International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
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ARTICLE TITLE	THE IMPACT OF DIGITAL COGNITIVE REHABILITATION TOOLS ON THE SOCIAL INTEGRATION OF PEOPLE WITH BRAIN INJURIES
DOI	https://doi.org/10.31435/ijitss.1(49).2026.4945
RECEIVED	27 December 2025
ACCEPTED	02 March 2026
PUBLISHED	16 March 2026
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THE IMPACT OF DIGITAL COGNITIVE REHABILITATION TOOLS ON THE SOCIAL INTEGRATION OF PEOPLE WITH BRAIN INJURIES

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ABSTRACT

Traumatic brain injury (TBI) is a major global health concern, frequently resulting in persistent cognitive impairments that limit social integration and quality of life. Social integration—defined as meaningful participation in interpersonal relationships, employment, and community life—is strongly influenced by deficits in memory, attention, executive functioning, and social cognition. While traditional cognitive rehabilitation has demonstrated clinical benefits, its accessibility and long-term sustainability are often constrained by cost, resource demands, and reliance on in-person delivery. In recent years, digital cognitive rehabilitation tools, including mobile applications, virtual reality (VR), and tele-rehabilitation platforms, have emerged as promising alternatives that enable scalable, adaptive, and home-based interventions.

This narrative review synthesizes current evidence on the impact of digital cognitive rehabilitation on social integration following TBI, with attention to clinical outcomes, socio-economic implications, and technological barriers. Findings suggest that digital interventions are effective in improving core cognitive domains and may indirectly enhance social functioning by supporting communication, self-efficacy, motivation, and participation in daily activities. VR-based approaches, in particular, offer ecologically valid environments that facilitate the transfer of cognitive gains to real-world social contexts. Economic evidence indicates that digital rehabilitation is often cost-effective or cost-saving, reducing healthcare system burden and supporting return-to-work outcomes.

However, direct evidence linking digital cognitive rehabilitation to measurable social integration outcomes remains limited, and significant barriers persist related to digital access, usability, literacy, and ethical considerations. Future research should prioritize participation-level outcomes, long-term follow-up, and inclusive implementation strategies to maximize the social and societal benefits of digital rehabilitation after brain injury.

KEYWORDS

Brain Injury, Digital Cognitive Rehabilitation, Virtual Reality, Social Integration

CITATION

Miszela Kałachurska, Martyna Rożek, Constancia Esther Guy, Maria Nowakowska, Aleksandra Lisowska, Bartosz Nowak, Oliwia Jerzyńska, Maria Sierant, Aleksandra Kowalewska-Kurek, Mateusz Gural. (2026) The Impact of Digital Cognitive Rehabilitation Tools on the Social Integration of People With Brain Injuries. *International Journal of Innovative Technologies in Social Science*. 1(49). doi: 10.31435/ijitss.1(49).2026.4945

I. Introduction

Brain injuries, including traumatic brain injury (TBI), represent a major global health challenge due to their high incidence and complex clinical consequences. It is estimated that approximately 69 million people worldwide sustain a TBI each year, leading to long-term cognitive, emotional, and social impairments regardless of injury severity (Chi et al., 2025; Dewan et al., 2019). Deficits in memory, attention, executive functions, and perception are considered among the most burdensome consequences of TBI, as they directly affect individuals' ability to function independently and to participate in social life. Social integration—understood as active participation in interpersonal relationships, employment, leisure activities, and everyday life—is a key determinant of quality of life in individuals after brain injury; its impairment is associated with reduced psychological well-being and limited independence (Chi et al., 2025).

Traditional cognitive rehabilitation focuses on therapist-led interventions delivered by specialists such as neuropsychologists and occupational therapists and includes memory exercises, attention training, and strategy-based approaches. Although these methods have demonstrated effectiveness in improving specific cognitive functions, their reach and accessibility are often limited by high costs, dependence on direct clinician involvement, and logistical challenges related to ensuring continuity of therapy for patients in home environments or in settings with limited healthcare resources.

In recent years, there has been growing interest in digital cognitive rehabilitation, which utilizes computer-based technologies, mobile applications, and virtual reality (VR) environments to deliver engaging, adaptive, and accessible therapeutic interventions. Mobile applications provide cognitive tasks and skills training, often

incorporating progress monitoring and adaptive difficulty levels (Jiao, 2025). In contrast, VR systems create immersive environments that simulate everyday situations, potentially supporting cognitive rehabilitation in a more ecologically valid context than traditional exercises (Zhang et al., 2025). The integration of artificial intelligence and real-time feedback further enhances therapy personalization and the potential effectiveness of these tools. Beyond improvements in cognitive functioning alone, these technologies have the potential to influence social functioning, for example by enhancing social, communication, and motivational skills, as well as by increasing engagement in rehabilitation through elements of gamification and immersion.

Despite promising findings regarding the effectiveness of digital interventions, a gap remains in the literature concerning their impact on the social integration of individuals after brain injury, as well as with regard to technological barriers and the socio-economic aspects of implementation. A narrative review offers a unique opportunity to synthesize available clinical, technological, and socio-economic evidence, allowing for the identification of areas requiring further research as well as practical implications for health policy and healthcare systems. The key questions addressed in this review include: (1) what effects digital cognitive rehabilitation—particularly mobile applications and VR—has on social integration following brain injury; (2) what the main technological barriers to their use are; and (3) what socio-economic benefits may result from their implementation in long-term care.

II. Methodology

This study was conducted as a narrative review aimed at synthesizing current evidence on the impact of digital cognitive rehabilitation tools on social integration in individuals after traumatic brain injury (TBI), with particular focus on mobile applications and virtual reality (VR). A targeted literature search was performed in PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar using keywords related to TBI, digital cognitive rehabilitation, virtual reality, mobile health, and social participation. Priority was given to peer-reviewed articles published within the last 5–7 years, supplemented by earlier key publications to provide clinical context. Eligible studies included clinical trials, observational and qualitative studies, reviews, and health technology or economic evaluations. Due to the narrative nature of the review, findings were synthesized thematically without formal quality assessment, with attention to clinical outcomes, social functioning, technological barriers, and socio-economic implications.

III. Results

1. Digital cognitive rehabilitation tools – an overview

1.1 Mobile applications

Mobile applications represent one of the most scalable and accessible forms of digital cognitive rehabilitation and have gained substantial popularity in both clinical practice and self-managed rehabilitation programs. Commercial platforms such as *CogniFit*, *Lumosity*, and *BrainHQ* provide structured cognitive training tasks targeting attention, memory, processing speed, and executive functions, often supported by adaptive algorithms that adjust task difficulty based on user performance (Cha, 2024). In clinical and research settings, more specialized software solutions, including *RehaCom* and app-based cognitive training programs integrated into multidisciplinary rehabilitation pathways, have demonstrated utility in patients with acquired brain injury, including traumatic brain injury (TBI) (Fernández et al., 2012).

The primary training mechanisms employed by mobile applications include repetitive task practice, adaptive difficulty scaling, immediate performance feedback, and motivational elements such as scoring systems and gamification (Cha, 2024; Lumsden et al., 2016). These features are designed to promote neuroplasticity through repeated cognitive engagement while enhancing adherence to therapy, which is a critical factor in long-term rehabilitation outcomes. Importantly, mobile applications allow for frequent, home-based training, reducing dependence on in-person clinical sessions and potentially facilitating the transfer of cognitive improvements to everyday activities and social participation. Some studies suggest that improved attentional control and executive functioning achieved through app-based training may indirectly support social functioning by enhancing communication, task initiation, and social problem-solving skills (Cha, 2024).

1.2 Virtual Reality (VR/AR)

Virtual reality (VR) and augmented reality (AR) technologies offer more immersive and ecologically valid approaches to cognitive rehabilitation by enabling patients to engage in simulated real-world environments. VR-based interventions can be classified into non-immersive (desktop-based), semi-immersive, and fully immersive systems utilizing head-mounted displays, each differing in the level of sensory engagement and user interaction (Gao et al., 2021). Neurorehabilitation-specific platforms such as *VRRS*, *MindMotion PRO*, and custom-designed VR environments have been applied to cognitive and functional training after brain injury, including scenarios that simulate daily activities, navigation, and social interactions (Calabrò et al., 2023; Perez-Marcos et al., 2017).

A key advantage of VR lies in its capacity to integrate cognitive demands with multisensory stimulation, combining visual, auditory, and proprioceptive inputs within goal-oriented tasks. This sensory–cognitive integration may enhance ecological validity and promote generalization of cognitive gains to real-life social contexts, such as managing conversations, multitasking in social environments, or navigating community settings (Parsons, 2015). Furthermore, VR environments can be tailored to gradually increase task complexity and social demands, offering a safe and controlled space for practicing skills that are critical for social reintegration. Emerging evidence suggests that VR-based cognitive rehabilitation may improve motivation, self-efficacy, and engagement, factors that are closely linked to social participation and long-term functional recovery (Maggio et al., 2019).

1.3 Tele-rehabilitation platforms

Tele-rehabilitation platforms integrate digital cognitive training tools with remote supervision and communication, enabling continuity of rehabilitation beyond traditional clinical settings. These platforms typically include features for remote monitoring of cognitive performance, adherence, and training intensity, allowing clinicians to assess progress asynchronously and adjust intervention parameters as needed (Brennan et al., 2009). In addition, therapist–patient interaction is facilitated through synchronous (e.g., video consultations) or asynchronous (e.g., messaging systems, feedback dashboards) communication, supporting personalized goal setting and sustained therapeutic engagement (Brennan et al., 2009; Estebanez-Pérez et al., 2026).

Tele-rehabilitation models have been increasingly adopted in neurorehabilitation, particularly following the COVID-19 pandemic, and have demonstrated feasibility and effectiveness in maintaining cognitive and functional outcomes while reducing geographical and logistical barriers to care (Laver et al., 2020). From a socio-economic perspective, tele-rehabilitation platforms may lower costs associated with travel, in-person visits, and prolonged institutional care, while supporting long-term rehabilitation in home environments. By enabling ongoing professional support and structured cognitive training, these platforms may contribute to improved social reintegration, reduced caregiver burden, and more efficient use of healthcare resources (Chi et al., 2025).

Table 1. A comparative overview of commonly used mobile applications, virtual reality systems, and tele-rehabilitation platforms.

Tool category	Examples (commercial / clinical)	Core functions	Targeted cognitive domains	Level of ecological validity	Social functioning relevance	Key literature sources
Mobile applications	CogniFit, Lumosity, BrainHQ (commercial); RehaCom (clinical)	Repetitive cognitive tasks, adaptive difficulty, performance feedback, gamification	Attention, memory, processing speed, executive functions	Low–moderate	Indirect (improved attention, communication efficiency, task initiation)	(Cha, 2024; Fernández et al., 2012; Hardy et al., 2015)
Virtual Reality (VR/AR) systems	VRRS, MindMotion PRO, custom neurorehabilitation VR environments	Immersive task-based training, multisensory stimulation, real-life simulations	Executive functions, attention, working memory, visuospatial skills	High	Direct (training social interaction, multitasking, navigation, community participation)	(Maggio et al., 2019; Parsons, 2015; Rizzo & Koenig, 2017)
Tele-rehabilitation platforms	Integrated digital rehab platforms with clinician dashboards	Remote monitoring, asynchronous/synchronous therapist feedback, progress tracking	Cognitive and functional domains (depending on integrated tools)	Moderate	Moderate–high (continuity of care, sustained engagement, caregiver involvement)	(Chen et al., 2015; Chi et al., 2025; Laver et al., 2020)

2. Influence on Social Functioning and Social Integration

Traumatic brain injury (TBI) frequently results in long-term disturbances that extend beyond physical and cognitive impairments to profoundly affect social functioning and community integration. Social integration—understood as meaningful participation in interpersonal relationships, family roles, employment, leisure activities, and community life—is a key determinant of long-term quality of life after TBI(Cicerone, 2004). Cognitive impairments, particularly in memory, attention, executive functions, and social cognition, are among the strongest predictors of poor social outcomes and reduced participation, regardless of injury severity (Lu et al., 2023). As a result, rehabilitation strategies that improve cognitive functioning may indirectly support social reintegration. In recent years, digital cognitive rehabilitation tools—including mobile applications, virtual reality (VR), and tele-rehabilitation platforms—have emerged as promising interventions not only for cognitive recovery but also for broader psychosocial functioning (Chi et al., 2025).

2.1 Cognitive improvement as a pathway to social integration

The relationship between cognitive recovery and social integration after TBI is multifaceted and mediated by several core cognitive domains. Memory, attention, and executive functions are fundamental to effective social interaction, as they enable individuals to process social cues, maintain conversational flow, regulate behavior, and adapt flexibly to changing social contexts. Deficits in attention can impair the ability to follow conversations or remain engaged in social situations, while memory impairments may lead to difficulties remembering names, social commitments, or contextual information, contributing to social withdrawal and embarrassment (Dikmen et al., 2009). Executive dysfunction, including impaired planning, impulse control, and self-monitoring, is particularly detrimental to social behavior, often resulting in inappropriate responses, reduced insight, and interpersonal conflict (Rabinowitz & Levin, 2014).

Digital cognitive rehabilitation interventions have demonstrated efficacy in improving these cognitive domains in individuals with TBI. A recent systematic review and meta-analysis by Chi et al. found that digital cognitive interventions significantly improved global cognition, attention, working memory, and executive function compared to control conditions (Chi et al., 2025). Although these interventions primarily target cognitive performance, improvements in these foundational skills may facilitate better social functioning by enabling individuals to engage more effectively in interpersonal interactions and daily activities.

Moreover, social cognition—defined as the ability to perceive, interpret, and respond appropriately to social information—plays a crucial role in social integration after TBI. Impairments in emotion recognition, theory of mind, and perspective-taking are common following brain injury and are strongly associated with poor social outcomes (Rodríguez-Rajo et al., 2022). Emerging evidence suggests that digitally mediated cognitive training, particularly when delivered in immersive and interactive formats such as VR, may support social cognitive processing by providing repeated exposure to complex, socially relevant stimuli (Parsons, 2015). While direct evidence linking digital cognitive rehabilitation to improvements in social cognition remains limited, the theoretical basis for such effects is supported by neuroplasticity models emphasizing experience-dependent learning in ecologically valid contexts.

2.2 Translation of cognitive gains into social behavior

The translation of cognitive improvements into observable social behavior is not automatic but depends on the extent to which rehabilitation tasks resemble real-world demands. Traditional cognitive rehabilitation often relies on decontextualized exercises, which may limit generalization to everyday social situations. In contrast, digital tools—especially VR-based interventions—offer higher ecological validity by simulating real-life environments such as shops, public transport, workplaces, or social gatherings (Parsons, 2015). These environments require simultaneous engagement of multiple cognitive processes, including attention, memory, executive control, and emotional regulation, thereby approximating the cognitive load of real-world social participation.

Participation-oriented outcomes, such as community integration and social activity involvement, are increasingly recognized as essential endpoints in TBI rehabilitation (Cicerone, 2004). Studies using the Community Integration Questionnaire (CIQ) consistently show that individuals with TBI experience persistent limitations in social and productive activities years after injury. Cognitive functioning has been identified as a significant predictor of CIQ scores, suggesting that improvements in cognition may support better social participation over time (Lu et al., 2023).

Digital cognitive rehabilitation may also influence social behavior indirectly by enhancing self-efficacy and confidence. Patients who perceive improvements in their cognitive abilities often report increased

willingness to engage in social situations and reduced avoidance behaviors. This is particularly relevant given that social anxiety, fear of failure, and reduced self-confidence are common barriers to social participation after TBI (Ownsworth & McKenna, 2004). By providing structured, adaptive, and feedback-driven training, digital tools may foster a sense of mastery and predictability that supports re-engagement in social roles.

2.3 Examples of Social Outcomes and Participation Effects

Although relatively few studies explicitly measure social integration as a primary outcome of digital cognitive rehabilitation, available evidence suggests several positive social effects. Observational studies and secondary analyses of intervention trials report increased participation in social and leisure activities, improved communication, and reduced social isolation following cognitive rehabilitation programs that include digital components (Elbogen et al., 2019). These outcomes are particularly evident when digital interventions are embedded within broader, multidisciplinary rehabilitation frameworks that address psychosocial needs alongside cognitive training.

Reduction of social isolation is a critical outcome, as individuals with TBI are at increased risk of loneliness and diminished social networks. Difficulties in communication, emotional regulation, and social problem-solving often lead to withdrawal from previously valued relationships and activities (Morton & Wehman, 1995). Digital rehabilitation tools may mitigate these effects by improving the cognitive and emotional skills necessary for sustained social engagement and by enabling continuity of rehabilitation in home environments, thereby reducing barriers to long-term participation.

Improvements in communication are another reported social benefit. Enhanced attention and executive control may support better conversational turn-taking, topic maintenance, and response inhibition, while improved working memory may facilitate understanding and recall of conversational content. Although these changes are subtle and not always captured by standardized measures, they are frequently described by patients and caregivers as meaningful improvements in everyday interactions (Elbogen et al., 2019).

2.4 Clinical Evidence and Qualitative Perspectives

Qualitative studies, case reports, and patient narratives provide valuable insights into how digital cognitive rehabilitation influences social functioning from the perspective of individuals with TBI and their families. Qualitative analyses of VR-based rehabilitation programs reveal that patients often perceive improvements not only in cognitive performance but also in social confidence, emotional regulation, and readiness to engage in community activities (Parsons, 2015). Participants frequently describe virtual environments as “safe spaces” for practicing challenging tasks without fear of social judgment, which may facilitate gradual re-exposure to real-world social situations.

Caregiver and family interviews further highlight perceived improvements in interpersonal behavior, including reduced irritability, improved emotional control, and greater initiative in social engagement following participation in digital cognitive rehabilitation programs (Elbogen et al., 2019). These changes, although difficult to quantify, are highly relevant to long-term social reintegration and family functioning.

Importantly, quality of life outcomes often reflect subjective perceptions of social participation rather than objective measures alone. Research indicates that quality of life and social integration, while related, represent distinct constructs in TBI recovery (Cicerone, 2004). Digital rehabilitation may therefore contribute to improved quality of life by enhancing perceived competence and autonomy, even when objective participation measures show modest change.

In summary, digital cognitive rehabilitation tools appear to influence social functioning and integration after TBI through multiple, interacting pathways. Improvements in memory, attention, executive function, and social cognition provide a cognitive foundation for adaptive social behavior, while ecologically valid training environments support the generalization of cognitive gains to real-world contexts. Clinical and qualitative evidence suggests that these interventions may reduce social isolation, enhance communication, and increase participation in social activities, particularly when integrated into comprehensive rehabilitation programs. Although further research is needed to establish direct causal links between digital cognitive rehabilitation and social integration outcomes, existing evidence supports the inclusion of social participation as a key consideration in the design and evaluation of digital rehabilitation interventions.

3. Socio-Economic Benefits of Digital Cognitive Rehabilitation

3.1 Costs versus Effectiveness: Traditional versus Digital Rehabilitation

A central issue in evaluating the socio-economic impact of digital cognitive rehabilitation is the relationship between costs and therapeutic effectiveness when compared with traditional, in-person rehabilitation models. Conventional rehabilitation typically relies on repeated face-to-face sessions delivered in clinical settings, requiring physical infrastructure, continuous professional supervision, and frequent patient travel. These elements contribute substantially to direct healthcare costs as well as indirect costs borne by patients and caregivers, such as transportation expenses, time off work, and organizational burden. In contrast, digital rehabilitation—delivered through tele-rehabilitation platforms, mobile cognitive training applications, or immersive virtual reality (VR) systems—restructures service delivery by decentralizing care and enabling therapy to be conducted in home environments.

Systematic economic evaluations indicate that digital rehabilitation is often **cost-neutral or cost-saving** while maintaining comparable clinical outcomes. A comprehensive systematic review of cost-utility analyses by Baffert et al., although mostly on cardiological patients, demonstrated that telerehabilitation interventions frequently achieved similar health outcomes to conventional rehabilitation at lower overall costs, particularly when travel-related expenses and clinician time were included in the analysis (Baffert et al., 2023). Importantly, several studies included in this review classified digital rehabilitation as a “dominant” intervention—meaning it was both less costly and at least as effective as standard care. These findings suggest that digital modalities may optimize resource allocation without compromising therapeutic quality.

Cost-effectiveness is commonly assessed using economic models such as cost-utility analysis (CUA), which integrates financial costs with outcomes expressed in quality-adjusted life years (QALYs). Evidence synthesized in recent meta-analyses indicates that telerehabilitation interventions often fall below commonly accepted willingness-to-pay thresholds, reinforcing their economic viability within public healthcare systems (Shambushankar et al., 2025). Moreover, home-based digital rehabilitation reduces the need for repeated outpatient visits, thereby decreasing operational costs related to facility use, administrative overhead, and staffing requirements. A systematic review focusing on neurological and cardiological populations further confirmed that telerehabilitation can reduce direct medical costs while delivering equivalent functional outcomes (Del Pino et al., 2022).

In the context of cognitive rehabilitation following traumatic brain injury (TBI), these economic advantages are particularly relevant. Cognitive rehabilitation often requires long-term intervention, and sustained clinic-based therapy can be financially burdensome for both health systems and patients. Digital cognitive interventions, including computer-based and VR-based training, allow for scalable delivery and adaptive intensity, which may enhance cost-effectiveness over extended rehabilitation periods. A meta-analysis examining digital cognitive interventions in TBI populations reported significant improvements in cognitive function with digital tools, supporting the premise that cost reductions are not achieved at the expense of clinical efficacy (Chi et al., 2025). Taken together, current economic evidence suggests that digital cognitive rehabilitation represents a financially efficient alternative to traditional rehabilitation models, especially when evaluated using robust economic frameworks that account for both direct and indirect costs.

3.2 Extension of Effective Work Participation and Reduction of Absenteeism

Beyond direct healthcare costs, digital cognitive rehabilitation has significant implications for **workforce participation, productivity, and broader societal economic outcomes**. Individuals recovering from brain injuries frequently experience prolonged work absence due to cognitive deficits, fatigue, and reduced executive functioning. Traditional rehabilitation schedules—often involving frequent clinic visits—can further disrupt employment and delay return-to-work processes. Digital rehabilitation, by offering flexible and remote access to therapy, mitigates many of these barriers and supports earlier and more sustainable occupational reintegration.

One of the most tangible socio-economic benefits of digital rehabilitation is the **reduction of indirect costs associated with productivity loss**. Remote rehabilitation minimizes time spent traveling to healthcare facilities and allows patients to integrate therapy sessions into daily routines, thereby reducing work absenteeism and travel burden. Systematic reviews have found that telerehabilitation offsets productivity losses associated with travel time and lost wages compared to traditional rehabilitation services, contributing to significant economic benefits at both individual and societal levels (Shambushankar et al., 2025). These time-related savings are particularly important for working-age individuals recovering from TBI, for whom cognitive rehabilitation is a prerequisite for effective labor market participation.

Improved cognitive functioning achieved through digital rehabilitation also plays a critical role in enhancing workplace performance. Meta-analytic evidence indicates that digital cognitive interventions can significantly improve attention, executive functioning, and processing speed in individuals with TBI (Chi et al., 2025). These domains are directly linked to job performance, decision-making, and social interaction in professional environments. By facilitating targeted cognitive recovery, digital rehabilitation may shorten the duration of work incapacity and reduce the likelihood of long-term disability, thereby generating long-term productivity gains at the societal level.

From a macroeconomic perspective, even modest improvements in return-to-work rates among individuals with acquired brain injuries can yield substantial economic benefits. Reduced reliance on disability benefits, increased tax contributions, and lower caregiver dependency collectively contribute to positive socio-economic outcomes. While direct productivity data specific to cognitive telerehabilitation remains limited, broader evidence from telehealth economic analyses supports the conclusion that remote rehabilitation interventions are associated with favorable productivity-related outcomes and reduced societal costs (Shambushankar et al., 2025). Consequently, digital cognitive rehabilitation should be viewed not only as a healthcare intervention but also as an investment in human capital and workforce sustainability.

3.3 Reduction of Healthcare System Burden and Institutional Costs

Another critical socio-economic advantage of digital cognitive rehabilitation lies in its capacity to **reduce the burden on healthcare systems and institutional care structures**. Traditional rehabilitation services are resource-intensive, requiring specialized facilities, multidisciplinary teams, and ongoing in-person supervision. As demand for rehabilitation services increases—driven by aging populations and improved survival following neurological injury—healthcare systems face growing challenges related to capacity, workforce shortages, and financial sustainability.

Tele-rehabilitation and digital cognitive rehabilitation tools offer a scalable solution to these challenges by enabling remote monitoring, asynchronous therapy delivery, and more efficient use of clinical expertise. Studies evaluating home-based telerehabilitation have shown that digital interventions can reduce the frequency of outpatient visits and shorten hospital stays without compromising patient outcomes (Grigorovich et al., 2022). By shifting portions of rehabilitation from institutional settings to home environments, healthcare systems can reallocate resources toward patients with more complex needs and reduce congestion in outpatient services.

Economic evaluations further indicate that digital rehabilitation can lower institutional costs by decreasing readmission rates and preventing secondary complications through continuous engagement and monitoring. A recent clinical and economic evaluation of a digital telemedicine intervention in neurological populations found that digital care pathways were associated with lower per-patient costs and favorable cost-effectiveness ratios compared with standard care (Gandolfi et al., 2026). These findings align with broader telehealth literature suggesting that remote interventions can improve continuity of care while simultaneously reducing acute care utilization.

Importantly, digital rehabilitation also enhances service accessibility in underserved or rural areas, where traditional rehabilitation services may be limited or unavailable. By reducing geographical disparities in access to cognitive rehabilitation, digital tools contribute to more equitable healthcare delivery and may prevent long-term institutionalization resulting from inadequate post-acute care. From a system-level perspective, the integration of tele-rehabilitation into standard care pathways represents a strategic approach to cost containment, capacity expansion, and sustainable healthcare planning.

4. Technological and Social Barriers

Despite promising evidence that digital cognitive rehabilitation tools such as mobile applications and virtual reality (VR) can support cognitive recovery and potentially foster social reintegration after acquired brain injury, multiple interlinked technological and social barriers limit their equitable adoption and sustained use.

Access to technology is constrained by geographic and economic disparities that contribute to a persistent digital divide, with individuals in rural areas or lower-income groups having less access to reliable broadband, up-to-date devices, and supportive infrastructure necessary for advanced digital interventions (Hepburn et al., 2025). Even when hardware is available, usability challenges — including complex interfaces, frequent updates, and inadequate ergonomic design — can seriously limit engagement for people with cognitive or motor impairments (Henni et al., 2022; Zhou et al., 2024).

User skills and digital literacy are critical determinants of uptake: older adults and people with cognitive deficits often lack confidence, experience, and training in using digital tools, leading to frustration, avoidance, or under-utilization of potentially beneficial technologies; this digital literacy gap is further compounded by sensory changes and limited supportive training for users and caregivers alike (Wilson et al., 2021; Álvarez-Aguado et al., 2025). Additionally, adaptation challenges extend beyond skill acquisition to issues of motivation and self-efficacy, as many users report difficulty integrating unfamiliar technologies into daily routines without structured guidance.

Acceptance and engagement are shaped by a complex balance of motivators and deterrents: while perceived usefulness and caregiver encouragement can enhance sustained use, negative attitudes toward technology, concerns about its relevance, and lack of co-design with end users can decrease willingness to adopt and persist with digital interventions (Madeira et al., 2025). Caregivers and therapists play a pivotal role in facilitating engagement, yet their own attitudes and skills influence user adoption, highlighting the need for comprehensive training and support strategies integrated into implementation frameworks.

Ethical and legal barriers also pose significant hurdles, particularly concerning data privacy, security, and consent: digital rehabilitation tools routinely collect sensitive health and behavioral data, raising concerns about unauthorized access, data misuse, and unclear consent processes, especially in individuals with cognitive limitations; robust regulatory frameworks and transparent consent mechanisms are essential to build trust and protect users' autonomy (Goldschmitt et al., 2025; Jabin et al., 2025). Addressing these technological, educational, motivational, and ethical barriers is critical to ensuring that digital cognitive rehabilitation tools can meaningfully contribute to social participation and inclusion after brain injury.

IV. Discussion

1. Evidence from the Literature: Main Trends and Research Gaps

Traumatic brain injury (TBI) is a leading cause of long-term disability worldwide, affecting tens of millions of individuals each year and frequently resulting in persistent cognitive and social impairments (Dewan et al., 2019). Deficits in attention, memory, executive functions, and social cognition are well established as key predictors of reduced participation and limited community integration after TBI (Cicerone, 2004; Dikmen et al., 2009; Lu et al., 2023; Rabinowitz & Levin, 2014). In this context, digital cognitive rehabilitation has emerged as a promising approach to address both the clinical and systemic limitations of traditional rehabilitation models.

Systematic reviews and meta-analyses consistently demonstrate that digital cognitive interventions, including mobile applications and virtual reality (VR), are effective in improving core cognitive domains following brain injury (Cha, 2024; Chi et al., 2025; Zhang et al., 2025). VR-based interventions, in particular, appear to yield moderate-to-large effects on cognitive and psychological outcomes, likely due to their immersive, multisensory, and ecologically valid nature (Maggio et al., 2019; Parsons, 2015; Zhang et al., 2025). Mobile applications and computer-based platforms facilitate intensive, repetitive training and long-term engagement, especially when enhanced by adaptive algorithms and gamification strategies (Cha, 2024; Fernández et al., 2012; Lumsden et al., 2016). Emerging evidence also highlights the role of artificial intelligence in personalizing intervention intensity and progression, potentially optimizing therapeutic outcomes (Jiao, 2025).

Despite robust evidence for cognitive improvement, significant gaps remain regarding social integration outcomes. Participation-level indicators—such as employment, social relationships, and community involvement—are infrequently included as primary endpoints in digital rehabilitation studies (Chi et al., 2025; Cicerone, 2004). Most available evidence suggests indirect effects on social integration, mediated through cognitive recovery rather than direct measurement of social participation (Lu et al., 2023). Additionally, heterogeneity in outcome measures, intervention duration, and technological platforms limits comparability across studies and underscores the need for standardized frameworks focused on real-world functioning.

2. Integration of Digital Rehabilitation into Healthcare Systems

The literature strongly suggests that the effectiveness of digital cognitive rehabilitation depends on its integration into structured healthcare pathways rather than isolated or unsupervised use. Tele-rehabilitation models enable remote delivery of cognitive training while maintaining professional oversight, thereby addressing accessibility barriers and continuity of care challenges (Brennan et al., 2009; Calabrò et al., 2023; Laver et al., 2020). Randomized controlled trials demonstrate that telerehabilitation—including non-immersive VR—can produce clinical benefits comparable to conventional in-person rehabilitation, even in patients with severe acquired brain injury (Calabrò et al., 2023).

Hybrid care models, combining in-person therapy with home-based digital interventions, allow for increased therapy intensity without proportional increases in healthcare resource utilization. Virtual environments with high ecological validity support the transfer of cognitive gains to daily activities by simulating real-life tasks and social situations (Maggio et al., 2019; Parsons, 2015). Furthermore, evidence supporting the reliability of tele-assessment strengthens the feasibility of remote monitoring and outcome evaluation in routine clinical practice (Estebanez-Pérez et al., 2026).

However, successful implementation requires systemic readiness, including clinician training, technical support, and alignment with regulatory and reimbursement frameworks. Without these elements, the potential of digital rehabilitation to improve long-term functional and social outcomes may remain underutilized.

3. Socio-Economic Consequences

Digital cognitive rehabilitation has important socio-economic implications for patients, families, and healthcare systems. Economic evaluations consistently indicate that telerehabilitation is cost-effective or cost-saving compared with traditional in-person rehabilitation, particularly when indirect costs—such as travel, productivity loss, and caregiver burden—are considered (Baffert et al., 2023; Del Pino et al., 2022; Grigorovich et al., 2022; Shambushankar et al., 2025). Home-based digital interventions reduce institutional resource demands and support more efficient allocation of clinical services.

At the individual level, improved cognitive functioning is closely linked to employment outcomes and sustained workforce participation after TBI (Ownsworth & McKenna, 2004). Given that cognitive impairment is a major barrier to return to work, digital interventions that enhance executive function and attention may contribute to improved vocational reintegration and reduced long-term dependency. Mobile-based cognitive rehabilitation combined with structured support has demonstrated benefits in psychosocial functioning and behavior regulation, which are critical for maintaining social roles and interpersonal relationships (Elbogen et al., 2019; Morton & Wehman, 1995).

Nevertheless, socio-economic benefits are not uniformly distributed. Barriers related to digital access, usability, and literacy remain substantial, particularly among older adults and individuals with cognitive impairments (Henni et al., 2022; Hepburn et al., 2025; Wilson et al., 2021; Zhou et al., 2024; Álvarez-Aguado et al., 2025). Acceptance of digital interventions is further influenced by perceived usefulness, caregiver involvement, and user-centered design (Madeira et al., 2025). Ethical and legal challenges—including data privacy, informed consent, and autonomy—require particular attention in populations with cognitive vulnerability (Goldschmitt et al., 2025; Jabin et al., 2025). Addressing these barriers is essential to prevent digital rehabilitation from exacerbating existing health inequities.

Summary and Implications

In summary, digital cognitive rehabilitation represents an effective and scalable approach for improving cognitive outcomes after TBI, with indirect but potentially meaningful implications for social integration. While evidence for cognitive benefits is strong, future research should prioritize participation-level outcomes, long-term follow-up, and implementation strategies. When thoughtfully integrated into healthcare systems and supported by appropriate policy and ethical frameworks, digital rehabilitation tools have the potential to enhance not only individual recovery trajectories but also the sustainability and equity of neurorehabilitation services.

V. Conclusions

Digital cognitive rehabilitation tools offer an effective and scalable approach to supporting recovery after traumatic brain injury, with clear benefits for cognitive functioning and promising implications for social integration. By improving core cognitive domains and providing ecologically valid, accessible training environments, these interventions may facilitate greater participation in social, community, and occupational life. In addition, digital rehabilitation has the potential to reduce healthcare costs and improve long-term system efficiency. However, evidence directly linking digital interventions to social integration outcomes remains limited, and barriers related to access, usability, and equity persist. Future research should prioritize participation-focused outcomes and inclusive implementation strategies to fully realize the social and societal benefits of digital cognitive rehabilitation.

Conflicts of interest: No conflicts of interest to declare.

Abbreviations:

ABI - Acquired Brain Injury
AI - Artificial Intelligence
AR - Augmented Reality
CIQ - Community Integration Questionnaire
CUA - Cost-Utility Analysis
mHealth - Mobile Health
QALY - Quality-Adjusted Life Year
RCT - Randomized Controlled Trial
TBI - Traumatic Brain Injury
VR - Virtual Reality

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