victoria, funded as a special project by Kids Brain Health Network (NCE) | 2012 | PC based | English | The CQ consists of five hierarchically structured, self-adjusting minigames that train WM, inhibitory control, selective attention, and sustained attention | 22 |
| Brainastic | Casual (puzzle) | Commercial (Mindvivid Limited) | 2016 | Mobile phones | Chinese | Brainastic is an online application for cognitive training through video games and is performed on a tablet with each game targeting one of the five domains including 17 minigames (Forest of Memory, Catch the Star, Colored Light Bulbs, Master of Oriental Stitch, Conveyor Belt, Spot the Difference, Film Collector, Honey Haunters, Conquer the Ice, From Small to Big, Switch and Match, Piet Mondrian Mansion, Color or Shape, Save the Daruma, Pairing Detective, Fixing Pixels, Dance in the Rain) | 24 |
| RehAtt™ | Casual (puzzle) | Fordell et al. | 2016 | VR on PC based | English | The hardware creates a virtual 3D world. The robotic pen gives a guiding force feedback and a realistic touch sensation through vibrotactile feedback. The subject can see the robotic pen as a stick coming out of the screen. 3D objects can be moved, rotated, and manipulated, giving a sense of depth | 25 |
| Video game therapy: “Kinect Adventures” and “Kinect Sports” | Multiple: simulation (sport, adventure, action, Exergaming) | Commercial (Microsoft Game Studios+Rare) | 2010 | Xbox 360 Kinect | English | Preselected games were chosen from “Kinect Adventures” and “Kinect Sports” that encompassed a wide range of motor activities in a standing position | 26 |
| Game                               | Genre                           | Developer                                   | Released date | Platform            | Language | Description                                                                 | Paper number |
|------------------------------------|---------------------------------|---------------------------------------------|---------------|---------------------|----------|------------------------------------------------------------------------------|--------------|
| Space Fortress game                | Action (shooter)                | Emanuel Donchin (Daniel Gopher’s laboratory) | 1984          | BBC Micro (PC)      | English  | The player, using a joystick, navigates their spaceship in a frictionless environment, shooting missiles at the Space Fortress to destroy it, while simultaneously monitoring and collecting bonus points that appear at the bottom of the screen and constantly dealing with diamond-shaped foe or friend mines that appear on the screen (a) Carnival Games: Wheel of Fortune, Strength Test, Court King, Granny Fling, Alley Ball, Ring Fling, Knockout Punch, Pig Race, Funnel Game, Crash Test Dummies, and Monkey see Monkey do (b) Kinect Adventures: Space Pop and River Rush | 27           |
| Virtual reality-based games: (a) Carnival Games: Monkey see Monkey do and (b) Kinect Adventures | (a) Multiple: action, role-playing game (RPG), and party (b) Multiple: adventure and simulation (sport) | Commercial ((a) Cat Daddy Games and (b) Microsoft Game Studios) | (a) 2011 (b) 2010 | VR on Xbox 360 Kinect | English  | (a) Carnival Games: Wheel of Fortune, Strength Test, Court King, Granny Fling, Alley Ball, Ring Fling, Knockout Punch, Pig Race, Funnel Game, Crash Test Dummies, and Monkey see Monkey do (b) Kinect Adventures: Space Pop and River Rush | 29           |
on the screen in a virtual scenario and to avoid distractions with the hand contralateral to the neglected space. The goal of this game is to guide players through visual search tasks.

MeMo is divided into two parts, and the first part involves memory. The second part involves flexibility and mental attention, which includes the following three activities: Arrows for processing speed, inhibitory control, and mental flexibility training; Tricky Cards for working memory training; and Jumping Squares for reaction anticipation and inhibitory control training.

BrainHQ includes 29 exercises that cover six areas of cognition, including memory, attention, speed, people skills, navigation, and intelligence.

Video game tasks involve two types of tasks to train attention: the flow task and the control task. These tasks have the same content, except that the flow task is designed by increasing the difficulty of the task according to the patients’ skills and providing clear goals and quick feedback on the score. The task includes Square, Click Number, and Tower. In the Square task, patients must control a central blue square with the mouse and prevent red squares from entering the right, left, top, or bottom of the screen. If the squares coming towards the blue square are black, patients get points for hitting them. In the Click Number task, patients must click and delete disks in numerical order. In the Tower task, blocks of three colors are randomly stacked. Patients should click and delete the right, left, or center of the block based on its color as soon as possible. The removal time of all the blocks is calculated.

Caribbean Quest (CQ) is composed of five cognitive games: Scuba, Submarine, Wave, Pirate Delicatessen, and Squidditch. Scuba and Pirate Delicatessen are working memory games, Submarine and Wave are sustained attention games, and Squidditch is a selective attention game. Submarine and Wave are similar in cognitive tasks but different in terms of gameplay. Submarine is a static environment in which the player’s only control is the selection of fish from the middle porthole, while the Wave allows the user to navigate an avatar in an ocean.

Braininstruct includes 17 minigames, four of which are specific for attention. In Conveyor Belt, to learn versatility, you have to change the conveyor sorter and collect items with a specific color. In Spot the Difference, you need to find a unique insect to teach attention and the ability to filter information. In Film Collector, the film should be selected with a specific color or pattern to teach the immediate reaction to move objects. In Honey Haunters, to teach attention and the ability to filter information, you need to determine the correct number continuously over a short period.

RehaKit™ uses a 3D VR game environment to combine visual scanning training and multisensory stimulation. The hardware creates a virtual 3D world. The feeling of real touch and guidance is provided by a robotic pen and through vibrotactile feedback.

Video game therapy (Kinect Adventures and Kinect Sports) encompasses a wide range of physical activities. Kinect Adventures using full-body movement allows the player to participate in a variety of minigames. Kinect Sports is a collection of six sport simulations and eight small games designed to demonstrate the capabilities of Kinect motion. The six sports include bowling, boxing, athletics, table tennis, beach volleyball, and union football.

In Space Fortress, the player uses the joystick to steer a spaceship in an environment without friction and shoot the rocket into the space castle to destroy it; meanwhile, mines keep appearing on the screen.

VR-based games include the following: (a) Carnival Games: Monkey see Monkey (Wheel of Fortune, Strength Test, Court King, Granny Fling, Alley Ball, Ring Fling, Knockout Punch, Pig Race, Funnel Game, Crash Test Dummies, and Monkey) and (b) Kinect Adventures (Space Pop and River Rush).

3.5. Impact of Interventions on Attention Rehabilitation. In addition to attention measures, some studies also evaluated other cognitive domains such as executive functions, memory, and perception. Here, we only present the measures related to attention. Of 46 tools used in the studies, five used cross-modal oddball attention task [54, 56, 61, 73, 84], five game performance [42, 58, 66, 72, 80], three paced auditory serial additional test (PASAT) [53, 70, 77] and Symbol Digit Modalities Test (SDMT) [53, 70, 77], two Stroop test (ST) [53, 84], two the test of everyday attention (TEA) [62, 71], two the test of variables of attention (TOVA) [55, 64], and two the trail making test (TMT) [68, 70]. Other tools used once include EEG data analysis [52], ADHD-T questionnaire [52], CogState [55], Focused Spatial Attention Task [56], Distributed Spatial Attention Task [56, 57], Identification Test [57], digit cancellation task (D-CAT) [60], Digit Span Forward (DS-F) [60], Digit Span Backward (DS-B) [60], attentional blink [62], Toulouse-Pieron test (TPT) [63], attentional matrices [65], Vienna Test System (COG-S9) [66], negative priming task [84], Digit Symbol Substitution Test [68], Symbol Digit Modalities Test (SDMT) [70], continuous performance test X task (CPT-X) [70], Moss Attention Rating Scale (MARS) [70], neglect tests [75], Go/NoGo task [76], and Speed subtask [78]. These tools apply to different subdomains of attention.

Table 3 shows the evaluation results of each measure in each article. If no significant change is achieved in the measures, “No sig” is written in the result column. Also, in case of significant improvement, the word “Sig Improved” and for significant deterioration the word “Sig Deteriorated” are mentioned in the result column. In a total of 73 outcome measures related to attention, 42 measures did not have a significant result, 30 were significantly improved, one was significantly deteriorated, and four did not have any measures for attention evaluation. One article had conflicting results immediately after the intervention and on the three-month follow-up. Moreover, some articles did not evaluate specialized attention measures and, as such, are not listed in the table.

4. Discussion

This study identified and categorized serious computer games used for attention rehabilitation and assessed the
| Num | Assessment tools                                      | Attention subdomain                                      | Index                                                                 | Result          | Ref  |
|-----|-------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------------------|-----------------|------|
| 1   | EEG data                                              | General                                                  | Level of attention (% of time with an attention)                      | Sig improved    | [52] |
|     | EEG data                                              | General                                                  | Number of changes between threshold (*a lower number of changes is better) | Sig improved    |      |
| 1   | ADHD-T questionnaire                                  | General                                                  | Distracted frequency(*a lower number is better)                      | Sig improved    |      |
|     | CRSD-ant test questionnaire                           | Sustained attention                                      | Average score of sustained attention                                 | Sig improved    |      |
|     | Stroop test (ST)                                      | Sustained attention                                      | Mean (SD) score                                                      | Sig improved    |      |
| 2   | Paced auditory serial additional test (PASAT)         | Sustained attention                                      | Mean (SD) score                                                      | No sig          | [53] |
|     | Symbol Digit Modalities Test (SDMT)                   | Sustained attention                                      | Mean (SD) score                                                      | Sig improved    |      |
|     | Game performance                                      | General                                                  | Task difficulty level                                                | Sig improved    | [42] |
|     | Game performance                                      | General                                                  | Time limit                                                           | Sig improved    |      |
| 3   | Game dual task performance                            | Divided attention                                        | Diamond time (DT)                                                    | Sig improved    |      |
|     | Game task switching performance                       | Alternating attention                                    | Diamond time (DT)                                                    | Sig improved    |      |
|     |                                                       |                                                          | Distraction score                                                    |                 |      |
|     |                                                       |                                                          | Alertness score                                                      |                 |      |
| 4   | Cross-modal oddball attention task                    | Visual, spatial, focused, divided, selective, and transient attention | Score                                                               | No sig          |      |
|     | The test of variables of attention (TOVA)             | Sustained attention                                      | Simple reaction time: playing card turning                            | No sig          | [55] |
|     | CogState                                              | General                                                  | Choice reaction time: red playing card turning log msec              | No sig          |      |
|     | CogState                                              | General                                                  | Maze chase correct moves per second                                  | Sig deteriorated|      |
|     | Focused spatial attention task                         | Focused attention                                        | Mean accuracy (SD)                                                   | Sig improved    |      |
|     | Distributed spatial attention task                     | Divided attention                                        | Mean accuracy (SD)                                                   | Sig improved    |      |
| 6   | Cross-modal oddball attention task                    | Visual, spatial, focused, divided, selective, and transient attention | First cue-target interval RT (ms)                                    | No sig          | [56] |
|     |                                                       |                                                          | Second cue-target interval RT (ms)                                   | No sig          |      |
|     |                                                       |                                                          | First cue-target interval accuracy                                   | No sig          |      |
|     |                                                       |                                                          | Second cue-target interval accuracy                                   | No sig          |      |
| Num | Assessment tools                           | Attention subdomain                      | Index                          | Result          | Ref  |
|-----|-------------------------------------------|------------------------------------------|-------------------------------|-----------------|------|
| 7   | Identification test                        | Visual attention                         | Accuracy                      | No sig          | [57] |
|     |                                           |                                          | Speed perf. (ms)              |                 |      |
|     |                                           |                                          | Correct tries, number of omission errors, number of commission errors, number of uncompleted tries, correct response times, try time, engagement factor, inattention factor, impulsivity factor, error factor, and correct response factor | No sig          |      |
| 8   | Game performance                           | General                                  |                               | Sig improved    | [58] |
| 9   | Digit cancellation task (D-CAT)            | General                                  | Mean (SD) score              | No sig          | [59] |
| 10  | Digit Span Forward (DS-F)                  | General                                  | Mean (SD) score              | No sig          | [60] |
|     | Digit Span Backward (DS-B)                | General                                  | Mean (SD) score              | No sig          |      |
| 11  | Cross-modal oddball attention task         | Auditory, visual, focused, selective, divided, and transient attention | Distraction (mean (SD) score) | Sig improved    |      |
|     |                                          | Visual, selective attention              | Alertness (mean (SD) score)   | Sig improved    |      |
|     |                                          | Visual, selective attention              | Map search                    | Sig improved    |      |
|     |                                          | Visual, selective attention              | Telephone search              | No sig          |      |
|     |                                          | Alternating attention                    | Visual elevator (number correct) | Sig improved    |      |
|     | The test of everyday attention (TEA)     | Sustained attention                      | Elevator counting            | No sig          |      |
| 12  |                                          | Sustained attention                      | Telephone search (dual task decrement) | No sig          |      |
|     |                                          | Auditory, focused attention              | Elevator counting with reversal | Sig improved    |      |
|     |                                          | Auditory, alternating attention          | Score                         | No sig          |      |
|     |                                          | Visual, selective, focused, alternating, transient attention | Score                         | Sig improved    |      |
| 13  | Toulouse-Pieron test (TPT)                | Sustained attention                      | Percent omission errors, percent commission errors, response time (ms), response time variability (ms) | Sig improved    | [63] |
| 14  | The test of variables of attention (TOVA) | Sustained attention                      | Score                         | Sig improved    | [64] |
| 15  | Attentional matrices                       | Visual, auditory, focused attention      | Score                         | Sig improved    | [65] |
|     | Vienna Test System (COG-S9)               | Selective attention                      | Score                         |                 |      |
| 16  | Game performance                           | General                                  | Sum reactions, percentage incorrect reaction, sum correct reaction, sum incorrect reaction, mean time correct reactions, mean time incorrect reactions, sum hits, sum correct rejections | Sig improved    | [66] |
| 17  | Cross-modal oddball attention task        | Selective attention (distraction & alertness) | Mean differences in reaction time | No sig          | [84] |
|     | Stroop test (ST)                           | Effortful inhibitory control             | Mean reaction time            | No sig          |      |
|     | Negative priming task                      | Automatic passive inhibition              | Mean reaction time            | No sig          |      |
|     | Trail making test (TMT)                    | General                                  | Mean (SD) score              | No sig          | [68] |
| 18  | Digit symbol substitution test             | General                                  | Mean (SD) score              | No sig          |      |
| 19  |                                           |                                          |                               |                 | [69] |
| Num | Assessment tools | Attention subdomain | Index | Result | Ref |
|-----|------------------|---------------------|-------|--------|-----|
| 20  | Symbol Digit Modalities Test (SDMT) | General | Mean (SD) score | No sig | [70] |
|     | Trail making test (TMT) | General | Mean (SD) score | No sig | |
|     | Paced auditory serial additional test (PASAT) | General | Mean (SD) score | No sig | |
|     | Continuous Performance Test X task (CPT-X) | General | Mean (SD) score | No sig | |
|     | Moss Attention Rating Scale (MARS) | General | Mean (SD) score | No sig | |
|     | Visual, selective attention | Map search | No sig | |
|     | Visual, selective attention | Telephone search | No sig | |
|     | Alternating attention | Visual elevator (number correct) | No sig | |
| 21  | Test of everyday attention (TEA) | Sustained attention | Elevator counting | No sig | [71] |
|     | Visual, selective attention | Telephone search (dual task decrement) | No sig | |
|     | Auditory, focused attention | Elevator counting with distraction | No sig | |
|     | Auditory, alternating attention | Elevator counting with reversal | No sig | |
|     | Ghost’s ball: sustained attention | Mean difference in errors | No sig | |
| 22  | Test of attentional performance: Children’s version (KITAP): game performance | Sad/happy ghost: selective attention | Mean difference in errors | Sig improved | [72] |
|     | Owls: divided attention | Mean difference in errors | No sig | |
|     | Auditory, visual, focused, selective, divided, and transient attention | Mean differences in reaction time | Sig improved | [73] |
| 23  | Cross-modal oddball attention task | — | — | — | [74] |
| 24  | Neglect tests (VR-test battery) | Visual spatial attention | Mean score | Sig improved | [75] |
| 25  | Go/Nogo task | Selective visual attention | Mean (SD) score | Sig improved | [76] |
| 26  | Paced auditory serial additional test (PASAT) | General | Mean (SD) score | No sig | [77] |
|     | Symbol Digit Modalities Test (SDMT) | General | Mean (SD) score | No sig | |
| 27  | Speed subtask | Visual divided, selective attention | Mean (SD) score | Sig improved | [78] |
|     | — | — | — | — | [79] |
| 28  | Game performance (Lumosity Performance Index (LPI)) | General | Mean (SD) score | Sig improved | [80] |

EEG: electroencephalogram; Sig improved: significantly improved; No sig: no significant change; Sig deteriorated: significantly deteriorated.
effects of these games. Game categories were presented based on game genres and different platforms. To the best of our knowledge, this was the first review on this subject. Bogdanova et al. [5] conducted a systematic review somewhat closely related to this study, but they examined computer-ized rehabilitation programs, not computer games. On the other hand, they considered only attention deficits after acquired brain injury. Also, the study by Norman et al. was somewhat similar and examined the effectiveness of cognitive rehabilitation programs after acquired brain injury [5, 19]. Examples of the differences between serious games and traditional computer rehabilitation methods are the following: the ability to prevent boredom and monotony, increase motivation, and provide timely feedback and the ability to perform multitasking exercises, attractive visual interfaces, providing consistent content, and difficulty level according to the performance of players [85].

Upon examining 3937 articles, 30 articles and 22 unique games were included. Seven games were based on personal computer (PC) [42, 52, 55, 65, 70, 72, 77], five based on virtual and augmented reality [58, 59, 63, 75, 79], three based on web application [54, 61, 68, 69, 71, 73, 80, 84], two based on Kinect console [76], one based on Nintendo consoles [53, 60, 66], one based on mobile application [74], and three based on multiple platforms [56, 62, 64, 78].

Out of the 73 outcome measures, 30 showed significant improvement and only one showed significant deterioration [55]. Furthermore, 19 of the 26 studies that performed attention evaluation had at least one significant improvement in their measures [42, 52–54, 56, 58, 61–66, 72, 73, 75, 76, 78, 80, 84]. Therefore, most studies support the effects of serious game-based computer interventions for attention rehabilitation. Although these results are promising, several methodological issues need to be addressed in future studies to determine the effects of interventions more accurately. For example, most studies did not have an appropriate sample size to ensure the significance and validity of the results, so that 20 out of 30 studies had less than 20 participants in the intervention group [52–54, 57–63, 65, 66, 69, 71–73, 75–79]. Also, 5 studies were performed with 1 to 5 participants [58, 59, 65, 71, 79]. In addition, the type and severity of the disease causing the attention deficit may have affected the outcome. Participants’ age can also affect the rehabilitation process. Moreover, the control groups are different across studies; 11 studies provided routine care to the control group [53–55, 61–63, 66, 68, 70, 72, 77], whereas other studies included video, cartoon, and other active control groups. One-third of the studies did not have a control group at all, and out of 12 RCT studies, six studies include an active control group for comparison [57, 60, 73, 74, 78, 84]. Evidently, considering routine care as a control group will increase the risk of bias; that is, the positive effect of the intervention may not be due to increased physical, group, and social activity [86]. Therefore, it is recommended that future studies include active control groups.

The lack of long-term follow-up was another problem. As observed in the study by Ballesteros et al. [54], the results demonstrated a significant improvement immediately after the intervention but a nonsignificant result on the three-month follow-up. This could also be true in the case of other studies; therefore, follow-up should be performed at longer intervals to evaluate the validity and persistence of the result.

The reviewed studies used different tools to measure attention and its subdomains. Some tools can be applied to all cognitive domains, while some are specific to the domain of attention or its subdomains. There is no standard for measuring attention, and this necessitates a comprehensive and appropriate standard for this purpose. Another important point in game design is the role of scientific teams in game design. Other studies emphasize the participation of therapists and scientific teams in the design process [5, 36]. The benefits of being a therapist along with the use of these tools include higher patient motivation, better feedback for the physician, and better management and control of the device according to the patient’s condition [31]. Most of the reviewed studies did not mention the exact process or the team involved in game development. The development of standard games with the participation of various scientific groups and stakeholders seems to be necessary for attention and its subcategories, and standard methods must be developed to use and evaluate the attention rehabilitation process. Unfortunately, the increasing growth of programmers and commercial companies producing games and medical equipment, without the use of specialized scientific groups, poses many dangers and harms to the health of people in the community. It can be seen that there are many commercial tools that are unjustifiably advertised in the market to improve various mental skills. There is a need to take action to solve this problem [31]. For example, in all tools or games in the field of public health, basic criteria can be defined, both based on the interface and usability and based on their content. Extensive clinical evaluation may be mandatory for all instruments to obtain a license to use. Also, systematic review studies can be helpful for this purpose.

Due to the insufficient RCT studies and the existence of various measures, it was not possible to perform a meta-analysis on the data. Moreover, the control groups greatly differed. For many games, no clinical trial was performed. There were also many articles on general cognitive rehabilitation in which attention rehabilitation was a subscale. Thus, the search was very comprehensive and we tried to overcome this limitation by conducting a more comprehensive search and excluding irrelevant articles.

As mentioned in the introduction, attention deficit disorder is usually associated with other cognitive impairments, and each of these deficits may have a positive or negative effect on the other. Perhaps it would have been better if this study had evaluated all these cognitive deficits together, but due to their great complexity and diversity, this was not possible in the study. Therefore, because attention deficit is fundamental and rehabilitation and improvement can help promote other cognitive deficits and reduce disability, we focused only on the area of attention deficit [5]. The fundamentality of attention skills means that, for example, attention skills support patients’ visual and spatial perceptual ability to help predict next action. The ability of working memory is also required to temporarily store information to perform actions. On the other hand, maintaining patients’
attention is a prerequisite for using their working memory ability [87].

5. Conclusions

In this systematic review, we reported game-based computer technologies for attention rehabilitation and assessed the effects of these games. In 19 out of 26 articles measuring the criterion of attention, at least one significant improvement was reported; therefore, it can be concluded that games created for attention rehabilitation are effective and patients and therapists can use the significant benefits of these games to rehabilitate attention deficits. However, to prevent bias, factors such as the variety of criteria and differences in their measurement, small sample size, lack of accurate evaluations of clinical trials on games, absence of scientific teams, lack of long-term follow-up, the existence of different control groups, and not including active groups for comparison should be considered when designing, developing, and using game-based systems. On the other, most of the games found in our study are presented on PC and virtual reality platforms, and for the benefits of portability and continuity of use, we suggest that more games be made for portable platforms such as mobile and tablet.

Abbreviations

- ADHD: Attention-deficit hyperactivity disorder
- HIV: Human immunodeficiency virus
- RCT: Randomized controlled trial
- BCI: Brain-computer interfaces
- EEG: Electroencephalogram.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Supplementary Materials

Search strategy and process of screening of studies. (Supplementary Materials)

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