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VIDEO GAME-BASED INTERVENTIONS FOR COGNITIVE REHABILITATION IN ACQUIRED BRAIN INJURY: A SYSTEMATIC REVIEW

INTERVENCIONES BASADAS EN VIDEOJUEGOS PARA LA REHABILITACIÓN COGNITIVA EN LESIONES CEREBRALES ADQUIRIDAS: UNA REVISIÓN SISTEMÁTICA

INTERVENÇÕES BASEADAS EM VIDEOGAMES PARA A REABILITAÇÃO COGNITIVA EM LESÃO CEREBRAL ADQUIRIDA: UMA REVISÃO SISTEMÁTICA

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Palavras-chave: videogames; reabilitação cognitiva; dano cerebral adquirido; saúde mental.

A B S T R A C T

Acquired brain injury (ABI) is the leading cause of neurocognitive disability in young adults. Rehabilitation usually aims at improving cognitive functions. Digital interventions such as video games have been proposed as a new tool for cognitive rehabilitation, which could also have a positive collateral impact on mental health. In this paper, we systematically review the evidence supporting video game-based interventions for the cognitive rehabilitation of subjects with ABI. This review was carried out following the PRISMA guidelines. Databases searched included PsycINFO, Web of Science, MEDLINE, EBSCO, REDALYC, LILACS, SCIELO, Google Scholar, and SCOPUS. After the screening and full-text revision of the studies, 23 were included in this review. These studies indicate that video game-based interventions are a promising approach for cognitive rehabilitation in patients with ABI. The integration of validated cognitive training with engaging digital technologies, including video games and virtual environments, shows positive effects on both cognitive function and mental health.

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R E S U M E N

El daño cerebral adquirido (DCA) es la principal causa de alteración neurocognitiva en adultos jóvenes. La rehabilitación generalmente tiene como objetivo mejorar las funciones cognitivas. Las intervenciones digitales, como los videojuegos, se han propuesto como una nueva herramienta para la rehabilitación cognitiva, con un posible impacto positivo colateral en la salud mental. En este artículo, revisamos sistemáticamente la evidencia que respalda las intervenciones basadas en videojuegos para la rehabilitación cognitiva en personas con DCA. Esta revisión se llevó a cabo siguiendo las directrices PRISMA. Las bases de datos consultadas incluyeron PsycINFO, Web of Science, MEDLINE, EBSCO, REDALYC, LILACS, SCIELO, Google Scholar y SCOPUS. Tras el proceso de selección y la revisión completa de los textos, se incluyeron 23 estudios en esta revisión. Estos estudios indican que las intervenciones basadas en videojuegos son una aproximación prometedora para la rehabilitación cognitiva en pacientes con DCA. La integración de entrenamientos cognitivos validados con tecnologías digitales atractivas, como videojuegos y entornos virtuales, muestra efectos positivos tanto en la función cognitiva como en la salud mental.

R E S U M O

O dano cerebral adquirido (DCA) é a principal causa de comprometimento neurocognitivo em adultos jovens. A reabilitação visa, em geral, melhorar as funções cognitivas. Intervenções digitais, como os videogames, têm sido propostas como uma nova ferramenta para a reabilitação cognitiva, com possível impacto colateral positivo na saúde mental. Neste artigo, realizamos uma revisão sistemática das evidências que sustentam intervenções baseadas em videogames para a reabilitação cognitiva de pessoas com DCA. Esta revisão foi conduzida de acordo com as diretrizes PRISMA. As bases de dados consultadas incluíram PsycINFO, Web of Science, MEDLINE, EBSCO, REDALYC, LILACS, SCIELO, Google Scholar e SCOPUS. Após o processo de triagem e análise completa dos textos, 23 estudos foram incluídos nesta revisão. Os resultados indicam que as intervenções baseadas em videogames representam uma abordagem promissora para a reabilitação cognitiva em pacientes com DCA. A integração de treinamentos cognitivos validados com tecnologias digitais atrativas, como videogames e ambientes virtuais, apresenta efeitos positivos tanto na função cognitiva quanto na saúde mental.

ACQUIRED BRAIN INJURY

The World Health Organization (WHO) defines acquired brain injury (ABI) as a brain injury that occurs after birth. In general, the cause can be traumatic (e.g., traffic accidents, traumatic blows, or falls) or non-traumatic (e.g., poisoning, infections, brain tumors, stroke, hypoxia, anoxia, and ischemia). A recent global report found that there is an incidence of 76.5 cases with ABI per 100,000 inhabitants (Salgado, 2019). Additionally, between 20 and 50 million people with non-fatal ABI suffer physical, cognitive, behavioral, and emotional consequences, making ABI the leading cause of neurocognitive disability in young adults (WHO, 2018).

These alterations generally lead to a decrease in quality of life, and patients must learn how to adapt until these deficits can be either compensated, replaced, or rehabilitated (Ankolekar & Simoni, 2020; Baltaduonienƒó et al., 2019; van Aswegen & Ntsiea, 2017; Yip & Man, 2009). The cognitive domains with the greatest alterations are working memory, language expression and comprehension, sustained attention, information processing, and executive functions (de Luca et al., 2018; Nelson et al., 2019; Niemeijer et al., 2020).

Moreover, ABI can have a significant impact on mental health. Common mental health sequelae of ABI include mood disorders (e.g., depression, mania), impairment of social skills, and disruption of leisure and activities of daily living. Estimates of major depression in people with ABI range from 25-50%, and mania is estimated to occur in 9% (Holleman et al., 2018). Alexithymia (difficulty identifying and describing emotions) and anxiety are also common features of ABI (Longworth, 2018; Ricciardi et al., 2015).

Cognitive rehabilitation in patients with ABI

Cognitive rehabilitation encompasses interventions to improve cognitive functions, including attention, executive functions, reasoning, problem-solving, orientation, visual-spatial ability, memory, language, social cognition, and emotions (De Luca et al., 2024; Farokhi-Sisakht et al., 2019; Maggio et al., 2019; Sohlberg & Mateer, 1989; Wilson, 1999). Cicerone et al. (2019) defined cognitive rehabilitation as a systematic and functionally oriented therapeutic approach that uses therapeutic activities tailored to the patient's neuropsychological profile. For ABI patients, cognitive rehabilitation involves the application of techniques and procedures to improve their intellectual and perceptual abilities. It is a systematic process aimed at helping

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people with ABI resume activities of daily living safely and independently way, facilitating adaptation to their family, social, and work environments.

Cognitive rehabilitation interventions are applicable at all stages of recovery after injury and in various settings (e.g., hospital, outpatient, or home care). They can be administered individually, in family sessions, or in groups (Moore et al., 2001; Palmese & Raskin, 2000; Zencius et al., 1998) and by multidisciplinary healthcare professionals (e.g., neuropsychologists, cognitive and occupational therapists, and speech-language pathologists; Fortune et al., 2020; Harley et al., 1992; Podell et al., 2010; Sherer et al., 2002) or by trained caregivers (Leung et al., 2017; Quayhagen et al., 1995; Quayhagen, 2000). A typical cognitive rehabilitation session focuses on training specific cognitive skills, leveraging the patient's neurocognitive strengths and addressing weaknesses. It involves activities of increasing difficulty, and its duration adjusted to the individual's tolerance to the tasks (de Luca et al., 2018).

Video game-based interventions for cognitive rehabilitation in patients with ABI

In addition to conventional techniques, digital interventions, such as video games, have emerged as a promising new approach to cognitive and emotional rehabilitation both in general (Gontkovsky et al., 2002; Halligan & Derick, 2005; Lo Presti et al., 2004; Wood & Fussey, 2018) and specifically for ABI (Chou et al., 2018; De Luca et al., 2024; Li et al., 2013; Pantzartzidou et al., 2017; Fraser et al., 2019; Moon et al., 2019). For example, a type of video game known as serious games is designed with a specific primary objective that extends beyond mere entertainment and is used to try to solve problems in diverse fields, including the military, education, rehabilitation, and healthcare (Bavelier et al., 2011; Sardi et al., 2017; Savazzi et al., 2018; Van der Kuil et al., 2018; Wattanasoontorn et al., 2013). In cognitive rehabilitation, these games are thought to be helpful in maintaining a patient's attention and interest, as well as in addressing specific cognitive deficits (Rego et al., 2010; Shapi'i et al., 2015; Savazzi et al., 2018; Van der Kuil et al., 2018). While tasks in serious games typically focus on mitigating one primary deficit, they often concurrently improve multiple cognitive domains (Van der Kuil et al., 2018). Additionally, there is evidence that video games can have positive side effects on mental health, such as reduced psychological symptoms and enhanced well-being (Alashram et al., 2019; Jason et al., 2013).

Thus, video games could therefore be considered a viable and potentially favorable option for the cognitive rehabilitation of patients with ABI, which may also have an additional positive effect on their mental health. From this perspective, video games or video game-based intervention could complement standard rehabilitation strategies and constitute a comprehensive rehabilitation program for patients. In this sense, the goal of this study was to perform a systematic review of the literature examining the effects of video game-based interventions on cognitive rehabilitation in patients with acquired brain injury.

METHOD

This review followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (Moher et al., 2009).

Inclusion/exclusion criteria

The selected studies met the following inclusion criteria:

1. Studies written in English and/or Spanish;
2. Studies testing a video game or a video game-based intervention and analyzing its effects on compensation, replacement, or rehabilitation of cognitive functions following acquired brain injury;
3. Studies published between 2012 and 2024.

The exclusion criteria included:

Studies that did not provide measurable outcomes;

Studies that aimed at the cognitive rehabilitation of subjects with other diagnoses, such as dementia or any other neurodegenerative condition not related to acquired brain injury.

Search strategy and data extraction

A systematic literature search was conducted in the following databases: PsycINFO, Web of Science, MEDLINE, EBSCO, REDALYC, LILACS, SCIELO, Google Scholar, and SCOPUS. Search terms included: ("brain injury" OR "traumatic brain injury" OR "acquired brain injury" OR "cognitive rehabilitation") AND ("video game" OR "video-game" OR "virtual reality"). These search terms were applied to the "Title," "Abstract," and "Keywords" sections. When additional information was needed to establish the suitability of a study for inclusion, the full text was retrieved and reviewed. The references of the included studies were also screened.

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The following information was collected from the selected articles: authors and year of publication, research design, country, sample size, % of male participants, mean age and standard deviation in term of years, selection criteria of the sample characteristics, and n of intervention/control groups. Information was also gathered regarding the main research objectives, the video game-based intervention and its duration, the outcome measures, and the main findings.

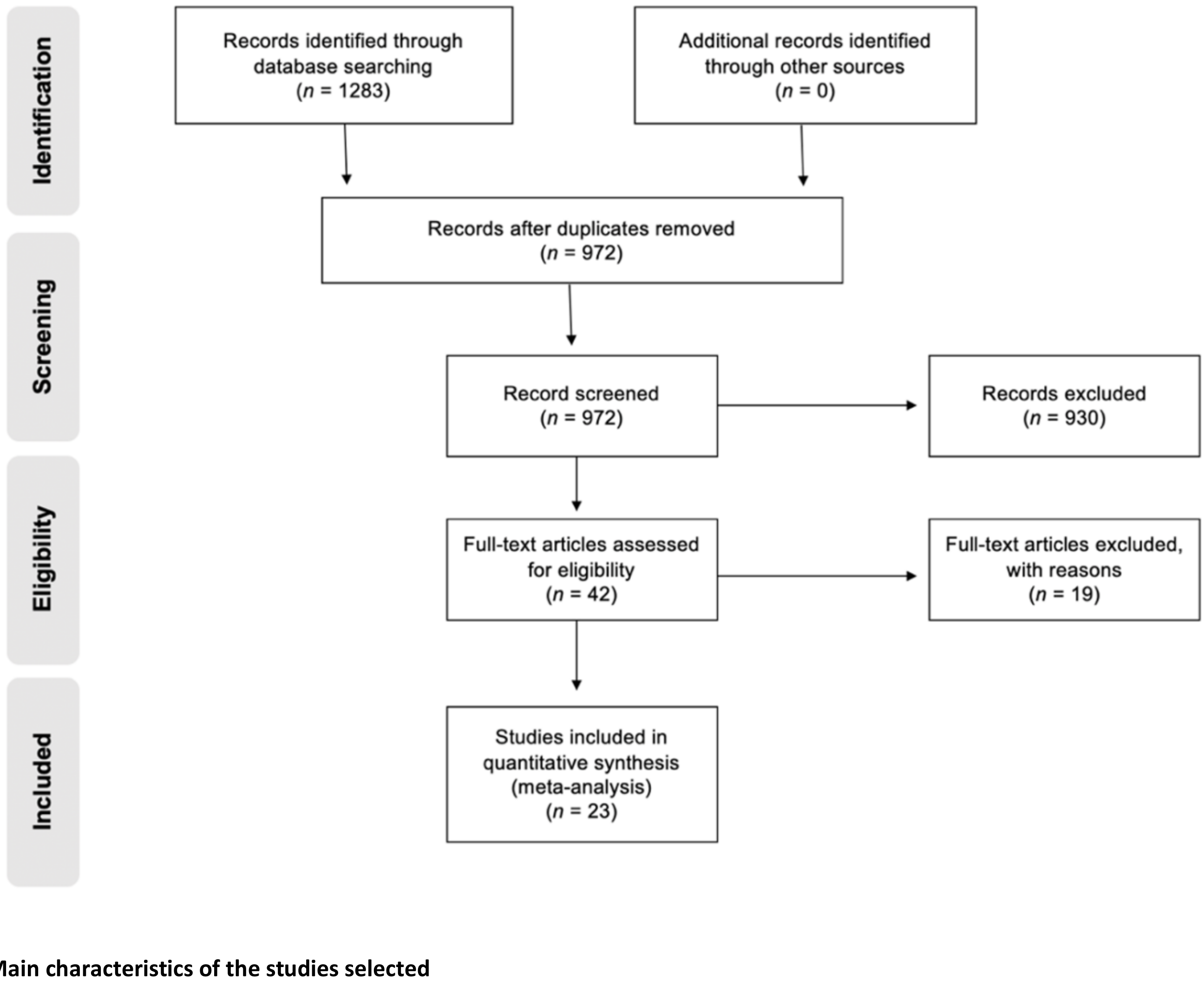
RESULTS

Literature review

Figure 1 presents a flowchart illustrating the article selection process. Initially, 1239 studies were identified through the search. In the next step, duplicates were discarded and the remaining abstracts were reviewed, leading to the identification of 38 potentially relevant articles. During the reading process, inclusion and exclusion criteria were applied, resulting in the exclusion of 15 studies and the inclusion of 23 studies.

Figure 1

Flowchart of the literature review



Main characteristics of the studies selected

Table 1 summarizes the key characteristics of the 23 articles that met the established criteria. Sample sizes ranged from 1 to 100 participants. The analysis of the studies revealed that the selected sample was predominantly male, with an average of 62.80% male participants and 37.20% female participants. The studies were conducted in various countries across different continents including Europe, North America, Asia, and Oceania, with Europe having the highest number of studies. The criteria for patient selection varied depending on the type of acquired brain injury, ensuring that all participants were adults, with a specific focus on acute, subacute, and chronic phases, as well as different types of brain injuries, such as traumatic brain injuries and strokes.

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Methodologies included randomized controlled trials (RCTs), controlled studies, exploratory studies, feasibility studies, and pretest-posttest designs. These methodological selections have made it possible to examine a wide range of interventions and therapeutic approaches in the context of acquired brain injury. RCTs were the most common design, with participants randomly assigned to control or experimental groups. Within the control group, participants commonly underwent standard treatment, while the experimental group typically received a combination of standard treatment and video game intervention. The interventions in these studies generally lasted between four and eight weeks.

Table 1
Main characteristics of the studies included

Authors and year	Design	Country	Sample size	% Male	Mean age (SD) years	Sample characteristics	Groups
Abelmann et al. (2023)	Randomized controlled trial	Netherlands	60	53.2	46 (12.3)	Subjects with acquired brain injury	Intervention: 30 Control: 30
Akerlund et al. (2012)	Randomized controlled study	Sweden	38	51	47.7 (11.2)	Subjects in the sub-acute phase after acquired brain injury	Intervention: 20 Control: 18
Björkdahl, A. et al. (2013)	Randomized controlled trial	Sweden	38	42	51(11)	Subjects with acquired brain injury	Intervention: 20 Control: 18
Caglio et al. (2009)	Exploratory study	Italy	1	100	24	Subject with acquired brain injury	Intervention: 1
Caglio et. al. (2012)	Exploratory study	Italy	1	100	24	Subject with acquired brain injury	Intervention: 1
Chatterjee et al. (2022)	Randomized controlled trial	Great Britain	40	32.4	18	Subjects with unilateral, confirmed stroke	Intervention: 30 Control: 10
Cox et al. (2010)	Feasibility study	United States	11	11	26.6 (5.3)	Subjects with acquired brain injury	Intervention: 5 Control: 6
de Luca et al. (2019)	Randomized controlled trial	Italy	100	57.9	38.7 (9.3)	Subjects with acquired brain injury	Intervention:50 Control: 50
de Luca et al. (2023)	Randomized controlled trial	Italy	20	55	44.6 (16.3)	Subjects affected by moderate to severe chronic acquired brain injury	Intervention:10 Control: 10
de Luca et al. (2024)	Randomized controlled trial	Italy	40	52.5	46.17 (15.02)	Subjects affected by severe acquired brain injury	Intervention:20 Control: 20
Faria, A. L. et al. (2020)	Randomized Controlled Trial	Portugal	32	50	65 (6.2)	Subjects with first stroke episode	Intervention: 14 Control: 18
Gamito et al. (2010)	Exploratory study	Portugal	1	100	20	Subject with traumatic brain injury	Intervention: 1
Gamito et al. (2015)	Randomized Controlled Trial	Portugal	20	45	55 (13.5)	Subjects diagnosed with stroke	Intervention: 10 Control: 10
Jacoby et al. (2013)	Randomized controlled trial	Israel	12	66.6	37 (8.2)	Subjects with traumatic brain injury	Intervention: 10 Control: 10
Kazuki et al. (2018)	Randomized controlled trial	Japan	20	80	44.5 (11.2)	Subjects with traumatic brain injury	Intervention: 10 Control: 10
Lee (2015).	Pretest-posttest	South Korea	10	40	51 (8.5)	Subjects with acquired brain injury	Intervention: 10
Li et al. (2013)	Exploratory study	United States	12	83.3	61 (15.79)	Subjects with acquired brain injury	Intervention: 12
Straudi et al. (2017)	Exploratory study and randomized controlled trial	Italy	21	80.9	36 (9.2)	Subjects with acquired brain injury	Intervention: 11 Control: 10
Vakili et al. (2016)	Randomized controlled trial	Australia	31	100	39 (19.32)	Subjects with acquired brain injury	Intervention: 15 Control: 16
van de Ven et al. (2017)	Randomized controlled trial	Netherlands	59	63	57 (9.1)	Subjects diagnosed with stroke	Intervention: 35 Control: 24
van der Kuil1 (2018)	Exploratory study and randomized controlled trial	Netherlands	30	50	47.2 (19.3)	Subjects with acquired brain injury	Intervention: 30 Control: 20
Yoo et al. (2015)	Randomized controlled trial	South Korea	46	34.7	53.2 (8.8)	Subjects diagnosed with stroke	Intervention: 23 Control: 23
Zickefoose et al. (2013)	Exploratory study	United States	4	100	40 (4.2)	Subjects with traumatic brain injury	Intervention: 4

Research objectives and outcome measures

Given the main inclusion criteria, a clear pattern of diverse but interconnected research objectives was observed across these studies, namely to assess the effectiveness of interventions for cognitive rehabilitation in individuals with ABI. Researchers investigated the impact of various approaches, including computerized training, virtual reality programs, and video games, which will be described in detail in the next section.

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Cognitive rehabilitation primarily targeted on memory and attention (Akerlund et al., 2012; Bjorkdahl et al., 2013; Caglio et al., 2009, 2012; de Luca et al., 2023; Gamito et al., 2010, 2015; Kazuki et al., 2018; Li et al., 2013; Straudi et al., 2017; Vakili et al., 2016; van de Ven et al., 2017; van der Kuil, 2018; Yoo et al., 2015; Zickefoose et al., 2013). Additional focus areas included executive functions, language, motor skills, problem-solving, visual-spatial ability (Chatterjee et al., 2022; Cox et al., 2010; de Luca et al., 2019, 2023; Jacoby et al., 2013; Faria et al., 2020; Lee, 2015; Vakili et al., 2016; van de Ven et al., 2017; van der Kuil, 2018; Yoo et al., 2015). Other studied outcomes encompassed improvements in the neurological status of consciousness (Akerlund et al., 2012), daily life functioning (Abelman et al., 2023; Bjorkdahl et al., 2013; Jacoby et al., 2013; Faria et al., 2020; Yoo et al., 2015), and mental health (Akerlund et al., 2012).

Regarding outcome measures, the studies predominantly employed a combination of screening and function-specific assessments to evaluate cognitive rehabilitation interventions for individuals with ABI. Function-specific assessments included for memory tests such as the Digit Span and Span Board of WAIS-III (Akerlund et al., 2012; Bjorkdahl et al., 2013; Caglio et al., 2009; Gamito et al., 2010, 2015), Rivermead Behavioural Memory Test-II (Bjorkdahl et al., 2013), Bisyllabic Word Repetition Test and Corsi Block-Tapping Test (Caglio et al., 2009, 2012), The Rivermead Behavioural Memory Test (Caglio et al., 2012), Rey's Auditory Verbal Learning Test and N-back (van de Ven et al., 2017). Attention was evaluated using Go/No-Go Test (Abelman et al., 2023; Straudi et al., 2017), Brixton Spatial Anticipation Test x Attention and Attention Network Test Language (Abelman et al., 2023), Toulouse-Pieron Test and the Rey Complex Figure (Gamito et al., 2015), Attentional Blink Task (Vakili et al., 2016; van der Kuil, 2018), and The Test of Everyday Attention (van der Kuil, 2018; Zickefoose et al., 2013). Speech and language were assessed by the Rey Auditory Verbal Learning Test (Caglio et al., 2012), planning was assessed by Tower of London (van de Ven et al., 2017), and motor skills and process skills were measured by Assessment of Motor and Process Skills (Bjorkdahl et al., 2013).

Other screening and diagnostic measures aimed at assessing several outcomes simultaneously were as follows: the Barrow Neurological Institute Screen for Higher Cerebral Functions, The Dysexecutive Questionnaire, the Trail Making Test A-B, the Montreal Cognitive Assessment, the Repeatable Battery for the Assessment of Neuropsychological Status, the Frontal Assessment Battery, the Paced Auditory Serial Addition Task, the Mini-Mental State Examination, the Executive Function Performance Test, the Symbol Digit Modalities Test, the Inventory of Executive Function-Behavior Rating Scale for Adults, The Behavior Rating Inventory of Executive Functioning-Adult version, and The Computerized Neuropsychological Test (Akerlund et al., 2012; Bjo¬®rkdahl et al., 2013; Caglio et al., 2009, 2012; Chatterjee et al., 2022; Cox et al., 2010; de Luca et al., 2019, 2023; Faria, et al., 2020; Gamito et al., 2010, 2015; Jacoby et al., 2013; Kazuki et al., 2018; Lee, 2015; Li et al., 2013; Vakili et al., 2016; van de Ven et al., 2017; van der Kuil, 2018; Yoo et al., 2015).

Additional outcomes measured were as follows: mental health, assessed by The Hospital Anxiety and Depression Scale, the Hamilton Rating Scale Depression, and the Hamilton Rating Scale Anxiety (Akerlund et al., 2012; de Luca et al., 2019, 2024); consciousness, measured by the Reaction Level Scale (Akerlund et al., 2012); effects of fatigue, by The Fatigue Impact Scale (Bj√∂rkdahl et al., 2013); quality of life, measured by the Comprehensive Quality of Life Scale (Vakili et al., 2016); and functional activity of daily living, by the Independence Measurement (Yoo et al., 2015).

Video game-based interventions

Three main categories of video game-based interventions were identified in the reviewed studies: minigames within a computer program or digital platform; traditional video games not specifically designed for cognitive rehabilitation; and virtual reality environments.

The first category consists of mini-games designed for cognitive rehabilitation. Akerlund et al. (2012) and Bjorkdahl et al. (2013) used Cogmed QM. This tool is a cognitive training program that includes mini-games of increasing levels of difficulty that involve tasks such as sorting numbers, remembering and finding letters, and rotating exercises, among others. Zickefoose et al. (2013) used Lumosity and Attention Process Training-3 (APT-3). Lumosity includes a variety of mini-games that challenge individuals, for example, to match symbols rapidly, remember an inventory and deliver bags, pay attention to simultaneous information and prevent ants from colliding, and solve puzzles, among many other challenges. APT-3 is a computer program that includes exercises such as listening to sounds or numbers and clicking when a specific sound or number is heard, reversing the order of numbers, or arranging words in alphabetical order. Abelman et al. (2023) analyzed Karman Line - Tempo Module, a time pressure management training program that trains individuals to recognize and deal with everyday situations that involve time constraints. Van de Ven et al. (2017) studied Brain Gymmer, an online platform featuring various games including flipping burgers quickly before they burn, helping a penguin find fish to eat, detecting which way a shark is facing, and many others. Kazuki et al. (2018) developed three video game tasks called Square, Click Number, and Tower. In the Square task, participants control a central blue square and must avoid red squares coming from all directions. In the Click Number task, they are required to click and delete disks in numerical order. The Tower task involves deleting color-coded blocks that are randomly stacked. Li

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et al. (2013) assessed the effectiveness of Parrot, also an online platform with over 100 different programs in which individuals must click on a colored box that appears randomly on the screen, recall and identify letters on a list, or identify the animation that represents a certain action, among other tasks. Yoo et al. (2015) investigated the impact of RehaCom, a computer software in which participants engage in activities such as recall and pattern recognition, mental rotation and orientation challenges, and discrimination and tracking. Finally, Van der Kuil (2018) used Navigation Training, which consists of different training games. The tasks include going from a starting point to an end-location as fast as possible, picking up some colored cubes positioned in the way, without touching the walls of the corridor, or reaching a destination by taking as few steps as possible and earning as many coins as possible. Researchers varied the movement control (mouse vs. keyboard), the instruction modality (text-based vs. video-based), and the feedback timing (cumulative vs. delayed).

The second category comprises commercial video games adapted for therapeutic use. Vakili et al. (2016) used a video game that was not intentionally designed for cognitive rehabilitation: Medal of Honor: Rising Sun. This is a first-person shooter action video game set in World War II. Players engage in combat scenarios and strategic maneuvers, using a variety of weapons to achieve their mission goals. Caglio et al. (2012) also used a video game that was not originally designed for cognitive rehabilitation: Midtown Madness 2. The patient was instructed to explore a virtual town and "cut down poles and trees found along the way" without access to a city map. In a previous study (Caglio et al., 2009), they also tested a driving simulator (unspecified). Straudi et al.'s (2017) intervention used "Kinect Adventures" and "Kinect Sports." Participants in this study were asked to play specific games that required balance and mobility-related motor tasks like stepping, jumping, and arm goal reaching, among others.

The third category involves immersive VR systems for rehabilitation. Cox et al. (2010) implemented a VR driving simulator. Patients were required to navigate through a 12-mile course comprising rural, highway, and urban segments. The driving simulation involved encountering various traffic patterns and challenges, including signaled and unsignaled sudden stops. In Jacoby et al.'s (2013) study, participants engaged with a VR supermarket and were tasked to explore and perform a range of complex activities involved in daily living. These activities required them to manage multiple cognitive processes simultaneously, mirroring the cognitive demands of real-world scenarios. In de Luca et al.'s (2019) study, participants underwent VR training using the BTs-Nirvana program. Patients are immersed in different real-world simulated scenarios (e.g., The Color of Fruit, Walk Through, Storm, and Piano), in which they must select, touch, move, and manipulate specific objects (e.g., flowers, animals) or create associations (e.g., number-color). As they perform this task with the help of a therapist, they receive audio or video feedback. Similarly, Chatterjee et al. (2022) employed the VIRTUE immersive VR system. The therapist selects a real-world scenario (i.e., kitchen) that meets the patient's needs. Each scenario contains smaller modules with different tasks (i.e., make a toast). Likewise, Lee's (2015) Virtual Reality Exercise program (VREp) used the Interactive Rehabilitation and Exercise System (IREX) from GestureTek Health. Activities included playing the drums, playing soccer, and shooting coconuts, among others. Gamito et al. (2010, 2015) employed a virtual reality platform featuring a small town populated by digital robots. Participants interact with the robots and engage with everyday tasks such as morning hygiene and breakfast or going to the minimarket to buy specific items. In the studies conducted by De Luca et al. (2023, 2024), researchers employed the Virtual Reality Rehabilitation System, which includes forty-seven different exercises such as matching geometric and colored figures, matching hidden images, spelling an object's name, or detecting a rotated image in a sequence, among many others. In the VR-based intervention conducted by Faria et al. (2020), participants engaged in the Reh@City v2.0 platform, consisting in a virtual city where patients also engage in daily living activities and are asked to perform tasks such as buying food, picking up a package at the post office, and paying bills at the bank's ATM.

Main Findings

The reviewed studies demonstrate consistent evidence for video game-based interventions as effective tools across multiple cognitive domains. Table 2 summarizes the main findings of video game-based interventions for cognitive rehabilitation of patients with ABI. In general, the use of VR and computer-based cognitive training programs or video game-based interventions appears to offer substantial benefits in memory, attention, and executive functions, along with secondary mental health improvements.

For example, de Luca et al. (2024) reported significant improvements in cognitive functioning and depression symptoms in their experimental group. Compared to controls, the experimental group showed greater enhancements across cognitive, emotional, and adaptive functioning measures.

Regarding memory, for example, Akerlund et al. (2012) and Bjorkdahl et al. (2013) reported significant enhancements in working memory and executive functions in the intervention group, along with secondary benefits of reduced depressive symptoms and anxiety. Similarly, Caglio et al. (2009) found notable improvements in visual-spatial and verbal memory

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functions post-training, while Kazuki et al. (2018) and Li et al. (2013) revealed significant improvement in memory through computer-based cognitive training.

Intervention on attention also exhibited a marked increase. Zickefoose et al. (2013) observed substantial improvements in attention among participants, although generalization beyond the targeted tasks was limited. Abelman et al. (2023) reported enhancements in attention and quality of life, with secondary positive effects on mental health. Additionally, Van de Ven et al. (2017) found improvements in executive functions, attention, reasoning, and psychomotor speed in both the intervention and control groups, although targeted cognitive function rehabilitation did not show a pronounced advantage over general training. Executive functions were prominently improved in several studies. Straudi et al. (2017) found significant enhancements in executive attention, including better control over automatic responses and focus on goals. De Luca et al. (2019, 2023) highlighted considerable progress in cognitive flexibility, visuo-executive abilities, and mood in the intervention group. Moreover, virtual reality (VR) interventions showed promising results, with Gamito et al. (2010, 2015) indicating that VR applications effectively enhanced working memory, attention, and overall quality of life, without adverse effects on mental health. Chatterjee et al. (2022) also found notable cognitive improvements and reduced hospital time among stroke survivors.

Table 2

Main findings of video game-based interventions for cognitive rehabilitation of patients with ABI

Study	Main objective	Video game-based intervention	Outcome measures	Main finding
Abelman et al. (2023)	To investigate the possible generalization of compensatory strategy, use in everyday situations through a video game-based intervention, with the aim of enhancing executive functions	Karman Line – Tempo Module	Sustained attention: Go/No-Go Test Brixton Spatial Anticipation Test x Attention: Attention Network Test Language: National Adult Reading Test	The study showed that the game-supported cognitive strategy training led to significant improvements in compensatory strategy use compared to the control group, both immediately after the 8-week training period and at a 3-month follow-up. Participants in the experimental group also achieved their treatment goals, demonstrating the effectiveness of the training in enhancing compensatory strategy utilization.
Akerlund et al. (2012)	To explore whether individuals with impaired working memory can enhance their cognitive functions and psychological well-being	Cogmed QM	Neurological Status of Consciousness: Reaction Level Scale Working memory: Digit Span and Span Board Wechsler Adult Intelligence Scale III Speech/language, orientation, attention/concentration, visual-spatial /visual problem-solving, and memory: The Barrow Neurological Institute Screen for Higher Cerebral Functions Executive functions: The Dysexecutive Questionnaire. Anxiety and Depression: The Hospital Anxiety and Depression Scale	Both sets of participants demonstrated enhancements following QM training, specifically in working memory and executive functions. The improvements in both were notably more pronounced in the intervention group (IG) than in the control group (CG) due to their more substantial progress after training. Both groups experienced an improvement in psychological well-being, as they reported reduced depressive symptoms, and the CG also reported reduced anxiety following the training.

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Bjorkdahl, A. et al. (2013)	To investigate the efficacy of computer-based working memory training in improving daily life functioning following a brain injury, with a specific emphasis on attention, working memory, and executive functions	Cogmed QM	Working memory: Wechsler Adult Intelligence Scale -III Digit Span Reversed. Everyday working memory: Rivermead Behavioural Memory Test-II Effects of fatigue on quality-of-life: The Fatigue Impact Scale Dysexecutive problems: The Dysexecutive Questionnaire Motor skills and process skills: Assessment of Motor and Process Skills	The Intervention Group (IG) demonstrated significant improvements in working memory and episodic memory functions compared to the Control Group (CG). While both groups showed improvements in motor skills, the IG showed a tendency for significant improvement in the Process Skills score, suggesting enhancements in executive functions and procedural memory. Additionally, following the training period, the CG exhibited improvements in working memory and episodic memory functions.
Caglio et al. (2009)	To assess changes in cognitive functions, specifically focusing on spatial and verbal memory after training with a driving simulator	Driving Simulator	Verbal and spatial short-term memory: Bisyllabic Word Repetition Test and Corsi Block-Tapping Test Working memory: Wechsler Adult Intelligence Scale -III Digit span. Language: Rey Auditory Verbal Learning Test Executive functions: Trail Making Test A-B	The patient demonstrated notable cognitive improvements post-training, particularly in visual-spatial and verbal memory functions. While short-term memory remained stable throughout the follow-up period, significant enhancements were observed in the patient's ability to learn and recall visual-spatial sequences. Additionally, there was a marked improvement in the patient's verbal memory learning ability, indicating substantial cognitive rehabilitation in both visual-spatial and verbal memory domains.
Caglio et. al. (2012)	To improve spatial and verbal memory functions in ABI patients through virtual navigational training with a 3D videogame	Midtown Madness 2	Short-term spatial memory: Corsi Block-Tapping Test Language: Rey Auditory Verbal Learning Test. Phonemic FluencyExecutive Functions: Trail Making Test TMT A-B Everyday memory functioning: The Rivermead Behavioural Memory Test	The navigational training led to enhanced working memory and attention levels, indicating a positive impact on cognitive functions targeted for rehabilitation. Additionally, this intervention potentially promotes autonomy and improves overall quality of life, reflecting a positive secondary effect on mental health.
Chatterjee et al. (2022)	To improve cognitive functions such as memory, visual-spatial abilities, executive functions, attention, language, and orientation in stroke survivors by means of an immersive virtual reality system	VIRTUE	Memory, visual-spatial abilities, executive functions, attention, language, and orientation: Montreal Cognitive Assessment	Patients in the intervention group showed significant cognitive improvements and spent less time in the hospital compared to the control group.
Cox et al. (2010)	To rehabilitate cognitive functions, including orientation, attention/concentration, visual-spatial /visual problem-solving, and memory	Virtual Reality Driving Simulator	Orientation, attention/concentration, visual-spatial /visual problem-solving, and memory: Repeatable Battery for the Assessment of Neuropsychological Status	Virtual reality rehabilitation training significantly enhanced cognitive functions, particularly attention. This was reflected in improved driving performance in the intervention group, who also reported reduced road rage incidents and lower perceived driving risk post-intervention.
de Luca et al. (2019)	To assess the effects of virtual reality training on the recovery of cognitive functions, including orientation, attention/concentration, visual-spatial /visual problem-solving, memory, and language skills	BTs-Nirvana	Orientation, attention/concentration, visual-spatial /visual problem-solving, memory and language: Montreal Cognitive Assessment Depression: Hamilton Depression Rating Scale Anxiety: Hamilton Rating Scale Anxiety Frontal abilities: Frontal Assessment Battery Visual Search: Trial Making Test	The study revealed significant improvements in cognitive functioning and mood for both groups (intervention and control). Participants in the intervention group exhibited significant enhancements in cognitive flexibility, switching skills, and selective attention.
de Luca et al. (2023)	To explore how non-immersive virtual reality training can enhance executive functions and attention and investigate its potential to reduce anxiety and depression symptoms	Virtual Reality Rehabilitation System	Attention: Trial Making Test Executive Functions: Frontal Assessment Battery	The intervention group had a significant improvement in cognitive, executive functions, attention functioning, mood, and coping strategies. The control group had a significant improvement only in some of the outcome measures. The intervention group had higher scores in attention and coping.

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de Luca et al. (2024)	Investigate the feasibility and potential effects of virtual reality orientation therapy (VR-rot) on optimizing spatial, personal, and temporal orientation, behavioral functioning, and depressive symptoms post-severe adquire brain injury.	Virtual Reality Rehabilitation System	Orientation: spatial, temporal and personal: Mini mental state examination; Montreal Cognitive Assessment Depression: Hamilton Rating Scale for Depression	The experimental group (EG) demonstrated significant improvements in cognitive functioning and a significant reduction in depression symptoms. The control group (CG) also showed improvements in MMSE scores, but these were less pronounced than in the EG. Overall, the EG showed greater enhancements in cognitive abilities, mood, and coping strategies compared to the CG.
Faria, A. L. et al. (2020)	To compare the rehabilitation of cognitive functions such as attention, memory, executive functions, language, and visual-spatial ability between a paper-and-pencil training task and an equivalent content-based VR-based ADL simulation	Reh@City v2.0	Attention, memory, executive functions, language, and visual-spatial ability: Montreal Cognitive Assessment	The Reh@City v2.0 intervention group showed significant improvements in various cognitive functions, including attention, visual-spatial ability, and executive functions, along with benefits in verbal memory, processing speed, and self-perceived cognitive deficits. In contrast, the control group demonstrated limited improvements. Between-group analysis highlighted the superiority of Reh@City v2.0 in overall cognitive functioning, visual-spatial ability, and executive functions.
Gamito et al. (2010)	To evaluate an online platform tailored for individuals with acquired brain injury, focusing primarily on rehabilitating two essential cognitive functions: attention and memory	Virtual Reality Platform of a Small Town	Working memory and attention: Paced Auditory Serial Addition Task Working memory: Wechsler Adult Intelligence Scale -III	The intervention led to improved working memory and attention levels, suggesting that VR applications may enhance autonomy and overall quality of life for these patients.
Gamito et al. (2015)	To assess the effectiveness of a virtual reality-based intervention for cognitive training and rehabilitation, with a specific emphasis on memory, attention, and overall cognitive impairment	Virtual Reality Platform of a Small Town	Memory: Wechsler Memory Scale Attention: Toulouse-Pieron Test and the Rey Complex Figure Cognitive impairment: Mini-Mental State Examination	The intervention led to significant improvements in attention and memory functions compared to the control group. Additionally, there were no reported adverse effects on mental health in either group.
Jacoby et al. (2013)	To assess the efficacy of a virtual reality supermarket in rehabilitating executive functions, as opposed to conventional occupational therapy methods	VMall	Executive Functions: Executive Functions Performance Test	The results indicated a trend toward greater improvement in executive functions and complex activities of daily living for those in the experimental group.
Kazuki et al. (2018)	To determine whether engaging in a game tailored to the patient's skill level induces a state of flow and improves attention	Square, Click Number and Tower	Attention: Trail Making Test; The Symbol Digit Modalities Test; Paced Auditory Serial Addition Test	Both groups showed significant improvement in attention, with the flow group exhibiting a higher (but not statistically significant) improvement. Additionally, as attention improved, participants also reported higher flow states.
Lee (2015)	To investigate the rehabilitation of cognitive functions, focusing on orientation, registration, attention, and language, through a virtual reality exercise; additionally, to explore any associated benefits on motor functions and daily living performance	VRep - IREX	Orientation, registration, attention and language: Mini-Mental State Examination	Patients showed improvement in the total score of cognitive functions (but not in its subscores), in activities of daily living and functional (motor) recovery.
Li et al. (2013)	To assess the efficacy of a commercially available computer-based cognitive training program in enhancing memory and attention	Parrot, Parrot	Attention and Memory: Montreal Cognitive Assessment	Patients exhibited an enhancement in memory and attention.
Straudi et al. (2017)	To assess the effects of commercially available video game therapy on two outcomes: balance and mobility (visual-spatial function) and selective attention	Kinect Adventures and Kinect Sports	Selective visual attention: Go/No go task Balance (visual-spatial function): Community Balance & Mobility Scale, Unified Balance Scale and Time Up and Go test	Control (standardized balance platform training) and video game group improved balance and mobility (CB&M). The videogame group showed significant improvements in balance and mobility (UBS and TUG) and in selective attention.

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van de Ven et al. (2017)	To determine whether computer-based cognitive flexibility training enhances executive functions	Brain Gymmer	Executive Functions: Trail Making Test; Tower of London. Attention: Trail Making Test-A; Paced Auditory Serial Addition Task; Digit-Symbol-Coding. Memory: Rey's Auditory Verbal Learning Test; N-back	Both cognitive interventions and control conditions led to improvement in training tasks and various cognitive functions, including executive functions, attention, reasoning, and psychomotor speed. However, specific rehabilitation of targeted cognitive functions did not show a significant advantage over control conditions in the intervention group, suggesting that improvements may be due to non-specific training effects.
van der Kuil (2018)	To test whether three key attributes in games (motion control within 3D virtual environments, instructional modality, and feedback timing) enhance cognitive rehabilitation on attentional and executive functions	Navigation training	Attention: Attentional Blink Task; The Test of Everyday Attention Executive Functions: The Behavior Rating Inventory of Executive Functions-adult version	Participants in the intervention group, using 3D mouse-controlled interaction, showed greater cognitive rehabilitation compared to the control group using keyboard-controlled interaction. While both groups had similar knowledge acquisition, participants preferred video instructions. Feedback time did not affect performance or motivation. Positive mental health effects were reported by participants in both groups.
Yoo et al. (2015)	To investigate the impact of computer-based cognitive rehabilitation on cognitive function, focusing on memory, language, and attention. Also, to assess improvements in activities of daily living	RehaCom	Memory, Language, Attention: The Computerized Neuropsychological Test Functional activity of daily living: Independence Measurement	The training group experienced a statistically significant improvement in cognitive functions, including digit span, visual span, visual learning, auditory continuous performance, and visual continuous performance, after five weeks of therapy.
Zickefoose et al. (2013)	To determine whether two different computer-based treatments rehabilitated cognitive functions, particularly attention.	Attention Process Training-3 (APT-3) and Lumosity	Attention: Test of Everyday Attention.	The study found significant cognitive improvements among participants undergoing both interventions, particularly in attention functions. However, limited generalization was observed beyond the targeted tasks. Only a few individuals showed notable enhancements in specific cognitive functions related to attention.

DISCUSSION

The aim of this study was to provide a systematic review of the literature examining the effects of video game-based interventions on cognitive rehabilitation in patients with acquired brain injury. Consistent positive effects emerged across multiple cognitive domains, including: memory, attention, executive functions, and visual processing (Bj√∂rkdahl et al., 2013; Caglio et al., 2009; Caglio et al., 2012; de Luca et al., 2019; Faria et al., 2020; Gamito et al., 2010, 2015; Green et al., 2017; Li et al., 2013; Wu et al., 2013). Despite methodological heterogeneity in sample size, duration of gameplay, and outcome measures used, an overall analysis makes it possible to draw conclusions. Since results remain consistent across different research approaches, they reinforce one another and overcome possible limitations inherent in each individual approach. Notably, positive effects were extended to well-being, negative affect, social functioning, Reductions in anger, depressive and anxiety symptoms (Akerlund et al., 2013; Cox et al., 2010; Jason et al., 2013).

Video game-based interventions include mechanics that seem to favor cognitive rehabilitation. They have clear objectives, their difficulty curve is continuously adjusted in real time to match the patients' abilities, and they are entertaining and engaging. These features may promote sustained attention while reducing anxiety. The ability to induce flow states may further enhance outcomes (Akerlund et al., 2013; Cox et al., 2010). The therapeutic effects described in the reviewed studies may be partially attributed to the ability of video game-based interventions to adapt to the players' skill levels and facilitate the experience of flow states when playing. In this context, Alashram et al. (2019) suggested that video games have immediate effects since they offer an opportunity to distract oneself from anxiety-inducing situations and provide intrinsic gratification that captures one's full attention.

Crucially, several studies demonstrated transfer to daily functioning. In this regard, Van der Kuil et al. (2018) reported that the therapeutic changes extrapolated to everyday life activities. Specifically, they observed that the design options offered by the video game-based interventions facilitated transferring acquired cognitive and behavioral skills to real-life situations. A similar conclusion was also highlighted by Faria et al. (2020), who reported that improvements in overall cognitive functioning, including attention, short-term memory, visual-spatial abilities, and executive functions, were generalized to verbal memory, processing speed, and reductions in depressive symptoms. Research suggests that it is important to offer individuals with cognitive impairments due to ABI a variety of treatment options that promote their autonomy and adherence to the treatment plan. Choosing video game-based interventions as a cognitive rehabilitation option could be an attractive choice that aligns with patients' needs and preferences. Additionally, when individuals actively participate in their treatment plan, they often report better outcomes, such as reduced anxiety and stress symptoms.

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Video game-based interventions have emerged as a potentially favorable therapeutic tool for cognitive rehabilitation in patients with ABI. Video games with purposes beyond entertainment have proven effective in improving specific cognitive skillsand, additionally, promoting well-being while reducing depressive symptoms. Moreover, they seem to provide a sense of gratification, self-efficacy, and motivation, while promoting the development of virtues and strengths in players. They can also serve as a means to face and overcome different challenges and obstacles, potentially leading to improvements in perseverance and the ability to face failure in everyday life.

Collectively, the evidence supports video game-based interventions as promising tools for ABI rehabilitation. Optimal outcomes may require combining evidence-based protocols with engaging technology. Overall, the results suggest that the use of digital games and technologies, such as virtual reality, can have positive effects not only on cognitive functioning but also on mental health.

Limitations

This review has three primary limitations that should inform future research. First, the considerable heterogeneity in study designs, sample sizes, intervention protocols, and outcome measures limits direct comparisons between studies.. This variability complicates direct comparisons and may limit the ability to draw broad conclusions. Second, there is a lack of long-term follow-up studies: most of the reviewed reports focused on the immediate effects of video games on cognitive and emotional rehabilitation, but long-term studies are needed to assess their lasting impact on cognitive function and emotional well-being in patients with acquired brain injury. Finally, the frequent omission of which can play a key role in shaping the outcomes of rehabilitation. Different brain regions are responsible for various cognitive functions, so understanding the site of the injury could provide analysis of how injury topography mediates intervention outcomes.

Future research

There are several promising areas of research related to video games and cognitive and emotional rehabilitation in patients with ABI. First, longitudinal studies with extended follow-up periods (,â•12 months) are needed to evaluate the durability of cognitive and emotional improvements from video game interventions. This would involve following patients over time and assessing their progress and potential changes in cognitive function and emotional well-being. Second, comparative effectiveness research should systematically examine how different game genres (e.g., action games, puzzle games, exergames) impact specific ABI-related deficits. This would help determine which characteristics of video game-based interventions are most effective and in what specific contexts. A third priority involves mechanistic studies using advanced neuroimaging (functional magnetic resonance imaging, electroencephalography) to identify neuroplasticity patterns underlying cognitive-emotional benefits. This could help to better understand the underlying mechanisms and brain networks involved in cognitive and emotional improvement induced by video games. Lastly, researching and developing new video game technologies, such as virtual reality (VR) or augmented reality (AR), will be important for cognitive rehabilitation. These technologies can offer immersive and personalized experiences that could enhance the effectiveness of rehabilitation. These research directions could contribute to expanding current knowledge about the use of video games in cognitive and emotional rehabilitation in patients with acquired brain injury and enable more effective and personalized development of video game-based interventions in the future.

This systematic review may contribute to academic comprehension in educational environments, particularly for undergraduate students, by organizing and synthesizing information related to video game based interventions and the different approaches employed in the rehabilitation of various cognitive functions. Additionally, it provides an overview of the scientific methodologies commonly used to generate empirical knowledge in this emerging field.

With regard to its relevance for clinical professionals, this work provides an up to date synthesis of the available empirical evidence, which may serve as a scientific foundation for therapeutic decision making involving the use of video games as complementary tools in cognitive rehabilitation processes. In general terms, video game based interventions appear to offer a potentially favorable outlook, as they present characteristics that may support their integration into rehabilitation practices. These include reduced costs, playful and engaging formats, adaptability to the patient's level of cognitive functioning, real-time feedback, activation of neural plasticity, as well as increased motivation, commitment, and adherence to treatment. These properties suggest a potential for effective transfer to clinical practice, complementing traditional strategies and contributing to the design of more personalized, accessible, and sustainable interventions for individuals with ABI.

Prisma checklist

This study followed the PRISMA methodology. Table 3 summarizes this systematic review using the PRISMA 2020's checklist.

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Table 3

PRISMA 2020 Checklist

Item (PRISMA 2020)		Description
Title		
Title	1	Video game-based interventions for cognitive rehabilitation in acquired brain injury: A systematic review
Objective	2	To provide a systematic literature review examining the evidence regarding video game-based interventions for the cognitive rehabilitation of subjects with acquired brain injury
Method		
Eligibility Criteria	3	Studies met the following inclusion criteria: 1. Studies written in English and/or Spanish; 2. Studies testing a video game or a video game-based intervention and analyzing its effects on compensation, replacement, or rehabilitation of cognitive functions following acquired brain injury; 3. Studies published between 2012 and 2024. The exclusion criteria included: 1. Studies that did not provide a measurable outcome; 2. Studies that aimed at the cognitive rehabilitation of subjects with other diagnoses, such as dementia or any other neurodegenerative condition not related to acquired brain injury.
Information Sources	4	Search strategy and data extraction: A systematic literature search was conducted in the following databases: PsycINFO, Web of Science, MEDLINE, EBSCO, REDALYC, LILACS, SCIELO, Google Scholar, and SCOPUS. Search terms included: ("brain injury" OR "traumatic brain injury" OR "acquired brain injury" OR "cognitive rehabilitation") AND ("video game" OR "video-game" OR "virtual reality"). These search terms were applied to the "Title," "Abstract," and "Keywords" sections. When additional information was needed to determine the suitability of a study for inclusion, the full text was retrieved and reviewed. The references of included studies were also screened.
Risk of Bias in Studies	5	The risk of bias in selected studies is largely associated with the sample in the research. All participants in a study have unique and individual characteristics, making some more likely to benefit from video game-based interventions. This can limit the generalizability of results to a broader population. Additionally, if there is no random assignment of participants to treatment groups, there is a risk that pre-existing differences between groups may influence the outcomes. Participants may exhibit biased responses due to the nature of the treatment, meaning they may feel more motivated or excited when receiving a video game-based treatment, which could influence their responses or cognitive test performance. Lastly, the choice of measures used to assess outcomes can also introduce biases.
Results		
Study Selection	7	Tables 1 and 2 summarize studies exploring the effects of video game-based interventions for cognitive rehabilitation in subjects with acquired brain injury. The studies originated from a diverse range of samples from the (e.g. USA, Europe, Latin America, and Asia). The search encompassed the years 2012–2024
Synthesis Results	8	Among the most relevant findings of the systematic review, it was observed that video game-based interventions were useful for cognitive rehabilitation and also showed a positive effect on well-being.
Discussion		
Limitations of the Evidence	9	The evidence examining video games as part of cognitive rehabilitation treatment for acquired brain injury was obtained using different methodological approaches. Moreover, most studies focused on specific populations, which limits the generalizability of findings to other age groups or individuals without specific conditions. Additionally, some studies are based on specific interventions or programs, which restricts the applicability of results to other interventions or therapeutic approaches. Therefore, caution is required when extrapolating these results to broader populations.
Interpretation	10	Video games as a tool for cognitive rehabilitation can have positive effects on well-being, memory, attention, executive functions, and visual processing.

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