Current Psychology
https://doi.org/10.1007/s12144-024-06526-z

Remote delivered cognitive rehabilitation programs in Acquired Brain Injury: a systematic review of methods and outcomes

Joana Câmara[1,2,7] · Andreia Geraldo[3,4,5] · Manuela Vilar[1] · Eduardo Fermé[2,6]

Accepted: 5 August 2024

Abstract

Remote delivered cognitive rehabilitation programs (r-CRP) are increasingly recognized as alternative and complementary intervention approaches to traditional cognitive rehabilitation (CR) in the context of several neurological conditions, including acquired brain injuries (ABI). This systematic review examines the methodological characteristics of currently available r-CRP for ABI patients and investigates their impact on cognitive and noncognitive outcomes. A systematic search was performed on EBSCOhost, PubMed, and Web of Science, complemented by a manual search. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses and the Cochrane Collaboration Guidelines were followed. Out of 1624 studies, a total of 19 studies were included. The results demonstrate that most r-CRP were administered to middle-aged community-dwelling chronic stroke survivors and that there was no consensus regarding assessment and intervention protocols. Moreover, most r-CRP were delivered through information and communication technologies (ICTs), primarily relying on cognitive training (CT) interventions addressing multiple cognitive domains (e.g., attention, memory). These ICT-based CT programs included tasks with low ecological validity, i.e., tasks with limited real-world application (e.g., cancelation tasks with artificial stimuli), and were asynchronous, meaning that participants performed the sessions at their own pace, without real-time monitoring from a therapist. In terms of the impact of r-CRP, class I studies reported mixed and inconsistent results regarding the effect of this mode of delivery on cognitive and noncognitive outcomes of ABI patients while supporting its high feasibility and acceptability among patients. Specific recommendations for future research are provided to improve the methodological quality of clinical studies and establish the evidence base for r-CRP.

Keywords Cognitive Rehabilitation · Acquired Brain Injury · Remote delivered interventions · Protocols · Efficacy · Cognitive and noncognitive outcomes

Introduction

Acquired brain injuries (ABI) can be described as a set of non-congenital and non-degenerative conditions affecting the brain as a result of traumatic and non-traumatic injuries (Campbell, 2004). These injuries can lead to a broad spectrum of transient or chronic deficits, which can be quite disabling in the short and long term. Worldwide, the two most common types of ABI are stroke and traumatic brain injury (TBI), accounting for high mortality and morbidity rates

✉ Joana Câmara
joana.camara@arditi.pt

1 Center for Research in Neuropsychology and Cognitive and Behavioral Intervention (CINEICC), Faculty of Psychology and Education Sciences, University of Coimbra, Coimbra, Portugal

2 NOVA Laboratory for Computer Sciences and Informatics (NOVA LINCS), University of Madeira, Funchal, Portugal

3 HEI-Lab: Digital Human-Environment Interaction Labs, Lusófona University, Lisboa, Portugal

4 Laboratory of Neuropsychophysiology, Faculty of Psychology and Education Sciences, University of Porto, Porto, Portugal

5 School of Health, Polytechnic Institute of Porto, Porto, Portugal

6 Faculty of Exact Sciences and Engineering, University of Madeira, Funchal, Portugal

7 Agência Regional para o Desenvolvimento da Investigação Tecnologia e Inovação (ARDITI), Funchal, Portugal

Published online: 01 October 2024

(Tagliaferri et al., 2006). Generally, ABI negatively affects several dimensions of human functioning, namely the physical, the cognitive, the emotional and the psychosocial (Cernich et al., 2010; Entwistle & Newby, 2013). Considering ABI's multidimensional consequences, patients' rehabilitation is often undertaken by a multidisciplinary team, including neurologists, physiatrists, rehabilitation nurses, neuropsychologists, physical and occupational therapists, speech and language therapists, nutritionists, and social workers (Brasure et al., 2013).

Neuropsychological rehabilitation (NR) is a non-pharmacological approach defined as a "two-way interactive process concerned with the amelioration of the cognitive, emotional, psychosocial, and behavioral deficits caused by an insult to the brain" (Wilson, 2019, p.1). Cognitive rehabilitation (CR) is a key component of NR and aims at producing functional gains and improving social and community participation, as well as promoting patients' quality of life. CR combines restorative (e.g., paper-and-pencil cognitive training (CT), computer-based CT) and compensatory approaches (e.g., internal and external strategies training) (Fish & McKnight, 2021).

Nonetheless, CR in traditional clinical environments is not always available or accessible to many ABI patients, especially if patients live far from health centers (Allott & Lloyd, 2009; Lawson et al., 2022). There are three significant main barriers narrowing patients' access to face-to-face CR, namely: (a) the scarce availability of these services due to the lack of specialized healthcare staff or the existence of long waiting-lists; (b) patients' cognitive and motor restrictions; and (c) travel distance and economic costs associated with in-presence sessions attendance (Allott & Lloyd, 2009; Lawson et al., 2020). Moreover, unprecedented events, such as the COVID-19 pandemic, can highly limit the delivery of in-presence healthcare services to vulnerable populations (Dores et al., 2020; Geraldo et al., 2022). Information and communication technology (ICT)-based solutions (e.g., telehealth, computer-based interventions, virtual reality [VR]) have emerged as a promising alternative to face-to-face methods, enabling the delivery of remote CR and thereby fostering continuity of care (Maggio et al., 2020; Mantovani et al., 2020).

The World Health Organization (WHO) defines telehealth as "the delivery of healthcare services, where patients and providers are separated by distance" (WHO, 2022, p. 7). Telerehabilitation is a telehealth branch involving the provision of remotely supervised rehabilitation services to patients through ICTs (Stephenson et al., 2022). Telerehabilitation interventions can be divided into three different types: (a) therapist-facilitated, (b) self-guided and (c) hybrid (Tsaousides & Ashman, 2017). On the one hand, therapist-facilitated telerehabilitation requires synchronous supervision, meaning that therapists must provide real-time feedback and support to patients during sessions. This first type can be further categorized into four different types: (i) telephone communication (e.g., Bombardier et al., 2009), (ii) videoconference (e.g., Torrisi et al., 2019), (iii) instant messaging (IM) (e.g., Bergquist et al., 2009), and (iv) screen sharing (e.g., Man et al., 2006) (O'Neil et al., 2020; Tsaousides & Ashman, 2017). On the other hand, self-guided telerehabilitation involves asynchronous supervision, and therapists monitor and provide feedback to patients after the session has been completed through videoconference, telephone or the email (O'Neil et al., 2020; Tsaousides & Ashman, 2017). Examples of remotely supervised self-guided interventions are web-based platforms (e.g., Välimäki et al., 2018), computer-based programs (e.g., Zhou et al., 2018), mobile applications (e.g., Choi et al., 2016), and VR systems (e.g., Mendes et al., 2021). Finally, hybrid interventions combine both of the approaches described above.

Remote delivered CR programs (r-CRP) offer numerous advantages over face-to-face CRP, such as the reduction of inpatient hospital stays; the extension of rehabilitation care to patients with motor impairments or that live in rural areas, thus, increasing the programs accessibility; flexibility and convenience; the involvement of patients' social support network (e.g., significant others such as a friend or family member) on the rehabilitation process; and the increase of rehabilitation intensity and personalization through the use of ICT-based CR tools, which allow training adaptation to patients specificities (e.g., neuropsychological profile, performance between tasks) (Câmara et al., 2022; Dores et al., 2020; Geraldo et al., 2018; Solana et al., 2014).

Considering the current clinical relevance and application of r-CRP, it is urgent to shed light on the characteristics of available r-CRP and to understand if they are, in fact, an effective intervention approach for ABI patients. Nowadays, a growing number of studies are focused on assessing the efficacy of r-CRP in ABI (Gil-Pages et al., 2022; Lawson et al., 2020; Torrisi et al., 2020; Withiel et al., 2018). Previous systematic and scoping reviews have analyzed: the efficacy of CRP compared to face-to-face rehabilitation programs in several neurological conditions (e.g., mild cognitive impairment, multiple sclerosis, and ABI) (Cacciante et al., 2022); the use of remote supervision in TBI rehabilitation (O'Neil et al., 2019); the application of mobile Health (mHealth) in TBI (Juengst et al., 2019); and the use of telerehabilitation approaches to improve poststroke patient's functional prognosis (Chen et al., 2015). For instance, Cacciante et al. (2022) found improvements in the cognitive telerehabilitation groups to be at least comparable to those obtained through face-to-face CR. While this study focused on cognitive telerehabilitation, a form of r-CR, it did not explore other r-CR approaches. Besides, it analyzed cognitive

telerehabilitation in a very wide spectrum of neurological conditions, encompassing both neurodegenerative and acquired conditions. Also, Juengst et al. (2019) concluded that mHealth can be a promising tool to support patients in: (a) compensatory strategies use for multidimensional cognitive impairment (e.g., memory, organization, planning and problem-solving deficits); (b) social and community participation, as well as goal attainment; and (c) monitoring and reducing chronic symptoms typically observed following TBI (e.g., pain, depression). Despite promising results, methodological issues such as the small sample sizes, the heterogeneity of the clinical samples, and the significant variability of assessment measures and intervention programs prevent the scientific community from producing solid evidence base recommendations on the efficacy of r-CRP.

To the best of our knowledge, there is no systematic review describing the assessment and intervention protocols of currently available r-CRP administered following ABI, and exploring their impact on cognitive and noncognitive patient's outcomes. Thus, we aim to synthetize the methodological features of available r-CRP (i.e., assessment and intervention protocols) for ABI patients and to understand these intervention's effects on patient's outcomes to better inform clinical practice and decision-making in the field of CR (e.g., selection of the most adequate remote delivered intervention approach considering patients characteristics and specific needs).

The following research questions (RQ) guided this review:

- RQ 1: In what stage and severity of ABI are r-CRP usually initiated?
- RQ 2: What type of r-CRP are typically implemented (e.g., therapist-facilitated or self-guided cognitive telerehabilitation, therapist-facilitated or self-guided computer-based or tablet-based programs)?
- RQ 3: What is the usual dose of r-CRP (i.e., number of sessions, frequency, session and intervention duration)?
- RQ 4: What techniques, target domains, content, adaptation and personalization procedures are employed in r-CRP?
- RQ 5: What are the assessment procedures frequently utilized to assess the efficacy of r-CRP (i.e., assessment moments, timing of assessment, target variables and instruments used)?
- RQ 6: What are the main results of r-CRP?

Materials and methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P) (Moher et al., 2009) and the Cochrane Collaboration guidelines (Shamseer et al., 2015).

Search strategy

A comprehensive literature search between 1985 and December 2022 was performed across multiple databases, including EBSCOhost (APA PsycInfo, Academic Search Ultimate, Psychology, and Behavioral Sciences Collection, ERIC, APA PsycArticles, Library & Information Science Source, and Fonte Académica), PubMed, and Web of Science. Additionally, to mitigate potential selection and publication biases, we conducted a manual search of the reference lists of included studies and contacted authors in the field to inquire about unpublished data. The search equation, restricted to titles and abstracts, was: *(Tele OR remote OR at-distance OR online OR web-based OR home-based OR at-home OR eMental OR e-Mental OR computer-assisted OR computer-mediated OR cyber OR digital OR virtual-reality OR new technolog*) AND (neurorehabilitat* OR cognitive rehabilitat* OR cognitive train* OR neuropsycholog* rehabilitat* OR cognitive remediat* OR cognitive retrain* OR cognitive stimul*) AND (head injur* OR brain injur* OR cerebrovascular accident* OR stroke OR brain tumor OR encephalitis) NOT (upper limb OR upper extremity OR postural OR motor).*

Study selection

Studies were included if they met the following eligibility criteria: (a) participants were adults diagnosed with ABI (≥ 18 years old); (b) studies describing r-CRP and focusing on the assessment of their efficacy in ABI adults-related outcomes; (c) studies reporting the use of at least one performance-based cognitive outcome measure (e.g., Montreal Cognitive Assessment to measure global cognition); and (d) studies published in English, Portuguese or Spanish. Conversely, the following exclusion criteria were applied during the preliminary study selection stage: (i) systematic reviews and meta-analysis, book chapters, dissertations, editorials, study protocols, qualitative or survey studies; (ii) studies conducted with pediatric populations (e.g., children and adolescents with ABI diagnosis) or with adults diagnosed with non-acquired brain conditions (e.g., neurodegenerative disorders, psychiatric disorders); (iii) studies reporting and investigating interventions that were not classified as r-CRP, such as cognitive stimulation therapy, motor rehabilitation,

occupational therapy, neurofeedback, if it was not possible to isolate the results of r-CRP; (iv) studies presenting solely in-person CRP; and (v) studies retrieved under the search string that were not related to the main theme of the systematic review (e.g., animal studies, assessment instruments validation or psychiatric studies).

Two independent researchers (JC and AG) selected the studies for eligibility according to the Cochrane Collaboration's recommendations (Higgins & Green, 2011). This process was conducted using the Rayyan Intelligent Systematic Review software (Ouzzani et al., 2016), a research collaboration platform to conduct literature and systematic reviews, which integrates a blind mode functionality to minimize the selection bias. The study selection process comprised two stages. In the first stage, both researchers independently screened the retrieved studies titles and abstracts, applying the pre-defined criteria outlined in the study selection subsection. Following independent screening, (i) an inter-rater agreement was calculated using the Cohen's Kappa calculator, (ii) a comparison of both researchers' decisions was performed, and (iii) all disagreements, if any, were solved with the assistance of a third reviewer (MV). Subsequently, the second stage involved full-text reading of all potentially eligible studies identified during the initial screening stage. Then, a second inter-rater agreement value was calculated, and any remaining conflicts were again solved by a third reviewer.

Data collection, management and analysis

Data extraction for each study was facilitated by a standardized coding matrix developed in Microsoft Excel©, which included the following data: first author, year, study objectives and hypotheses, experimental design, study class according to Cicerone's quality assessment of research studies (i.e., class I, class Ia, class II, and class III) (Cicerone et al., 2000); characteristics of the study sample (e.g., ABI subtype, experimental conditions, control conditions, number of participants, gender, age, level of education, time since ABI); r-CRP usual dose (e.g., session duration, frequency, number of sessions); r-CRP main characteristics (e.g., name of the r-CRP, format of delivery, type of r-CRP, target domains, rehabilitation techniques, adaptation and personalization procedures); the passive or active control intervention characteristics, if any, (brief description of the intervention); assessment protocol used in the study (assessment moments and timings, variables and performance-based and/or self-report instruments used to assess the intervention efficacy); intervention methods (i.e., description of the study implementation procedure); main outcomes (i.e., programs' impact in the target cognitive and noncognitive variables); limitations and future directions. An additional column was added to insert complementary information that might be relevant (e.g., reference of an article cited on the reviewed study that could be potentially included in this systematic review). Furthermore, the analysis of the r-CRP outputs focused on the presence or absence of statistically significant differences in participants' performance and/or self-report outcomes from pre- to post-intervention, and, when available, from pre-intervention to follow-up. Comparisons were made between the intervention and control groups if applicable.

Results

A total of 1624 studies were identified from database search, and three included by manual search. After removing the duplicates, two independent researchers screened the titles and abstracts of 1076 studies. One thousand and twenty articles were excluded after applying the abovementioned exclusion criteria. In this first phase, the inter-rater agreement was calculated, and Cohen's k-coefficient values were 0.936, indicating an almost perfect agreement between reviewers (Landis & Koch, 1977). The remaining 56 studies were considered for full-text analysis, and 37 were excluded due to the following reasons: in-person CRP studies ($n=12$); studies lacking performance-based cognitive outcome measures ($n=15$); rehabilitation programs not classified as r-CRP ($n=4$); assessment study ($n=1$); study protocol ($n=1$); poster ($n=1$); abstract ($n=1$); case-study with a multiple sclerosis patient ($n=1$); and inability to access full-text ($n=1$). In this final phase, the values found for Cohen's k coefficient were 0.849, indicating an almost perfect agreement (Landis & Koch, 1977). Ultimately, 19 studies were included in this systematic review (cf. Figure 1). To facilitate results' readability, studies are numbered from 1 to 19 throughout the text according to Tables 1, 2 and 3.

Study characteristics

The characteristics of the included studies are summarized in Table 1. The methodological quality of the studies was analyzed considering Cicerone et al. (2000) classification. Hence, a total of ten studies were classified as belonging to Class I (prospective, randomized and controlled experimental design); two studies to Class Ia (prospective design with quasi-randomized assignment to treatment conditions); one to Class II (prospective and nonrandomized cohort studies or retrospective studies with nonrandomized control group; or clinical series with control group); and six to Class III (clinical series without controls or case-study designs).

In total, the included studies comprised 694 participants, of which 414 were male (59.65%) and 280 were female

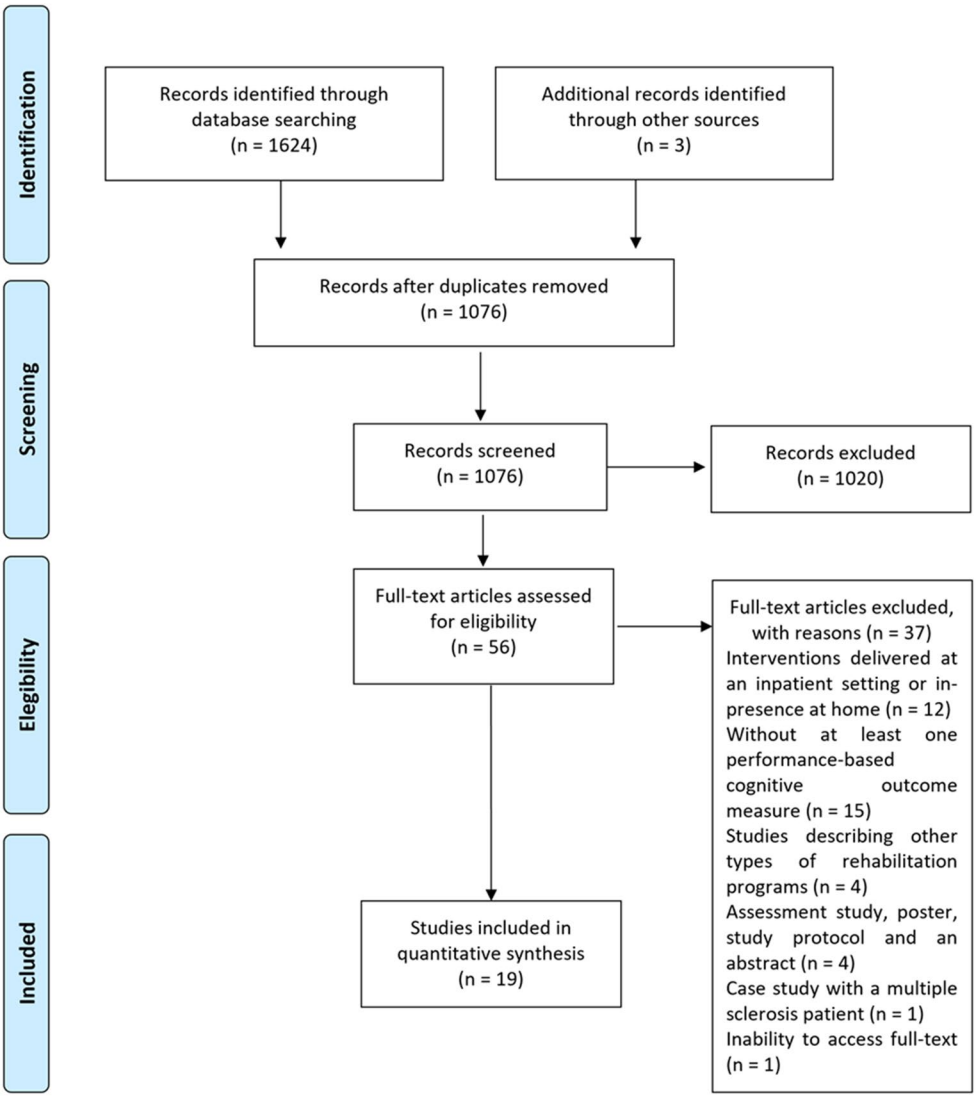

Fig. 1 Flow diagram of the literature search

(40.35%). Participants' ages ranged between 18 and 82 years old, and years of formal education between 9 and 27 years. Six studies did not report formal education (studies 2, 3, 4, 7, 11, 17) and two reported education levels (studies 8, 19). Regarding the type of ABI, stroke was the most referred cause of brain injury ($n=385$; 55.48%), followed by TBI ($n=224$; 32.28%), brain tumor ($n=49$; 7.06%), arterioventricular malformation ($n=27$; 3.89%), unspecified ABI ($n=8$; 1.15%), and, finally, anoxic brain damage ($n=1$; 0.14%). The time since the brain injury ranged from 1 month to 40 years. Three studies did not report this information (studies 1, 13, 15).

Comparison groups were included in class I, class Ia and class II studies. The experimental group (EG), i.e., participants allocated to the target r-CRP, was compared to active control groups (aCG) in six studies (studies 1, 5, 6, 7, 15, 19), while three (studies 3, 13, 17) compared it with a passive control group (pCG). In three studies the EG was compared with both aCG and pCG (studies 2, 8, 12). In terms of the aCG, participants attended conventional CRP delivered face-to-face or unstructured treatments delivered remotely, and participants in the pCG did not perform any non-pharmacological treatment (waiting list). Conversely, all class III studies lacked a CG (studies 4, 9, 10, 11, 14, 18).

Lastly, studies were published in 19 different journals, and the journal with a greater number of records was the "Neuropsychological Rehabilitation" ($n=3$).

Intervention characteristics

Target ABI stage and severity for initiating remote delivered cognitive rehabilitation programs

Regarding the ABI stage and severity for implementing r-CRP (RQ 1), while most r-CRP were administered in the chronic stage ($n=11$; studies 2, 4, 5, 6, 8, 9, 10, 11, 14,

Table 1 Characteristics of the included studies

Study nr.	First author and year	Class	Country	Clinical condition	Sample size	Age M (SD) [Min-Max]	Education - years M (SD) [Min-Max]	Time since injury – days, months or years M (SD)	Male: Female ratio
1	Lawson, 2020	II	Australia	Stroke	*n* = 46 EG: 28 aCG:18	EG: 53.36 (11) [35-82] aCG: 62 (4.69) [32-81]	EG:14 (4.02) [10-23] aCG: 14.72 (2.44) [10-20]	NA	26:20 EG (15:13) aCG (11:7)
2	Välimäki, 2018	I	Finland and China	TBI	*n* = 90 EG: 29 aCG: 29 pCG: 32	EG: 42.14 (12.15) aCG: 40.90 (12.01) pCG: 39.34 (12.08)	NA	EG: 122 (133) m aCG: 137 (107) m pCG: 84 (101) m	45:45 EG (15:14) aCG (13:16) pCG (17:15)
3	Peers, 2021	I	UK	Stroke	*n* = 80 EG-SAT: 26 EG-WMT: 27 pCG: 27	EG I-SAT: 58 (15.4) EG II-WMT: 62 (12.2) pCG: 61 (13.8)	NA	EG-SAT: 2.33 (3.56) yr EG-WMT:3.85 (5.92) yr pCG: 3.10 (4.35) yr [3 wk-25 yr]	50:30 EG-SAT (17:9) EG-WMT (15:12) pCG (18:9)
4	Eilam-Stock, 2021	III	USA	TBI	*n* = 1	29	NA	4 yr	1:0
5	Braley, 2021	I	USA	Stroke	*n* = 32 EG: 17 aCG: 15	EG: 58.9 (10) aCG: 64.2 (9.9)	EG: 15.8 (2.7) aCG: 15.3 (2.5)	EG: 53 (56) m aCG: 38.1 (32) m	18:14 EG (10:7) aCG (8:7)
6	Mahncke, 2021	I	USA	TBI	*n* = 83 EG: 41 aCG: 42	EG: 35.4 (8.8) aCG: 32.3 (8.5)	EG: 14.2 (1.7) aCG: 14.6 (2.2)	EG: 7.4 (6.1) yr aCG: 7.2 (6.9) yr	67:16 EG (32:9) aCG (35:7)
7	Zhou, 2018	I	China	Stroke	*n* = 20 (discharged patients) EG:10 aCG:10	EG: 59.80 (11.26) aCG: 56.50 (14.34)	NA	EG: 31.00 (17.06) d aCG: 32.80 (19.89) d	13:7 EG (7:3) aCG (6:4)
8	Man, 2006	I	China	ABI (Stroke=55, TBI=13, arte-rioventricular malformation=27, and others=8)	*n* = 103 EG: 25 aCG I: 28 aCG II: 30 pCG: 20	EG: 44.24 (12.61) aCG I: 42.68 (11.82) 44.87 (10.47) aCG II: 44.87 (10.47) pCG: 48.55 (8.85)	Primary EG: 8 aCG I: 2 aCG II: 5 CG: 5 Secondary EG: 11 aCG I: 23 aCG II: 22 CG: 14 Tertiary EG: 6 aCG I: 3 aCG II: 3 CG: 1	EG: 5.15 (5.53) yr aCG I: 3.46 (4.02) yr aCG II: 3.48 (3.17) y pCG: 4.13 (3.86) yr	59:44 EG (13:12) aCG I (15:13) aCG II (18:12) pCG (13:7)

Table 1 (continued)

Study nr.	First author and year	Class	Country	Clinical condition	Sample size	Age M (SD) [Min-Max]	Education - years M (SD) [Min-Max]	Time since injury – days, months or years M (SD)	Male: Female ratio
9	Shochat, 2017	III	Israel	Stroke (n=5) and anoxic brain damage (n=1)	*n* = 6	60.16 (13.45) [37-71]	14 (3.52) [8-18]	3.5 (1.87) yr [1-6]	3:3
10	Withiel, 2018	III	Australia	Stroke	*n* = 5	59.4 (9.44) [48-74]	15.2 (2.94) [12-20]	38.6 (33.59) m [8-78]	2:3
11	Kiran, 2014	III	USA	Stroke	*n* = 4	68.5 (9.60) [56-77]	NA	89.5 (79.22) m [14-168]	4:0
12	Mendes, 2021	Ia	Portugal	TBI	*n* = 27 EG: 8 aCG: 10 pCG: 9	EG: 37.0 (12.17) aCG: 37.2 (10.13) pCG: 39.4 (16.19)	EG: 10.37 (3.35) aCG: 9 (3.66) pCG: 9.63 (3.90)	EG: 5.09 (4.73) m aCG: 53 (44.37) m pCG: 1.66 (0.90) m	22:5 EG (8:0) aCG (8:2) pCG (6:3)
13	van der Linden, 2021	I	Netherlands	Brain tumor (low-grade glioma and meningioma)	*n* = 49 EG: 23 pCG: 26	EG: 45.7 (11.7) pCG: 52.6 (10.4)	EG: 15.4 (3.6) pCG: 15.1 (3.6)	NA	20:29 EG (6:17) pCG (14:12)
14	Lebowitz, 2012	III	USA	TBI	*n* = 10	46.3 (16.6) [34-62]	19 (3.62) [14-27]	106 (99.32) m [6 m-22 y]	1:9
15	Maresca, 2019	I	Italy	Stroke	*n* = 30 EG: 15 aCG: 15	EG: 51.1 (10.3) aCG: 51.4 (12.7)	EG: 13.7 (2.4) aCG: 12.8 (3.9)	NA	14:16 EG (7:8) aCG (7:8)
16	Torrisi, 2019	I	Italy	Stroke	*n* = 40 EG: 20 aCG: 20	EG: 57.1 (15.9) aCG: 53.2 (20.8)	EG: 11.1 (3.7) aCG: 10.6 (4.2)	[3-6] m	26:14 EG (14:6) aCG (12:8)
17	Peers, 2020	I	UK	Stroke	*n*= 30 EG I-SAT: 10 EG II-WMT:10pCG: 10	EG-SAT: 60.17 (10.34) EG-WMT: 59.29 (7.36) pCG: 59.11 (14.21) [28–74]	NA	EG-SAT: 7.67 (4.63) EG-WMT: 10.14 (5.46) pCG: 8.44 (3.84) [7 m-17 yr]	18:12 EG-SAT (5:5) EG-WMT (6:4) pCG (7:3)
18	Choi, 2016	III	South Korea	Stroke	*n* = 8	50.7 (8.87) [37-62]	14.12 (2.99)	29.81 (26.77) m [2-90] m	4:4
19	Gil-Pagés, 2022	Ia	Spain	Stroke	*n* = 30 EG: 13 aCG: 17	EG: 48.1 (10.3) aCG: 52.8 (5.3)	EG Primary: 3 Mid-level: 5 High: 5 aCG Primary: 6 Mid-level: 9 High: 2	EG 1.9 (0.6) yr aCG 1.8 (0.4) yr	19:11 EG (7:6) aCG (12:5)

aCG = active Control Group; CG = Control Group; d = Days; EG = Experimental Group; m = Months; NA = Not Available; pCG = passive Control Group; SAT = Selective Attention Training; yr = Years; wk = weeks; WMT = Working Memory Training; [1]Continuous data was reported using median (range); [2]Median and interquartile ranges

17, 19), information about the severity of the condition was lacking ($n = 14$; studies 1, 2, 3, 5, 7, 8, 9, 10, 11, 13, 15, 16, 17, 19). Two studies conducted interventions in the subacute stage (studies 7, 16), and the remaining did not report this information ($n = 3$; studies 1, 13, 15). In addition, only four studies indicated ABI severity, specifically: moderate ABI ($n = 1$; study 4), mild to severe ABI ($n = 2$; studies 14, 19), and moderate to severe ABI ($n = 1$; study 12) (cf. Table 2).

Types of remote delivered cognitive rehabilitation programs

In terms of the types of r-CRP (RQ 2), a total of sixteen ICT-based programs were described: the adapted version of the Monash Memory Skills Program (study 1), CogniFit (study 2), online Adaptive Attention Training (SAT) (studies 3, 17), Cogmed (studies 3, 17), BrainHQ (studies 4, 6), Constant Therapy – Research app (CT-R) (studies 5, 11), Wispirit Inc. (study 7), Online Therapist Interactive Computer-assisted Analogical Problem-Solving Skills Training (study 8), Active Brain Training (ABT) (study 9), Lumosity (study 10), Virtual Centre for the Rehabilitation of Road Accident Victims (VICERAVI) (study 12), Remind app (study 13), Cortex with InSight (study 14), Virtual Reality Rehabilitation System-Tablet (VRRS-Tablet) (studies 15, 16), iAphasia app (study 18), and Guttmann NeuroPersonal Trainer (GNTP) (study 19). Among the various ICTs used, studies reported that programs were delivered through web-based platforms ($n = 7$; studies 2, 3, 4, 6, 10, 14, 17), telehealth systems ($n = 6$; studies 1, 7, 8, 15, 16, 19), VR platforms ($n = 2$; studies 9, 12), and mobile applications ($n = 4$; studies 5, 11, 13, 18). Internet connection was required for accessing r-CRP.

Furthermore, most r-CRP were classified as asynchronous and self-guided ($n = 11$; studies 2, 3, 5, 6, 10, 11, 13, 14, 17, 18, 19), which means that the interaction between therapists and participants was conducted at different times, i.e., not during the programs' sessions, through various means of communication, such as the telephone, email, videoconference or by accessing the software/web-based platform logs. On the other hand, seven studies reported therapist-facilitated r-CRP involving real-time interaction between therapists and participants (studies 1, 4, 8, 9, 12, 15, 16). One study reported a hybrid r-CRP (i.e., involving both self-guided and therapist-facilitated sessions) (study 12), and another study omitted this information (study 7) (cf. Table 2).

Usual dose of remote delivered cognitive rehabilitation programs

Considering the r-CRP's usual dose (RQ 3), the number of sessions varied from seven (study 1) to 80 sessions (study 12), and seven studies did not report this information (studies 2, 7, 11, 13, 15, 16, 18). Session's frequency ranged from three (study 16) to six times a week (study 11), with the most reported frequency being five times a week ($n = 9$; studies 3, 4, 5, 6, 10, 12, 14, 15, 19). A total of eight studies did not report this information (studies 2, 7, 8, 9, 13, 15, 18, 19), and one study simply mentioned sessions were administered on a weekly basis (study 1). Duration of sessions ranged from 20 (study 3) to 180 min (study 13), with 30 ($n = 4$; studies 2, 4, 5, 10) and 60 min (studies 6, 7, 11, 19) being the most reported. Two studies reported an interval of duration (studies 9, 12), and three lacked this information (studies 15, 18, 19). The r-CRP length ranged from four (studies 3, 4, 7, 17, 18) to 16 weeks (study 12), with the most reported intervention period being four weeks (cf. Table 2).

Techniques, target domains, content, adaptation and personalization procedures of remote delivered cognitive rehabilitation programs

Most studies employed one rehabilitation technique (RQ 4), with CT being the most common ($n = 16$; studies 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 18, 19). Few studies reported r-CRP involving two (studies 1, 12) or more rehabilitation techniques (study 13). In terms of target domains (RQ 4), most r-CRP addressed multiple cognitive domains ($n = 11$; studies 2, 4, 5, 6, 7, 11, 12, 13, 14, 16, 19). Content-wise (RQ 4), most r-CRP training tasks had low ecological validity (e.g., memorization of series of numbers, picture identification, n-back tasks) ($n = 14$; studies 2, 3, 4, 5, 6, 7, 10, 11, 14, 15, 16, 17, 18, 19). Hence, a minority of programs incorporated some tasks that resembled daily life activities (e.g., learning how to use a calendar system, paying the correct amount of money for groceries, and implementing specific problem-solving strategies when performing daily life activities) ($n = 5$; studies 1, 8, 9, 12, 13), with the aim of promoting generalization of intervention gains to patient's functional outcomes (cf. Table 2).

Lastly, most studies indicated r-CRP had adaptation and personalization features (RQ 4) ($n = 14$; studies 2, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 19). Overall, the majority of the studies provided generic descriptions about this procedure. Some examples being: (a) training was incrementally adaptative by increasing task difficulty through the modulation of task parameters as participants improved ($n = 8$; studies 2, 4, 9, 10, 14, 15, 16, 17); (b) training was progressive and

Table 2 Intervention characteristics

First author, year [study number]	ABI severity	ABI stage	r-CRP name [Type of program]	r-CRP Format and duration	Number of sessions, session's length and frequency	r-CRP techniques [approach]	r-CRP target domains	r-CRP content	r-CRP adaptation and personalization procedures
Lawson, 2020 [1]	NA	NA	Monash Memory Skills Program–Modified version for a telehealth format [Telehealth, Therapist-facilitated]	Individual 6 wk	Number: 7 (6 + 1 booster session) Length: 120 min Frequency: only say weekly	Psychoeducation and internal and external strategy training [Compensatory]	Single domain Memory	E.g., session 1: structure of memory, internal strategies (learning names), external strategies (introduction to external aids), life-style factors (the home/office environment)	NA
Välimäki, 2018 [2]	NA	Chronic	CogniFit [Web-based, Self-guided]	Individual 8 wk	Number: NA Length: 30 min Frequency: NA	Cognitive training [restorative]	Multidomain Memory, spatial perception and mental planning	Three categories of exercises: memory, spatial perception and mental planning. Participants could play at least one exercise from the three categories mentioned or could choose to play whatever exercise they wished	NA
Peers, 2021 [3]	NA	Early subacute to chronic	SAT computerized program [Web-based, Self-guided] WMT computerized program (Cogmed) [Web-based, Self-guided]	Individual 4 wk	Number: 20 Length: 20 min Frequency: 5x/wk	Cognitive training [restorative]	Single domain SAT: Attention WMT: Working memory	SAT: 5 time-limited games (3-5 min) WMT: 4 time-limited games (3-5 min)	Both provided trial-by-trial feedback, feedback on overall progress, and incrementally adaptation by increasing task difficulty as participants' performance improved
Eilam-Stock, 2021 [4]	Moderate	Chronic	BrainHQ [Web-based, Therapist-facilitated]	Individual 4 wk	Number: 20 Length: 30 min Frequency: 5x/wk	Cognitive training [restorative]	Multidomain Attention, working memory, processing speed, and executive functions, through both visual and auditory modalities	Adaptive CT: variety of tasks addressing attention, working memory, processing speed and executive functions (visual and auditory modalities) RS-tDCS: the anodal electrode was placed on top of the left DLPFC region, and the cathodal electrode on top of the right DLPFC region (20 min of stimulation/session)	The level of difficulty of the CT was adapted in real time to participants

Table 2 (continued)

First author, year [study number]	ABI severity	ABI stage	r-CRP name [Type of program]	r-CRP Format and duration	Number of sessions, session's length and frequency	r-CRP techniques [approach]	r-CRP target domains	r-CRP content	r-CRP adaptation and personalization procedures
Braley, 2021 [5]	NA	Chronic	Constant Therapy-Research app [Mobile application, Self-guided]	Individual 10 wk	Number: 50 Length: 30 Frequency: 5x/wk	Cognitive training [restorative]	Multidomain 9 different cognitive, speech and language domains	Across exercises there were over 100 000 stimuli within 350 + levels of difficulty. Some e.g., of exercises include: name pictures, symbol matching and written word comprehension	A NPE algorithm optimizes therapeutic delivery (i.e., progress across tasks or reduce the difficulty level) according to participants individual performance
Mahncke, 2021 [6]	Mild	Chronic	BrainHQ [Web-based, Self-guided]	Individual 13 wk	Number: 65 Length: 60 Frequency: 5x/wk	Cognitive training [restorative]	Multidomain Attention, processing speed, and social cognition	23 exercises targeting speed and accuracy of neural information processing, required attentional focus to perform correctly, and were accompanied by video game-like rewards when trials were performed correctly. Each session, participants performed 6 tasks. Importantly, exercises included in the first sessions tackled minimal higher-order cognitive functions (e.g., visual speed task where participants identified the location of a peripheral target among distractors). Progressively, training sessions included exercises targeting higher order cognitive functions (e.g., social cognition task, where participants were shown a face and had to identify the target face from different viewing angles among distractors)	Task adaptation on a trial-by-trial basis to the participant's performance (completion of 80% of trials correctly)
Zhou, 2018 [7]	NA	Early subacute	Wispirit Inc. Computerized combined cognitive and speech-language training + family topics communication [Telehealth, NA]	Individual 4 wk	Number: NA Length: 60 min Frequency: NA	Psychoeducation and cognitive training [restorative]	Multidomain Attention, language, memory and executive functions	Some e.g., of tasks: auditory comprehension, reading comprehension, repetition, naming, writing, go-no-go, stroop, flanker, and n-back working memory	Training was adaptive and more challenging tasks were introduced if the accuracy level is high (>80%)

Table 2 (continued)

First author, year [study number]	ABI severity	ABI stage	r-CRP name [Type of program]	r-CRP Format and duration	Number of sessions, session's length and frequency	r-CRP techniques [approach]	r-CRP target domains	r-CRP content	r-CRP adaptation and personalization procedures
Man, 2006 [8]	NA	Chronic	Online therapist interactive computer-assisted analogical problem-solving skills training [Telehealth, Therapist-facilitated]	Individual and group NA	Number: 20 Length: 45 min Frequency: NA	Cognitive training [restorative]	Single domain Executive functions (Problem-solving abilities)	Basic problem-solving training (i.e., convergent, divergent, comparison and contrast problem-solving), and functional problem-solving training (i.e., identifying effects, causes and providing solutions to situations)	Training was progressive and paced according to the participant's ability
Shochat, 2017 [9]	NA	Chronic	Active Brain Trainer (ABT) [VR-based exergame CT platform, Therapist-facilitated]	Individual 5-7 wk	Number:15-20 Length: 20 min Frequency: NA	Cognitive training [restorative]	Single domain Executive functions	E.g., of a game: The Bad Neighborhood game is based on the principles of the go-no-go task and the continuous performance task. The player operates an avatar of a food truck owner who sells food to customers and his/her goal is to serve food to as many positive customers, while avoiding thieves, in order to make as much money as possible. Each session included 4 training games (5 min each)	Task parameters were adapted gradually based on the player's success, taking into account both *Go* and *No Go* trials
Withiel, 2018 [10]	NA	Chronic	Lumosity [Web-based, Self-guided]	Individual 6 wk	Number: 30 Length: 30 min Frequency: 5x/wk	Cognitive training [restorative]	Single domain Memory	Face Memory Workout; Familiar Faces; Follow that Frog; Memory Lane; Memory Match; Memory Match Overdrive; Memory Matrix; Moneycomb; Monster Garden; Pinball Recall; Rhyme Workout; Rotation Matrix, and Tidal Treasure	Game complexity increased and decreased systematically based on participants' performance
Kiran, 2014 [11]	NA	Chronic	Contant Therapy app [Mobile application, Self-guided]	Individual 10 wk	Number: NA Length: 60 min Frequency: 6x/wk	Cognitive training [restorative]	Multidomain Attention, memory, language, visuospatial processing, and executive function	Symbol cancelation, telling time/analog clock, visuospatial picture/written word/spoken matching, voicemail task; response inhibition, alphabetical word/picture ordering, arithmetic tasks (addition, subtraction, etc.), instruction sequencing, word spelling, sound-to-letter matching, and reading passages	Performances higher than 80% on a particular task meant patients were assigned a new task with higher difficulty (e.g., rhyming instead of sound identification)

Table 2 (continued)

First author, year [study number]	ABI severity	ABI stage	r-CRP name [Type of program]	r-CRP Format and duration	Number of sessions, session's length and frequency	r-CRP techniques [approach]	r-CRP target domains	r-CRP content	r-CRP adaptation and personalization procedures
Mendes, 2021 [12]	Moderate to severe	Early subacute, late subacute and chronic	VICERAVI program [VR-based platform, Hybrid]	Individual and group 16 wk	Number: 80 Length:40-60 min Frequency: 5x/wk	Cognitive training, affective and psychosocial rehabilitation [restorative and social skills] NEP-UM platform Affective and Psychosocial training	Multidomain NEP-UM online CT platform: attention, memory, language, and executive functions Affective and psychosocial training: social skills and self-help	NEP-UM: NA Affective and psychosocial training: hot seat session, in which participants described the characteristics of one of the group members	In the NEP-UM CT tasks had different difficulty levels (e.g., level 1, 2, 3, 4 and 5)
van der Linden, 2021 [13]	NA	NA	ReMind app [Mobile application, Self-guided]	Individual 10 wk	Number: NA Length: 180 min Frequency: NA	Psychoeducation, strategies training and cognitive training (attention) [Restorative and compensatory]	Multidomain	6 modules: cognitive functions, influences, compensation, attention, planning, and control, and memory. Involved psychoeducational information, strategy training and attention retraining	The CT module addressed the attentional domain and included tasks that were hierarchically graded
Lebowitz, 2012 [14]	Mild to severe	Chronic	Cortex With InSight software [Web-based, Self-guided]	Individual 6 wk	Number: 30 Length: 40 min Frequency: 5x/wk	Cognitive training [restorative]	Multidomain	Game-like tasks such as selecting a target stimulus out of an array of distracters or visually tracking an occluded moving target stimulus	Difficulty adaptation contingent to participants' performance
Maresca, 2019 [15]	NA	NA	VRRS-Tablet [Telehealth, Therapist-facilited]	Individual 12 wk [discharge phase: T1-T2]	Number: NA Length: 50 Frequency: 5x/wk	Cognitive training [restorative]	Single domain Language	2D tasks involving naming of figures represented on the screen and tasks of composition, writing and rewriting suggested by acoustic, textual and visual items. 3D exercises allowed patients to interact with 3D virtual scenarios and immersive objects through a magnetic localization sensor generally positioned on the hand (which allowed the detection of the final effector's 3D position). In this study, the linguistic module with 2D scenarios was mainly used	Exercises were automatically adapted to the patient's performance. Each exercise had a self-advancement of difficulty to allow personalized training (e.g., reaction time, type, and number of variable stimuli of exercises are set according to patient's abilities and needs)

Table 2 (continued)

First author, year [study number]	ABI severity	ABI stage	r-CRP name [Type of program]	r-CRP Format and duration	Number of sessions, session's length and frequency	r-CRP techniques [approach]	r-CRP target domains	r-CRP content	r-CRP adaptation and personalization procedures
Torrisi, 2019 [16]	NA	Late subacute	VRRS-Tablet [Telehealth, Therapist-facilitated]	Individual 12 wk [discharge phase: T1-T2]	Number: NA Length: 50 min Frequency: 3x/wk	Cognitive training [restorative]	Multidomain Attention processes, spatial cognition, memory, reasoning and executive abilities	2D exercises in which patients interacted with objects and scenarios through the touch screen or a particular magnetic sensor coupled with a button, which simulated mouse interaction [training performed after discharge]. E.g., memory training: observation of peculiar elements and need to remember them (e.g., colors, numbers, animals) in a recall trial, in which the patient was required to identify the location (e.g., position) and the name of the element(s) that where observed	The level of difficulty increased based on the task's parameters (e.g., number of distractors, reducing the time to execute the tasks, number of elements to remember)
Peers, 2020 [17]	NA	Chronic	SAT [Web-based, Self-guided] WMT (Cogmed) [Web-based, Self-guided]	Individual 4 wk	Number: 20 Length: NA Frequency: NA	Cognitive training [restorative]	Single domain SAT: Attention WMT: Working memory	SAT: 5-time limited tasks targeting selective attention (e.g., aliens, visual search, jigsaw, rotations and button sorting). Example of a SAT task: In the visual search task, participants were presented with an abstract shape for a few seconds on the computer screen; then, an array of objects appeared, and the participant had to select the one that matched exactly the original shape WMT: 15 trials of 8 tasks in each session covering both verbal and visuospatial working memory	Both training programs were adaptive and provided trial-by-trial feedback for both learning and motivational aspects SAT: in the visual search task the difficulty adaptation involved increasing the similarity of the distractor objects to the target by manipulating parameters such as shape, size, color and texture. WMT: NA

Table 2 (continued)

First author, year [study number]	ABI severity	ABI stage	r-CRP name [Type of program]	r-CRP Format and duration	Number of sessions, session's length and frequency	r-CRP techniques [approach]	r-CRP target domains	r-CRP content	r-CRP adaptation and personalization procedures
Choi, 2016 [18]	Mild to severe	Early subacute and chronic	Telerehabilitation program iAphasia [Mobile application, Self-guided]	Individual 4 wk	Number: NA Length: NA Frequency: NA	Cognitive training [restorative]	Single domain Auditory comprehension, reading comprehension, repetition, naming, writing, and verbal fluency.	Picture identification, word-word matching, sentence repetition, picture naming, proverb completion, divergent naming, number counting, and verbal problem solving	Only mentioned that the program has six levels of difficulty
Gil-Pagés, 2022 [19]	NA	Chronic	GNPT® [Telehealth, Self-guided]	Individual 6 wk	Number: 30 Length: 60 min Frequency: 5x/wk	Cognitive training [restorative]	Multidomain Attention, memory, and executive functions	Included selective attention tasks (e.g., find a pair of pictures among a set of distractors), memory tasks (e.g., memorize series of numbers), and executive functions (e.g., go/no-go tasks)	The GNPT allowed therapists to configure and schedule rehabilitation sessions, consisting of set of personalized exercises using an automated process that adjusts difficulty levels according to patients' assessment and performance throughout the sessions

CT = Cognitive Training; DLPFC = Dorsolateral prefrontal cortex; GNPT = Guttmann Neuropersonal Trainer; NA = Not Available; NEP-UM = Neuropsychological Enrichment Program – University of Minho; NPE = NeuroPerformance Engine; RS – tDCS = Remotely supervised transcranial direct current stimulation; SAT = Selective Attention Training; VICERAVI = Virtual Centre for the Rehabilitation of Road Accident Victims; VR = Virtual Reality; wk = weeks; WMT = Working Memory Training;

paced according to participants ability ($n=1$; study 8); (c) a Neuroperformance Engine optimized adaptation based on participants performance ($n=1$; study 5); and (d) an automated process was engaged to adjust difficulty levels ($n=1$; study 19) to participants' assessment and performance throughout sessions. The remaining three studies stated specific criteria to personalize training, referring that progression throughout tasks implied completing 80% of the trials correctly ($n=1$; study 6) or attaining above 80% accuracy in each task ($n=2$; studies 7, 11) (cf. Table 2).

Assessment procedures

Regarding the assessment moments (RQ 5), all studies comprised a pre- and post-intervention assessment (see Table 3). Most studies did not conduct a follow-up assessment ($n=11$; study 4, 5, 7, 8, 9, 11, 12, 14, 15, 16, 17). Among the eight studies that performed a follow-up assessment (studies 1, 2, 3, 6, 10, 13, 18, 19), the follow-up timing ranged from one (study 18) to 12 months (study 13) after the intervention, with the most frequently reported timing being three months ($n=3$; studies 2, 3, 6).

The included studies assessed a wide range of cognitive and noncognitive variables, as their target domains varied across interventions (see Table 3). In result, different instruments were used among studies to measure the target variables. For instance, the cognitive variables (RQ 5) assessed among studies were cognitive functioning ($n=7$; studies 5, 6, 11, 12, 13, 14, 16); attention and processing speed ($n=7$; studies 2, 3, 4, 12, 16, 17, 19); memory ($n=10$; studies 1, 2, 3, 4, 10, 12, 13, 16, 17, 19); language ($n=10$; studies 5, 7, 8, 11, 12, 13, 15, 16, 18, 19); communication ($n=1$; study 7); executive functioning ($n=7$; studies 2, 4, 8, 9, 12, 16, 19); and subjective cognitive, attentional or memory failures/complaints ($n=7$; studies 1, 3, 6, 10, 13, 14, 19). The assessment of cognitive variables relied mostly on the administration of performance-based instruments (RQ 5). Notably, a significant variation in assessment tools was observed across studies, even when addressing the same target cognitive variables, which posed a considerable challenge in making meaningful comparisons of r-CRP effects (see Table 3). Cognitive functioning was mostly assessed by the Montreal Cognitive Assessment (MoCA) ($n=2$; studies 12, 16); attention and processing speed by the Trail Making Test ($n=5$; studies 2, 4, 12, 16, 19); memory by the Rey Auditory Verbal Learning Test (RAVLT) ($n=5$; studies 1, 4, 10, 16, 19); language by the Western Aphasia Battery (WAB) ($n=4$; studies 5, 7, 11, 18); and executive functions by the Stroop Test ($n=2$; studies 12, 19).

On the other hand, the noncognitive variables (RQ 5) assessed included: depressive symptoms ($n=7$; studies 2, 4, 6, 12, 13, 15, 16); behavioral functioning ($n=5$; studies 2, 6, 13, 14, 19); quality of life ($n=5$; studies 3, 5, 12, 15, 17); anxiety symptoms ($n=3$; studies 4, 12, 16); fatigue symptoms ($n=2$; studies 4, 13); goal attainment ($n=2$; studies 1, 10); instrumental activities of daily living ($n=2$; studies 6, 8); compensatory strategies use ($n=1$; study 1); overall health ($n=1$; study 6); sleep, pain and fatigue ($n=1$, study 4); adaptability ($n=1$; study 6), post-traumatic stress symptoms ($n=1$; study 6); positive and negative affect ($n=1$; study 4); self-awareness ($n=1$; study 19); competency ($n=1$; study 19); neglect impact ($n=1$; study 3); and psychosocial impact ($n=1$; study 15). Lastly, the r-CRP feasibility and acceptability among participants were measured in seven studies (studies 1, 2, 9, 10, 13, 14, 19). Similarly, distinct self-report instruments (RQ 5) were used to evaluate subjective cognitive complaints and noncognitive variables (see Table 3). Among the different subjective cognitive self-report measures, the Cognitive Failures Questionnaire (CFQ) was the most used to assess participant's cognitive failures ($n=4$; studies 3, 6, 13, 14). For noncognitive variables, depressive symptoms were mainly assessed by the Beck Depression Inventory-II (BDI-II) ($n=2$; studies 4, 6) and the depression subscale of the Hospital Anxiety and Depression Scale (HADS) ($n=2$; studies 12, 13); behavioral functioning by the Behavior Rating Inventory of Executive Function (BRIEF-A) ($n=3$; studies 2, 13, 19); quality of life by the European Brain Injury Questionnaire (EBIQ) ($n=2$; studies 3, 17); and anxiety symptoms by the anxiety subscale of the HADS ($n=2$; studies 12, 13). Other self-report instruments included the Goal Attainment Scale (GAS) ($n=2$; studies 1, 10), and the Patient Competency Rating Scale (PCRS) ($n=1$; study 19). Concerning the programs' feasibility and acceptability, studies considered essentially participants' rates of enrollment and attrition ($n=2$; studies 1, 13), adherence ($n=3$; studies 1, 10, 13), and satisfaction ($n=3$; studies 2, 13, 19) with the r-CRP.

Intervention methods and outcomes

Class I and Class Ia studies overview

Among the 10 class I studies, most described self-guided r-CRP ($n=6$; studies 2, 3, 5, 6, 13, 17). Välimäki et al. (2018) (study 2) investigated whether rehabilitation gaming (EG: CogniFit) was a more effective approach than entertainment gaming (aCG: PlayStation 3) in TBI participants. Also, Peers et al. (2020, 2021) (studies 17, 3) compared the effects of computerized CT through either the SAT (EG I) and the Cogmed (EG II) on attention and working memory outcomes, respectively, versus a pCG. Furthermore, Braley et al. (2021) (study 5) assessed the feasibility and efficacy of a 10-week tablet-based intervention with the CT-R app in poststroke aphasia in comparison to standard therapy

Table 3 Assessment procedures and main outcomes

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
Lawson, 2020 [1]	II	3 moments Pre Post FU (6 wk)	Verbal memory	RAVLT	Significant main effect of time ($p < .001$) for new learning (RAVLT) and delayed memory (RAVLT), suggesting that both groups showed declines in these indicators Both groups declined in new learning at post ($p = .002$, $d = .68$) and FU ($p < .001$, $d = .86$) Both groups declined in delayed memory at post ($p = .008$, $d = .51$) and FU ($p < .001$, $d = .91$)
			Prospective memory	RPA-ProMem	Significant main effect of time ($p < .001$) for prospective memory (RPA-ProMem), suggesting that both groups showed improvements in this outcome at post- ($p = .002$, $d = .68$) and FU ($p < .001$, $d = .93$). These improvements ranged from medium to large at post-intervention to large at FU
			Subjective everyday memory failures (SR)	EMQ-R	Significant group x time interaction ($p = .030$) in everyday memory (EMQ-R), with the EG improving more (medium to large effect size gains) than the aCG (small to medium effect size gains) at post-intervention. At FU, the EG reported further gains, while the aCG increased his memory failures
			Subjective prospective memory failures (SR)	CAPM – part A	Significant main effects of time ($p = .014$) in prospective memory failures (CAPM – A), indicating that both groups presented less prospective memory lapses at post-intervention ($p = .018$, $d = .50$) and FU ($p = .006$ $d = .63$), with a medium effect size at both assessment moments
			Compensatory strategies use (SR)	Report Strategy Use Checklist	Internal strategies: Significant group x time interaction ($p = .038$) in internal strategies use, indicating that the EG improved more in comparison to the aCG at post-intervention ($d = .74$), revealing a moderate to large effect size gains in internal strategies use, but losing some of those gains at FU ($d = .31$) External strategies use: ND
			Goal attainment (SR)	GAS	Significant improvements in the GAS for both groups over time (main effect of time: $p < .001$) GAS scores improved significantly at post-intervention ($p < .001$, $d = 1.92$) and remained at FU ($p < .001$, $d = 2.29$), with a large and very large effect size, respectively EG: 90.9% attained at least 1 goal at post-, and 100% attained at least 1 at FU aCG: 92.9% attained at least 1 goal at post-, and 85.7% attained at least 1 goal at FU
			Feasibility (SR)	(1) Rates of agreement to participate; (2) overall recruitment; (3) treatment adherence	EG: (1) 96.6% rates of agreement to participate; (2) recruitment rate ($n = 28$) higher than aCG; (3) treatment adherence (ND) aCG: (1) 94.7% rates of agreement to participate; (2) recruitment rate ($n = 18$); (3) treatment adherence (ND)
Välimäki, 2018 [2]	I	3 moments PrePost FU (3 m)	Processing speed and visuomotor abilities	TMT – A	ND
				TMT – B	ND
				Symbol Search (WAIS-IV)	No group x interaction effect for symbol search ($p = .85$), but there was a significant effect of time ($p = .01$), reflecting an improvement in score across assessment moments
				Cancelation (WAIS-IV)	ND
				Symbol Coding (WAIS-IV)	No group x time interaction on Symbol Coding ($p = .35$), but there was a significant effect of time ($p = .02$), indicating improvements of all groups across all assessment moments
			Executive functions – Inhibition	Simon task	ND
			Working memory	Digit Span (WAIS-IV)	ND
			Working memory	PASAT (2-3 s)	No time x group interaction on PASAT (3 s) ($p = .33$), nor on PASAT (2 s) ($p = .67$) Significant effect of time on PASAT (2 s) ($p < .001$), indicating an improvement in working memory across the different assessment moments, irrespective of the group

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
			Executive behavior (SR)	BRIEF – A	Significant main effect of time the BRIEF–A scores ($p = .03$), suggesting improvements in all groups throughout the course of the intervention
			Depressive symptoms (SR)	PHQ – 9	ND
			Self-efficacy (SR)	GSE	ND
			Feasibility (SR)	Adherence, usability, satisfaction and future use) through 3 yes/no questions	EG: adherence (65%); usability (70%); satisfaction (68%); future use (76%) aCG: adherence (66%); usability (83%); satisfaction (83%); future use (63%) aCG had higher scores on 3/4 indicators
Peers, 2021 [3]	I	3 moments Pre Post FU (3 m)	Attention	TVA whole – report OCS-BRIDGE (hearts cancelation, sustained attention lateralized reaction time subtests)	ND
			Working memory	OCS-Bridge (Forward and Backward Digit Span) AWMA (Dot Matrix and Spatial Span tasks)	ND
			Cognitive failures (SR)	CFQ	ND
			Quality of life (SR)	EBIQ	ND
			Neglect impact (SR)	SNQ	ND
Eilam-Stock, 2020 [4]	III	2 moments Pre Post	Auditory attention and working memory	Digit Span (WAIS-IV) Letter – Number Sequencing (WAIS-IV) PASAT	ND (> 1 SD) Letter – Number Sequencing (> 1 SD) PASAT
			Auditory and divided attention	BTA	ND
			Visual working memory	Symbol Span (WMS-IV)	ND
			Visual attention and working memory	CBB (two-back)	(> 1 SD) CBB (two-back)
			Visual attention and processing speed	CBB (detection and identification)	(> 1 SD) CBB (detection and identification)

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
			Visual attention and psychomotor speed	TMT – A	ND
			Executive function – set shifting and cognitive flexibility	TMT – B	ND
			Language – Verbal Fluency	Verbal Fluency (phonemic and semantic)	(> 1 SD) Semantic fluency
			Processing speed	SDMT	ND
			Visual memory	CBB (one card learning)	(< 1 SD) CBB One Card Learning
			Verbal memory	RAVLT NAB (story learning)	ND ND
			Depressive symptoms (SR)	BDI-II	(> 1 SD) BDI-II
			Anxiety symptoms (SR)	BAI	(> 1 SD) BAI
			Positive and negative affect (SR)	PANAS	(> 1 SD) PANAS (negative affect)
			Sleep, pain and Fatigue (SR)	PROMIS	(> 1 SD) PROMIS (sleep)
Braley, 2021 [5]	I	2 moments Pre Post	Cognitive functioning (screening)	BTACT	Significant improvement in the BTACT (verbal fluency score) for both groups ($p = .02$) at post-intervention ND between groups
			Language (battery)	WAB-R (WAB-AQ, WAB-LQ, WAB-CQ)	Significant improvements in the WAB – AQ ($p < .01$), WAB – CQ ($p < .05$), WAB – LQ ($p < .01$) in favor of the EG
			Quality of life (SR)	SAQOL-39	Significant improvements in the SAQOL–39 (mean score) ($p = .02$), communication score ($p = .04$) and energy subscores ($p = .006$) for both groups at post-intervention
Mahncke, 2021 [6]	I	3 moments Pre Post FU (3 m)	Cognitive functioning (composite)	Composite score derived from: RAVLT, RULIT, Digit Span (WMS-III), Anti-saccades, Flanker, NIH-EXAMINER (set-shifting)	Significant between-group differences in the composite cognitive score at both post-intervention ($p = .025$, $d = .55$) and FU ($p = .039$, $d = .59$) indicating greater improvements for the EG compared with the aCG
			Instrumental activities of daily living (SR)	TIADL	ND
			Health (SR)	SF-12 (Physical and Mental components)	ND

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
			Depressive symptoms (SR)	BDI-II	ND
			Post-traumatic stress (SR)	PCL-C	Significant between-group differences in the PCL-C at FU ($p = .028$, $d = -.625$), suggesting greater reductions in post-traumatic stress for the aCG compared with the EG. These results were not addressed in the discussion section of the study
			Executive behavior (SR)	FrSBe	ND
			Cognitive failures (SR)	CFQ	ND
			Neurobehavioral symptoms (SR)	NSI	ND
			Adaptability (SR)	MPAI	ND
Zhou, 2018 [7]	I	2 moments Pre Post	Language (battery)	WAB	The EG significantly improved his WAB scores (group x time, $p < .001$) in comparison to the aCG
			Communication	CADL	The EG significantly improved his CADL scores (group x time, $p < .001$) in comparison to the aCG
Man, 2006 [8]	I	2 moments Pre Post	Language	HRTB (Category Test for Adults)	Statistically significant within-group improvements for all three groups: aCG I (CCRG; $p = .01$), aCG II (TCRG; $p = .00$), and EG (OCRG; $p = .00$), except for the pCG ($p = .12$) at post-intervention ND between groups ($p = .564$), indicating a similar level of efficacy for the EG and the aCG at post-intervention
			Executive functions (problem-solving abilities) (SR)	10-Item Problem-Solving Self-Efficacy Scale	Only the aCG II (TCRG) showed a significant within-group improvement ($p = .002$) in problem-solving self-efficacy, compared to the aCG I (CCRG), EG (OCRG) and the pCG at post-intervention There were significant between-group differences among the groups ($p = .003$), suggesting that the aCG II (TCRG) presented higher improvements in problem-solving self-efficacy at post-intervention
				Problem-solving skills categories	Significant within-group improvements in the aCG I (CCRG) for basic skills ($p = .04$), functional skills ($p = .00$) and overall skills (basic and functional) ($p = .00$) at post-intervention Significant within-group improvements in the aCG II (TCRG) for basic skills ($p = .04$), functional skills ($p = .00$) and overall skills (basic and functional) ($p = .00$) at post-intervention Significant within-group improvements in the EG (OCRG) for divergence ($p = .01$), functional skills ($p = .00$), and overall skills (basic and functional) ($p = .00$) at post-intervention ND in the pCG for any problem-solving skills ($p > .05$) at post-intervention Significant between-group differences for divergence ($p = .03$), suggesting that the EG (OCRG) improved significantly more in this indicator than the remaining groups at post-intervention
			Instrumental activities of daily living (SR)	LIADL (Hong Kong version)	Statistically significant within-group improvements for the EG and the two aCG groups: EG (OCRG; $p = .00$), aCG I (CCRG; $p = .00$), and aCG II (TCRG; $p = .00$). ND for the pCG ($p = .27$)
Shochat, 2017 [9]	III	2 moments Pre Post	Executive functions	EFPT – Bill Payment Subtest	Medium effect size improvements in the EFPT at post-intervention ($d = .63$)
				NIH-EXAMINER	Medium effect size improvements in the EXAMINER executive composite at post-intervention ($d = .51$)
				WWT	Small effect size improvements in the WWT at post-intervention ($d = .42$)

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
			Emotional, behavioral and cognitive problems due to frontal dysfunction (SR)	DEX	ND in the DEX at post-intervention ($d = .05$, small effect size)
			Feasibility and acceptability (SR)	Questionnaire adapted from the Short Feedback Questionnaire and the System Usability Scale	Satisfaction (4/5), motivation (4.2/5), clear feedback (3.5/5), cognitive improvement (3/5), motor improvement (3.5/5), using the software during OT (3.7/5), using the software at home (3.7/5), and feeling of discomfort (1.3/5) Results supported the feasibility of ABT
Withiel, 2018 [10]	III	3 moments Pre Post FU (6 wk)	Visual working memory	Symbol Span (WMS-IV)	ND
			Verbal working memory	Digit Span backward (WAIS-IV)	ND
			Verbal memory	RAVLT	1/5 participants significantly improved at post-intervention (CC: RCI = ± 5.1), maintaining the improvement at FU No evidence to support the effectiveness of Lumosity on objective memory measures
			Visual memory	BVMT-R	1/5 participants showed significant improvements in the total learning score of the BVMTR TL at post-intervention (DD: RCI = ± 6.3), maintaining it at FU 1/5 participants showed significant improvements in the delayed recall score of the BVMTR at post-intervention (AA: RCI = ± 2.0), maintaining it at FU 2/5 participants showed significant declines in the delayed recall score of the BVMTR at post-interventions, maintaining it at FU (BB and EE) No evidence to support the effectiveness of Lumosity on objective memory measures
			Subjective everyday memory failures (SR)	EMQ-R	1/5 participants showed a significant increase in everyday memory complaints (BB: $p = .02$) at post-intervention 1/5 participants showed a significant improvement in everyday memory complaints (CC: $p = .01$) at FU No evidence to support the effectiveness of Lumosity on subjective memory measures
			Subjective prospective memory failures (SR)	CAPM part A	2/5 participants showed a significant increase in prospective memory failures (BB: $p = .04$; EE: $p = .02$) at post-intervention 1/5 participants showed a significant improvement in prospective memory failures at FU (CC: $p = .01$) No evidence to support the effectiveness of Lumosity on subjective memory measures
			Goal attainment (SR)	GAS	4/5 participants (CC, DD, EE, BB) reported an improvement in one out of two rehabilitation goals at post-intervention, which was maintained at FU for 3/5 participants (CC, DD, EE) 2/5 participants reported a decline in goal attainment at post-intervention (AA) and FU (BB and AA)
			Feasibility and acceptability (SR)	Rates of adherence to training schedule	High adherence rates (participants were able to complete ≥ 80% [25/30] training sessions without significant technical issues)

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
Kiran, 2014 [11]	III	2 moments Pre Post	Cognitive functioning (screening)	CLQT	4/4 participants improved at post-intervention
			Language (battery)	WAB	4/4 participants improved at post-intervention
			Language – Naming	BNT	2/4 participants improved at post-intervention
			Language – Semantics	PPTT	ND
Mendes, 2021 [12]	Ia	2 moments Pre Post	Cognitive functioning (screening)	MoCA	H1: ND (group; time x group; time); the EG was not superior to the pCG H2: ND (group; time x group), but significant effect of time ($p = .030$), with post-hoc intragroup analyzes showing a significant difference on the EG ($p = .045$) at post-intervention. The EG showed superior gains compared to the aCG
			Attention, processing speed, mental flexibility and spatial organization	TMT – A TMT – B	H1: ND (time; group x time; group); the EG was not superior to the pCG H2: ND (time; group x time; group); the EG and aCG seemed equivalent
			Attention (selective and sustained attention)	d2	NA
			Working memory	SL (WMS-III) LNS (WMS-III)	H1: ND (time; group x time; group); the EG was not superior to the pCG H2: ND (time; group x time; group); the EG and aCG seemed equivalent
			Verbal memory	HVLT	H1: ND (group; time x group), but significant effect of moment ($p = .012$), with post-hoc intragroup analyzes showing differences between pre- and post-intervention scores for the pCG H2: ND (group, time x group), but significant effect of time ($p = .030$), with intragroup post-hoc analyzes showing significant differences between pre- and post-intervention for the EG ($p = .042$) but not the aCG. The EG led to superior results compared to the aCG
			Executive functions – Planning, abstraction, mental flexibility, sequencing)	WCST	H1: ND (time x group; group), but significant effects of time ($p = .014$, $\eta_p^2 = .407$), with the EG and pCG improving across assessment moments. The EG was not superior to the pCG H2: ND (group; time x group), but significant effects of time ($p = .046$), with post-hoc intragroup analyzes showing a significant difference between pre- and post-intervention for the EG ($p = .046$). The EG led to superior results than the aCG
			Executive functions – Cognitive flexibility and concentration	Stroop Test	H1: ND (time x group; group), but significant effects of time ($p = .014$, $\eta_p^2 = .407$), with the EG and pCG improving across assessment moments H2: ND (time; group x time; group). The EG and aCG seemed equivalent
			Language – Comprehension	Token Test	H1: ND (group x time), but significant effects of group ($p = .048$, $\eta_p^2 = .73$) and of time ($p = .014$, $\eta_p^2 = .375$), with post-hoc intragroup analyzes indicating improvements for the pCG ($p = .012$). The EG was not superior to the aCG H2: ND (time; group x time; group). The EG and aCG seemed equivalent

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
			Depressive and anxiety symptoms (SR)	HADS	H1: ND (time x group; group), but significant effects of time ($p = .024$, $\eta_p^2 = .355$) on the depression scale (HADS). Post-hoc analyzes only identified a near significant ($p = .56$) difference in depression from pre- to post-intervention in favor of the EG H3: ND (time x group), but significant effect of group ($p = .004$, $\eta_p^2 = .703$) and time ($p = .008$, $\eta_p^2 = .422$), indicating that the EG showed a significant difference at post-intervention ($p = .042$) in the depression scale (HADS). Intergroup analysis showed differences in this domain ($p = .004$) in favor of the EG
			Quality of life (SR)	QOLIBRI	H1: ND (time x group; group), but significant effects of time ($p = .035$, $\eta_p^2 = .264$) on quality of life (QOLIBRI); post-hoc intragroup analysis indicated the pCG improved quality of life at post-intervention ($p = .024$) compared with the EG. The EG was not superior to the aCG H2: ND (time x group; time); significant effects of group ($p = .023$, $\eta_p^2 = .578$) on life satisfaction, emotional and physical factors indicators (QOLIBRI), with post-hoc intergroup analyzes showing significant differences in pre- ($p = .035$) and post-intervention ($p = .38$) in favor of the EG. The EG led to superior results compared to the aCG
van der Linden, 2021 [13]	I	3 moments Pre Post FU (12 m)	Cognitive functioning (battery)	CNSVS	ND (time x group) Significant effects of time for processing speed ($p < .001$), complex attention ($p = .003$), cognitive flexibility ($p < .001$) and working memory ($p = .048$), suggesting both the EG and pCG improved over time
			Working memory	Digit Span (WAIS-III)	ND (time x group)
			Language – Verbal Fluency	Verbal Fluency (phonemic)	ND (time x group)
			Cognitive failures (SR)	CFQ	ND (time x group)
			Depressive symptoms (SR)	HADS	ND (time x group)
			Executive behavior (SR)	BRIEF – A	ND (time x group) Significant main effects of time in behavioral regulation ($p = .006$) and metacognition ($p = .004$), suggesting both the EG and pCG improved over time
			Fatigue (SR)	MFI-20	ND (time x group) Significant main effects of time in mental fatigue ($p = .022$), suggesting both the EG and pCG improved over time
			Feasibility and satisfaction (SR)	Rates of enrollment and attrition, adherence and satisfaction	Enrollment and attrition EG: 79% ($n = 49$; T3-T6), and 72.5% ($n = 45$; T6-T12) Adherence rates EG: 85% completed strategy training and 91% retraining Patient satisfaction EG: 90% rated the program as "good" or "excellent", and 95% would recommend it
Lebowitz, 2012 [14]	III	2 moments Pre Post	Cognitive functioning (battery)	ANAM4	Small effect sizes: ANAM4 – procedural reaction time ($d = .03$), ANAM4 – mathematical processing ($d = .02$) Small to medium effect sizes: ANAM4 – matching to sample ($d = .45$), ANAM4 – simple reaction time ($d = .28$), ANAM4 – code substitution ($d = .47$) Medium to large effect sizes: ANAM4 – code substitution delayed memory ($d = .58$)
			Cognitive failures (SR)	CFQ	Small to medium effect sizes: CFQ – names subscale ($d = .33$), CFQ – distractibility subscale ($d = .41$), and CFQ – memory subscale ($d = .34$); Medium to very large effect sizes: CFQ total score ($d = .58$) and CFQ blunders subscale ($d = 1.45$)

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
			Executive behavior (SR)	FrSBe	Small effect sizes: FrSBe – apathy subscale ($d = .14$) Small to medium effect sizes: FrSBe – total score ($d = .29$), FrSBe – executive dysfunction subscale ($d = .38$), FrSBe – disinhibition subscale ($d = .23$)
			Feasibility and acceptability (SR)	UES	High feasibility and acceptability: all participants installed and used the software at home; 7/10 reported no difficulty using the software; 8/10 reported using the software at least 40 min/day, 5 days/wk; 8/10 reported mild fatigue; and 7/10 reported real-world benefits (e.g., concentration, executive functioning, visual processing)
Maresca, 2019 [15]	I	2 moments Pre Post Phase II T1-T2 (discharge)	Language (global)	ENPA	ENPA scores, specifically on the comprehension ($p < .001$), repetition ($p < .001$), naming ($p < .001$), reading ($p < .001$) and calculation ($p < .001$) domains were affected by the type of rehabilitation treatment. ND were found for the writing domain ($p = .18$). Overall, the EG improved consistently more on these language domains compared with the aCG
			Language (comprehension)	Token Test	Token Test scores were affected by the type of rehabilitation treatment ($p < .001$), with the EG improving significantly more compared to the aCG at discharge (T1-T2)
			Depressive symptoms (SR)	ADRS	ADRS scores were affected by the type of rehabilitation treatment ($p < .001$), with the EG improving significantly more compared to the aCG at discharge (T1-T2)
			Quality of life (SR)	EQ-5D (includes EQ VAS, records of patient's self-rated health on a vertical visual analogue scale)	ND between groups on quality of life (EQ-5D) ($p = .53$), although the EG exhibited an improvement in self-perceived health (EQ-VAS)
			Psychosocial impact (SR)	PIADS	The EG showed significant improvements ($p < .01$) at discharge (T1-T2) for all dimensions of PIADS (competence, adaptability, and self-esteem)
Torrisi, 2019 [16]	I	2 moments Pre Post Phase II T1-T2 (discharge)	Cognitive functioning (screening)	MoCA	Significant within-group differences on MoCA ($p < .001$) for the EG after discharge, suggesting an improvement in global cognition compared to the aCG
			Attention	TMT-A TMT-B AM	Scores of TMT – B ($p < .001$), AM ($p < .001$) were affected by the type of rehabilitation treatment ND for TMT – A scores ($p = .19$) Significant within-group differences on both TMT – B and AM in the EG indicating greater improvements
			Verbal Memory	RAVLT	Scores of the RAVLT immediate recall ($p < .001$) were affected by the type of rehabilitation treatment The EG improved more in immediate recall
				Digit Span	ND
			Executive function	FAB Weigl Test	ND

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
			Language – Verbal Fluency	Verbal Fluency (Phonemic and semantic)	Scores of the semantic fluency ($p < .001$), and the phonemic fluency tests ($p < .001$) were affected by the type of rehabilitation treatment Significant differences between the groups at T2 on the phonemic fluency scores ($p = .04$) in favor of the EG, which manifested greater improvements at discharge Significant within-group differences in the semantic fluency scores ($p < .001$) for the EG at discharge, suggesting an improvement in this domain
			Depressive and anxiety symptoms (SR)	HRS-D HRS-A	Scores of the HRS-A ($p < .001$) and HRS-D ($p < .001$) were affected by the type of rehabilitation treatment Significant within-group differences in HRS-A ($p = .001$) and HRS-D ($p < .001$) for the EG at discharge, suggesting an improvement in depressive and anxiety symptoms
Peers, 2020 [17]	I	2 moments Pre Post	Attention	Partial and whole report TVA paradigm Star Cancelation Task Line Bisection Test Temporal Order Judgment Task Lateral Reaction Time Task Slow and Variable Tone Counting Test	EG (SAT): significant improvements both in the bias score ($p < .05$) and the K' score ($p < .01$) at post-intervention, indicating only the SAT group presented an improvement on spatial awareness and in their ability to take in more information at a glance (K'), respectively ND between both groups (EG – SAT and EG – WMT) in star cancelation, line bisection, lateral reaction time and line bisection (of note is the fact that participants did not show significant clinical impairments on these tasks at pre-test)
			Working memory	AWMA (Dot Matrix and Spatial Span Tests)	Significantly greater improvements in the dot matrix only for the EG (WMT) ($p < .05$) Improvements in the AWMA spatial recall task only for the EG (WMT) ($p < .05$) between pre- and post-intervention
			Quality of life (SR)	EBIQ	Significant improvements in the EBIQ – Core symptoms score and the EBIQ – Cognitive symptoms score in both the EG (SAT) ($p < .005$) and EG (WMT) ($p < .001$), but not on the pCG
Choi, 2016 [18]	III	3 moments Pre Post FU (1 m)	Language (battery)	K-WAB (Korean version)	Significant post-intervention improvements in the mean k-WAB AQ scores ($p = .025$), and in the following subsections: fluency ($p = .039$), auditory comprehension ($p = .028$) and the aphasia coefficient ($p = .027$). Improvements in the EG were maintained at 1-month FU
			Feasibility and acceptability (SR)	Satisfaction questionnaire	High satisfaction (mean above 4 in a 5-point Likert scale) even though patients were not used to using interactive technologies. They reported high training intensity, training convenience, program's readability, program's impact on health and medical needs

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
Gil-Pagés, 2022 [19]	Ia	5 moments Phase I: Pre (T1) Post (T2) Phase II: Pre (T3) Post (T4) FU (T5) (6 m) *We will only consider results from phase I (T1-T2)	Processing speed	CPT-II (Hit response Index) Digit Symbol-Coding Test (WAIS-III)	ND
			Attention (sustained)	CPT-II	ND
			Selective and divided attention	TMT – A TMT – B	ND
			Verbal memory	Digit span Forward (WAIS – III) RAVLT	ND
			Language – Verbal fluency	Verbal fluency (Phonemic fluency – Spanish)	ND
			Executive functions (working memory)	Digit Span Backwards (WAIS-III) Letter-number Sequencing (WAIS-III)	ND
			Executive functions (inhibitory control)	Stroop Word Test	ND
			Self-awareness (SR)	PCRS	ND
			Attentional difficulties in daily life (SR)	RSAB	Significant between-group differences ($p = .02$, $d = .80$) in attentional difficulties of daily living (RSAB), where the EG showed less attentional complaints than the aCG at post-intervention

Table 3 (continued)

First author, year [study number]	Study Class	Assessment moments	Variables	Instruments/measures	Main outcomes
			Prospective memory complaints (SR)	PRMQ	Significant between-group differences ($p = .03$, $d = .90$) in prospective memory complaints (PRMQ), where the EG showed less memory complaints than the aCG at post-intervention
			Executive behavior (SR)	BRIEF-A	ND

ABT = Active Brain Trainer; aCG = Active Control Group; ADRS = Aphasia Depression Rating Scale; AM = Attention Matrices; ANAM4 = Automated Neuropsychological Assessment Metrics Version 4; AWMA = Automated Working Memory Assessment; BAI = Beck Anxiety Inventory; BDI-II = Beck Depression Inventory 2nd Edition; BNT = Boston Naming Test; BRIEF-A = Behavior Rating Inventory of Executive Function-Adult Version; BTA = Brief Test of Attention; BTACT = Brief Test of Adult Cognition by Telephone; BVMT-R = Brief Visuospatial Memory Test; CADL = Communicative Abilities in Daily Living; CAPM = Comprehensive Assessment of Prospective Memory; CBB = Cogstate Brief Battery; CCRG = Computer-Assisted training; CFQ = Cognitive Failures Questionnaire; CLQT = Cognitive Linguistic Quick Test; CNSVS = Central Nervous System Vital Signs; CPT-II = Conner's Continuous Performance II; DEX = Dysexecutive Questionnaire; EBIQ = European Brain Injury Questionnaire; EFPT = Executive Function Performance Test; EG = Experimental Group; EMQ = Everyday Memory Questionnaire; ENPA = Esame Neuropsicologico Per l'Afasia; EQ-5D = EuroQoL-5D; FAB = Frontal Assessment Battery; FrSBe = Frontal Systems Behavioral Scale; FU = Follow-up; GAS = Goal Attainment Scale; GSE = General Self-efficacy; HADS = Hospital Anxiety and Depression Scale; HRS-A = Hamilton Rating Scale-Anxiety; HRS-D = Hamilton Rating Scale-Depression; HRTB = Halstead-Reitan Neuropsychological Test Battery; HVLT = Hopkins Verbal Learning Test; LIADL = Lawton Instrumental Activities of Daily Living; LNS = Letter and Number Sequence; MFI-20 = Multidimensional Fatigue Inventory; MoCA = Montreal Cognitive Assessment; MPAI = Mayo-Portland Adaptability Index; NAB = Neuropsychological Assessment Battery; ND = No significant differences; NIH-EXAMINER = Health Executive Abilities Measures and Instruments for Neurobehavioral Evaluation and Research; NSI = Neurobehavioral Symptoms Inventory; OCRG = Online-interactive computer-assisted training; OCS = Oxford Cognitive Screen; PANAS = Positive and Negative Affect Schedule; PASAT = Paced Auditory Serial Addition Test; pCG = Passive Control Group; PCL-C = Post-Traumatic Stress Disorder Checklist-Civilian Version; PCRS = Patient Competency Rating Scale; PHQ-9= Patient Health Questionnaire 9; PPTT = Pyramids and Palm Trees Test; PRMQ = Prospective and Retrospective Memory Questionnaire; PROMIS = Patient-Reported Outcomes Measurement Information System; QOLIBRI = Quality of Life after Brain Injury; RAVLT = Rey-Auditory Verbal Learning Test; RCI = Reliable Change Index; RPA-ProMem = Royal Prince Alfred Prospective Memory Test; RULIT = Ruff Light Trails Test; SAQOL = Stroke and Aphasia Quality of Life Scale; SAT = Selective Attention Training; SD = Standard-Deviation; SDMT = Symbol Digit Modalities Test; SF-12 = 12-Item Short-Form Health Survey; SL = Spatial Location; SNQ = Subjective Neglect Questionnaire; SR = Self-report; TCRG = Therapist-administered training; TIADL = Timed Instrumental Activities of Daily Living; TMT = Trail Making Test; TVA = Theory of Visual Attention; UES = User Experiences Questionnaire; WAB = Western Aphasia Battery; WAIS-IV = Wechsler Adult Intelligence Scale IV; WCST = Wisconsin Card Sorting Test; Wk = Week; WMS-III = Wechsler Memory Scale III; WMT = Working Memory Training; WWT = Walking while Talking

(aCG). In another study, Mahncke et al. (2021) (study 6) assessed the efficacy of a 13-week self-led computerized plasticity-based CT program (BrainHQ app) targeting several cognitive functions in a sample of veteran military participants with mild TBI, and compared it to an aCG (engaged in 13 computer games like the Hangman, Boggle, Mah-jong). van der Linden et al. (2021) (study 13) evaluated the effects of a 10-week tablet-based multicomponent r-CRP (ReMind app) for brain tumor patients compared to a pCG (no intervention).

Now, regarding therapy-facilitated r-CRP ($n=3$; studies 8, 15, 16), one study (study 8) investigated the effectiveness of a 20-session analogy-based problem-solving skill training program delivered in three formats – online-administered (screen-sharing) (EG), computer-assisted (aCG I), and therapist-administered (aCG II) – in comparison to a pCG (no intervention). Two other studies (studies 15, 16) compared the effectiveness of a 12-week telerehabilitation program involving the VRRS-Tablet with traditional speech-language treatment (aCG; study 15), and face-to-face conventional CRP (aCG; study 16).

Finally, Zhou et al. (2018) (study 7) assessed the efficacy of a computerized cognitive and speech-language training intervention delivered via telehealth to discharged stroke patients with aphasia and compared it to an aCG (family topics communication). In this study it was not clear if the intervention was therapist-facilitated or self-guided.

Concerning the two class Ia studies, Mendes et al. (2021) (study 12) assessed the effects of the VICERAVI program, an online VR-based platform entailing both CT and affective and psychosocial training for TBI patients, when compared to two control conditions (aCG: face-to-face holistic NR; and pCG: no intervention). Gil-Pagés et al. (2022) (study 19) conducted a pilot double-blind cross-over clinical trial with a three-month washout period, involving the administration of two different r-CRP to chronic stroke patients in two different phases: phase I (T1-T2) and phase II (T3-T4). The first group (Group A) performed a customized CT with the GNPT platform, while the second group (Group B) was enrolled in a sham intervention, receiving non-customized CT. For the purposes of this review, we will focus on the results obtained during phase I (T1-T2), prior to the cross-over to the other intervention group. Therefore, we will consider Groups A and B as the EG and the aCG, respectively.

Performance-based outcomes of Class I and Class Ia studies Five out of 10 class I studies reported significant improvements in objective cognitive outcomes after the completion of the r-CRP. Specifically, when comparing the EG to an aCG or pCG, there were post-intervention significant gains favoring the EG in the following cognitive domains: global cognition ($n=2$, studies 6, 17), attention ($n=2$, studies 17, 18), working memory ($n=1$, study 18), verbal memory ($n=1$, study 17), language ($n=4$, studies 5, 7, 16, 17), and communication ($n=1$, study 7). Among these five studies, the only study assessing the long-term impact of the r-CRP confirmed the maintenance of global cognitive gains at one-month follow-up (study 6). The remaining three studies with a follow-up assessment did not find any changes between the r-CRP and the controls (studies 2, 3, 13). Noteworthy, while Man et al. (2006) (study 8) failed to demonstrate r-CRP's superiority over the two aCG, this finding was still considered to be encouraging. It suggested that r-CRP may be as effective in improving executive functioning (problem-solving abilities) as the other approaches (computer-assisted, and face-to-face therapist guided training).

Of the two class Ia studies, one (study 12) found that the EG demonstrated post-intervention improvements in verbal memory and executive functions (planning, abstraction, mental flexibility, sequencing) compared to the aCG. Additionally, the study hypothesized that the VR-based program would lead to equivalent results to those of the aCG (face-to-face NR) across cognitive measures, and this hypothesis was supported for working memory, executive functions (cognitive flexibility and concentration) and language (comprehension) at post-intervention. Despite the benefits the EG over the aCG, participants in the pCG showed similar improvements in various cognitive domains (e.g., global cognition, attention, working memory), which were attributed to learning effects and spontaneous recovery. In this study, maintenance of long-term gains was not assessed.

Self-report outcomes of Class I and Class Ia studies Among the 10 class I and the two class Ia studies that assessed non-cognitive outcomes, only five identified statistically greater improvements in the r-CRP (studies 1, 16, 17, 18, 19). In one study (study 1) the EG showed medium to large effect size improvements in subjective memory failures and internal strategies use at post-intervention, further reporting less memory failures at six weeks follow-up in comparison to the aCG. Similarly, in another study (study 19) the EG reported significantly less memory complaints and subjective attentional difficulties after the r-CRP than the aCG. Regarding emotional state, two studies (studies 16, 17) found significant improvements in depressive symptoms immediately after the r-CRP in comparison to the aCG, with one of the studies (study 17) also identifying improvements in anxiety symptoms at post-intervention. Moreover, in other two studies (studies 12, 18) participants in the r-CRP reported significantly higher quality of life compared to the controls. The long-term assessment of noncognitive outcomes was performed in four studies, with three (studies 2, 3, 13) not revealing any significant differences between participants

in the r-CRP and the control condition, and one showing a significantly greater improvement in post-traumatic stress symptoms in the aCG (study 6). Lastly, of the remaining studies that did not find differences between the EG and the controls, it is important to note that one of them (study 8) concluded that both the r-CRP and the two aCG significantly improved self-reported instrumental activities of daily living at post-intervention, something that did not happen in the pCG. In addition, three studies measuring feasibility and acceptability (studies 1, 2, 13) revealed high participant's adherence and satisfaction with the r-CRP.

Class II studies overview

The only class II study compared the EG (compensatory memory rehabilitation program via telehealth) with an aCG (face-to-face compensatory memory program) (study 1), and performed a follow-up assessment to measure the r-CRP impact at long-term[1] in a sample of stroke patients.

Performance-based outcomes of Class II studies This study demonstrated that both the EG and the aCG groups exhibited significant improvements in prospective memory at post-intervention, and six-week follow-up. Conversely, both groups significantly declined in new learning and delayed memory at post-intervention and follow-up.

Self-report outcomes of Class II studies The EG improved significantly in subjective everyday memory failures and internal strategies, having maintained the former at six-weeks follow-up. Both groups improved in subjective memory failures and goal attainment, suggesting that telehealth delivery of memory rehabilitation is comparable to face-to-face memory rehabilitation. Moreover, participants in the r-CRP reported high feasibility compared to participants in the aCG.

Class III studies overview

All six class III studies described in this review lacked a control group ($n=6$; studies 4, 9, 10, 11, 14, 18). Most r-CRP were self-guided (studies 10, 11, 14, 18) and delivered to chronic stroke patients (studies 9, 10, 11, 19). Three studies administered multidomain r-CRP (studies 4, 11, 14), while the remaining r-CRP were single-domain (studies 9, 10, 19). Overall, only two studies measured maintenance of gains after one month (study 18) and six weeks (study 10) since the r-CRP.

Regarding multidomain r-CRP, Eilam-Stock (2020) (study 4) conducted a case study of a TBI patient who underwent 20 sessions of therapist-delivered remotely supervised transcranial direct current stimulation (tDCS) over the left dorsolateral prefrontal cortex paired with multidomain adaptive CT (BrainHQ). In another study (study 11), four stroke patients were enrolled in multidomain CT (e.g., attention, memory, language and executive functions) with the CT-R app. Similarly, Lebowitz et al. (2012) explored the feasibility and impact of self-guided computerized brain plasticity-based CT (Cortex with Insight software) in 10 community-dwelling mild to severe TBI.

In terms of single domain r-CRP, Shochat et al. (2017) (study 9) assessed the initial efficacy of the ABT – a novel VR exergames platform targeting executive functions – in six ABI patients. Withiel et al. (2018) (study 10) conducted an AB single-case design with follow-up across five participants with stroke to explore the feasibility and efficacy of self-guided six-week computerized CT intervention (Lumosity app) on objective and subjective memory outcomes. Finally, Choi et al. (2016) (study 18) assessed the effects of a four-week tablet-based telespeech intervention (iAphasia app) in poststroke aphasia patients.

Performance-based outcomes of Class III studies Considering participants' baseline performance, five out of six studies reported significant post-intervention improvements in performance-based outcomes after the r-CRP (studies 4, 10, 11, 14, 18). Two out of two studies with a follow-up assessment reported maintenance of some cognitive improvements (studies 10, 18).

Eilam-Stock et al. (2021) (study 4) found clinically significant post-intervention improvements in visual attention, processing speed and semantic verbal fluency, which were consistent with the site of stimulation. Kiran et al. (2014) (study 11) concluded that all stroke patients improved their cognitive functioning and language abilities (WAB coefficients) following 10-weeks of CT-R training. Lebowitz et al. (2012) (study 14) reported: small to medium, and medium to very large effect size improvements on self-reported cognitive failures; and small to medium effect size improvements on many ANAM4 domains, such as processing speed and efficiency, spatial processing, visuospatial working memory, and delayed memory. Withiel et al. (2018) (study 10) found that three out of five stroke patients presented at least one significant improvement in visual memory or verbal memory at post-intervention, which were then retained at six-week follow-up. Finally, Choi et al. (2016) (study 18) verified that poststroke aphasia patients revealed significant

[1] The results regarding the administration of a booster session (i.e., plus one intervention session) are not described as these sessions were randomized regardless of the group (i.e., EG or aCG).

improvements in the WAB mean scores (fluency and auditory comprehension), as well as in the WAB-AQ mean scores, retaining gains at one-month follow-up and exhibiting new ones in the reading domain (WAB).

Self-report outcomes of Class III studies Of the six class III studies, five included self-report outcomes. Noncognitive improvements were found in three of the studies. Specifically, noncognitive significant gains were demonstrated in emotional state (study 4), goal attainment (study 10), cognitive failures (study 14), and behavioral functioning (study 14) at post-intervention. Importantly, in one study goal attainment was the only outcome that was maintained at follow-up in most participants (3/5 stroke survivors achieved at least one rehabilitation goal) (study 10). Lastly, five studies measured feasibility and acceptability, with participants reporting high scores on both indicators (studies 9, 10, 11, 14, 18).

Discussion

In the last few years, the scientific and clinical communities are experiencing a paradigm shift in the field of CR: transitioning from in-presence to remote delivered CR (Dores et al., 2020; Cogollor et al., 2018; O'Neil et al., 2020; Maggio et al., 2020; Mantovani et al., 2020). This shift aims to facilitate the access of patients to CR services. In this context, the purposes of this systematic review were primarily to describe the r-CRP methodological characteristics through the specification of the assessment and intervention protocols, and to summarize their main results in cognitive and noncognitive domains of ABI patients. A total of 19 studies were included in this systematic review, and most studies were classified as class I (Class I = 10; Class Ia = 2), meaning that they were developed under rigorous methodological standards. To enhance the clarity and organization of the discussion, we will structure it around the RQ outlined in the introduction.

Target ABI stage and severity for implementing remote delivered cognitive rehabilitation programs

Concerning the RQ 1 ("*In what stage and severity of ABI are r-CRP usually initiated?"*), most studies were conducted in samples of chronic ABI survivors, and have omitted information on the severity of the brain injury. In regard to the stage of the ABI, the guidelines recommend that ABI patients are enrolled in CR at the early stages of recovery to capitalize on the "brain's spontaneous recovery window" (within the first six months after the injury), in which brain plasticity mechanisms are activated (e.g., diaschisis, functional network recovery and behavioral compensatory readjustments) in order to better cope with the consequences of the brain insults (Fasotti, 2017). Thus, precocious CR has the potential to decrease the likelihood of patients learning maladaptive behavioral patterns to manage their impairments and develop psychopathologic conditions that negatively affect their prognosis (e.g., depression, anxiety, post-traumatic stress disorder) (Bennett, 2001). León-Carrión et al. (2013) found that early rehabilitation is key for functional recovery; patients initiating rehabilitation within nine months post-injury demonstrate enhanced global functionality, translated into greater locomotion function (92.31%), communication (91.67%), cognitive functioning (85%), and psychosocial adjustment (68.42%), in comparison with patients that started rehabilitation later. Notably, most patients enrolled in the r-CRP included in this review have initiated rehabilitation in the chronic phase, having apparently missed the ideal timeframe for achieving optimal cognitive and noncognitive benefits. However, some reasons for starting r-CRP in the chronic phase must be drawn. First, enrollment in inpatient rehabilitation programs (e.g., speech therapy, physiotherapy, occupational therapy), can pose challenges for clinical trial recruitment due to the complexity of managing and controlling confounding factors. Second, multidomain impairments (e.g., cognitive, emotional, physical) can compromise patient's compliance with remote interventions (Buckingham et al., 2022). Third, r-CRP may not be accessible due to the limited availability of r-CRP, and lack of trained and specialized healthcare providers. Finally, patients in the early stages of recovery may want to prioritize learning how to cope with their diagnosis and symptoms, while also dedicating time to their families (van der Linden et al., 2021).

Furthermore, the fact that most studies in this review have not specified the ABI severity is consistent with a previous review by Bogdanova et al. (2015). The underreporting of information regarding the ABI severity can compromise the applicability and replicability of the studies' findings. In fact, the severity of the condition is an important determinant of several factors impacting the rehabilitation process, including the establishment of patient-centered goals based on the areas of strength and weakness, the specific rehabilitation plan according to the areas of concern (e.g., emphasis on restoration, substitution, or compensation), and the mode of delivery of the intervention (i.e., if in-presence or at-distance). For instance, with respect to the mode of delivery of the intervention, patients with moderate to severe physical, sensory and cognitive impairments may not be the most suitable candidates for self-led remote interventions due to their increased need for feedback, monitoring and support from healthcare providers and significant others, compared

with patients with milder deficits (Buckingham et al., 2022). We speculate that in this context, in-presence CRP may be the most effective option for patients with moderate to severe impairments. However, no conclusions can be drawn in relation to this specific indicator, as this information is lacking in most studies reporting r-CRP.

Types of remote delivered cognitive rehabilitation programs

Considering the RQ 2 ("*What kind of r-CRP are typically implemented [e.g., therapist-facilitated or self-guided cognitive telerehabilitation, therapist-facilitated or self-guided computer-based or tablet-based programs]?")* most r-CRP described were ICT-based, and delivered through web-based platforms and telehealth systems, requiring internet connection. Moreover, the most frequently referred r-CRP were the Cogmed, SAT, BrainHQ, VRRS-Tablet, and the CT-R app. Over the last few years, many ICT-based programs have been developed and are increasingly recognized as a complementary therapeutic option over traditional methods (e.g., paper-and-pencil rehabilitation tasks), having the potential to be delivered remotely by resorting to several technological devices (e.g., tablet, computer, laptop) (Geraldo et al., 2018; Maggio et al., 2020; Mantovani et al., 2020). In the majority of the included studies, most programs were asynchronous and self-guided; in this case, patients performed sessions without the direct supervision from the therapists, having only received feedback after the sessions were completed. This mode of delivery may be suitable for patients in the chronic phase of stroke with milder deficits, and with support networks in order to facilitate adherence to rehabilitation. Nonetheless, it is not clear from this review if patients with moderate to severe deficits were exposed to self-guided r-CRP, as most of the studies did not mention this information, as reported earlier.

Usual dose of remote delivered cognitive rehabilitation programs

In response to the RQ 3 ("*What is the usual dose of r-CRP [i.e., number of sessions, frequency, session and intervention duration]*"*?*) there is no consensus on the session's number, frequency and duration, as well as to the intervention length, a finding that is consistent with previous systematic reviews (Bogdanova et al., 2015; Cicerone et al., 2000, 2019; Rogers et al., 2018). Nevertheless, it has been identified that 20 intervention sessions ranging between 30 and 60 min, delivered five times a week for a total of one month, is the most commonly reported r-CRP dose. There are yet no established recommendations for the "ideal" intervention dose for ABI patients engaging in CR. However, results from a recent systematic review and meta-analysis showed that delivering CR interventions three times a week or for more than 20 h in total was not reliably associated with larger effect sizes for most cognitive outcomes (Rogers et al., 2018). Therefore, the assumption that "the more CR, the better" may be misleading, as the effects of CR might not be linearly related to the treatment dose. Future research should focus on identifying the optimal dose-response relationship for different cognitive functions, therefore maximizing rehabilitation cost-effectiveness while reducing patients' burden and fatigue.

Techniques, target domains, content, adaptation and personalization procedures of remote delivered cognitive rehabilitation programs

Furthermore, in response to RQ 4 (*"What techniques, target domains, content, adaptation and personalization procedures are employed in r-CRP?"*), the majority of programs: (a) employed CT as the only rehabilitation technique, having, therefore, a restorative focus despite being mostly implemented in the chronic stage of stroke; (b) targeted multiple cognitive functions, as ICT-based programs encompassed several CT tasks aimed at addressing impaired cognitive domains (e.g., sustained attention, working memory, problem-solving, and verbal fluency); (c) included CT tasks with low ecological validity, meaning that tasks typically resembled digital versions of traditional paper-and-pencil CT tasks; and (d) mentioned the presence of adaptive and personalization features that allowed training difficulty adjustment based on participant's performance in individual tasks, but did not specify the criteria used to do so.

According to evidence-based recommendations (Cicerone et al., 2000, 2019), training with a restorative focus appears to be less effective for chronic cognitive deficits, especially memory deficits, which are typically more responsive to external compensatory strategies implementation in daily living (e.g., calendars, shopping lists, notebooks). Only 15.79% ($n = 3$) of the studies reviewed presented other intervention components aside from CT, including compensatory strategies training and social skills training. In terms of the multidomain nature of the r-CRP reported in this review, previous research stated that targeting several cognitive domains within a program can promote generalization of gains beyond the trained tasks, potentially leading patients to improve their performance on daily life activities (Gil-Pagés et al., 2022). However, despite most of the reported r-CRP allowed the training of multiple cognitive domains, the majority of training tasks were considered to have low ecological validity, which can actually affect this generalization of gains to patients real-world functioning

(e.g., ability to participate in society and perform activities of daily living) (Parsons, 2016; Pinto et al., 2024).

Finally, r-CRP commonly incorporates tasks that are grouped in different difficulty levels, with tasks being assigned to patients according to their performance. These personalization features differ from software to software, and are not given sufficient detail in most studies. Still, they are considered to enable an optimal training adjustment to patients' intervention needs (Câmara et al., 2022; Solana et al., 2014).

Overall, the diverse r-CRP characteristics explored in prior sections, particularly the substantial variation in intervention protocols (e.g., usual dose, rehabilitation techniques, target domains), coupled with the underreporting of crucial information, poses significant challenges to establishing clear, evidence-based guidelines for therapists working with ABI patients. This lack of consistent reporting makes it difficult for therapists, for instance, to select the most adequate CR for individual patients, optimize intervention delivery and standardize intervention protocols across clinical settings in order to replicate successful interventions. This conclusion aligns with the findings of a recent systematic review on the quality of post-stroke CR protocols (Small et al., 2022), in which the authors concluded that descriptions of intervention protocols remain highly variable and often lack detail, hindering therapists' and researchers' ability to comprehend, replicate and implement evidence-based CR in clinical practice. Hence, this substantial heterogeneity in terms of intervention protocols will necessarily hamper the determination of the efficacy of r-CRP in the context of ABI. To address this critical issue, future research should incorporate reporting checklists, such as the 12-item Template for Intervention Description and Replication (TIDieR). The integration of such a checklist would ensure comprehensive descriptions of CR interventions, facilitating their implementation in clinical practice, thereby reducing the risk of errors that can potentially undermine the effectiveness of the interventions while optimizing research and healthcare resource allocation (Small et al., 2022).

Assessment procedures

In response to RQ 5 ("*What are the assessment procedures frequently utilized to assess the efficacy of r-CRP [i.e., assessment moments, timing of assessment, target variables and instruments used]?*"), we only found consensus among studies in terms of assessment moments. Indeed, all studies incorporated at least two assessment moments (pre- and post-intervention assessments), allowing the evaluation of the programs' immediate effects, and about 47.37% ($n=9$) performed a follow-up assessment to measure the programs' long-term impact (maintenance of gains, if any have been verified). However, there was high heterogeneity among studies in terms of timing of assessment, target variables and instruments used to measure these variables. For instance, the timing of assessment varied greatly depending on the study, and was determined by the specific structure and characteristics of the interventions. Also, the number of variables (RQ 5) considered among studies ranged from two (studies 7, 18) to 16 (study 19). Regarding the cognitive variables, a high number of studies focused on language and communication ($n=10$; 52.63% of studies), and learning and memory ($n=9$; 47.37% of studies), which typically represent two of the most commonly impaired cognitive domains following ABI (van Heugten, 2017; Ponsford & Dymowski, 2017). Indeed, with respect to language and communication, about 41% of stroke survivors have aphasia (37.537 out of 88.974) and present communication difficulties (57.150 out of 88.974) (Mitchell et al., 2021). Deficits in these domains are also commonly reported in TBI patients, with 57% diagnosed with a cognitive-communication disorder and a smaller percentage with aphasia (16%) (Norman et al., 2021). Relatively to learning and memory deficits, a survey conducted by the Stroke Association (2017) found that about 77% of stroke survivors have memory deficits. Similarly, these deficits are quite prevalent in mild TBI (31% in the acute phase and 26% in the subacute phase), as well as in moderate-to-severe TBI (49% in the subacute phase and 21% of in the chronic phase) (Tsai et al., 2021). It is important to note that the included studies have considered multiple assessment instruments to measure the programs' target cognitive variables, even when they were the same across studies. Despite there being quite heterogenous assessment protocols, we verified that the most consensual instruments used to assess language and memory abilities were the WAB ($n=4$; Braley et al., 2021; Zhou et al., 2018; Kiran et al., 2014; Choi et al., 2016), and the RAVLT ($n=5$; Lawson et al., 2020; Eilam-Stock et al., 2021; Withiel et al., 2018; Torrisi et al., 2019; Gil-Pagés et al., 2022), respectively. Concerning the noncognitive variables targeted in the different studies, the most assessed were the emotional status ($n=6$; 31.58%), behavioral functioning ($n=5$; 26.32%), and quality of life ($n=5$; 26.32%). These domains are known to be frequently compromised in ABI patients with cognitive impairment (Brasure et al., 2013; Cernich et al., 2010; Entwistle & Newby, 2013). Similarly, studies reported multiple self-report instruments to assess the different noncognitive variables. Nevertheless, anxiety and depressive symptoms were most typically assessed by the BDI-II ($n=2$; Eilam-Stock et al., 2021; Mahncke et al., 2021) and the HADS ($n=2$; Mendes et al., 2021; van der Linden et al., 2021), behavioral functioning by the BRIEF-A ($n=3$; Välimäki et al., 2018; van der Linden et al., 2021; Gil-Pagés et al., 2022), and quality of life by the EBIQ (n

= 2; Peers et al., 2020, 2021). Despite the high heterogeneity of instruments used among studies, it is important to emphasize that 84.21% of included studies ($n = 16$) presented both cognitive and noncognitive outcome measures, which positively contributed to enhancing the ecological validity of the assessment protocols. Indeed, besides evaluating the programs' effect on cognitive dimensions, such as global cognition, learning and memory, and executive functions, most studies recognized the importance of considering participant's self-report on emotional, neurobehavioral and functional abilities domains. The inclusion of multidomain measures is a crucial step in predicting real-life performance. Nonetheless, most studies conducted these assessments in traditional clinical settings (e.g., hospital, rehabilitation center, research institution) and were based solely on participants' self-reports. Ultimately, to increase the protocol's ecological validity, it is fundamental to incorporate performance-based measures or, ideally, to assess functional abilities outside rehabilitation settings, to create a more complete picture of the real-life skills of the patient and to understand further if generalization has occurred (Cicerone et al., 2019).

Another aspect that should be highlighted is that none of the studies combined neurobehavioral measures with other biological correlates, such as neurophysiology or neuroimaging. In a recent systematic review (Geraldo et al., 2022) focused on understanding the contribution of functional connectivity analysis combined with behavioral indicators (i.e., neuropsychological instruments) for the assessment of the efficacy of CRP. These authors found that all programs were significantly associated with changes in functional connectivity, and 32 studies reported that changes in functional connectivity were related to improvements in neuropsychological outcomes (e.g., cognitive functioning, quality of life, and emotional state). Therefore, to evaluate more comprehensively the efficacy of r-CRP it could be important to perform a multilevel assessment, which incorporates both neurobiological and behavioral outcomes, to further deepen our understanding of the neural correlates or CR interventions, and to inform the development of more tailored CR interventions.

Finally, as pointed earlier in the sections describing the r-CRP intervention characteristics, the high variability of assessment protocols that was found among studies raises several challenges when establishing the efficacy of r-CRP in order to provide evidence-based support for its clinical application (e.g., deciding which interventions are more advantageous for patients with a particular ABI diagnosis, sociodemographic background and neuropsychological profile). Indeed, the inconsistency in standardized assessment procedures may increase the risk of bias among studies, as some assessment protocols may be more sensitive to change than others. For instance, language deficits might show greater improvement with a particular ICT-based CT program compared to memory deficits. If a study solely relies on language assessments, it could suggest that the intervention is effective for language, but its impact on memory would remain undetermined. Besides, this inconsistency further hinders the generalization of the results to studies with different protocols; if another study investigates the same ICT-based CT program and assesses its impact with a different language instrument, the results obtained might not be the same due to differences in the instrument's psychometric properties. Moreover, given the high heterogeneity of the studies assessment protocols, it is not possible to conduct a meta-analysis to provide quantitative estimates for the effects of r-CRP in different outcome measures. For this reason, it is a priority to carry out multicentric studies focusing on investigating specific r-CRP across different countries, employing a standardized assessment (focusing on core domains) and intervention protocol with larger patient samples (Bogdanova et al., 2015; Geraldo et al., 2018; O'Neil et al., 2019). Hence, the results obtained in such studies would be able to inform the development of new practice guidelines in the field of r-CRP, specifying the most appropriate methodology to implement r-CRP in clinical practice, and conduct robust scientific research to replicate the findings of multicentric studies in order to further consolidate the evidence base for r-CRP.

Effects of remote delivered cognitive rehabilitation programs

Finally, concerning RQ 6 (*"What are the main results of r-CRP?"*), we found that r-CRP results varied widely according to the methodological quality of the studies, with class III studies being more consistently supportive of this type of intervention approach especially when referring to noncognitive outcomes assessed by means of self-report rating scales/questionnaires. Overall, considering the class I and class Ia studies in this review, 33.33% ($n = 4$) reported superior benefits for the group that underwent the r-CRP when compared to an aCG (Zhou et al., 2018; Maresca et al., 2019; Torrisi et al., 2019) or a pCG (Peers et al., 2020). These benefits were observed in specific cognitive domains, such as global cognitive functioning, attention, verbal memory, language and communication, which were associated with the targets of r-CRP, as well as other noncognitive domains, including emotional status (e.g., depressive and anxiety symptoms) and quality of life. Moreover, 50% ($n = 6$) of the studies reported almost equivalent cognitive and noncognitive results for patients in the r-CRP and the aCG (Braley et al., 2021; Gil-Pagés et al., 2022; Man et al., 2006; Mahncke et al., 2021; Mendes et al., 2021; Välimäki

et al., 2018), while 33.33% ($n=4$) of the studies reported practically no differences between patients in the r-CRP and the pCG (Mendes et al., 2021; Peers et al., 2021; Välimäki et al., 2018; van der Linden et al., 2021). The four class I studies that included a follow-up assessment yield mixed results regarding the maintenance of cognitive and non-cognitive benefits resulting from the r-CRP. For instance, Mahncke et al. (2021) reported that patients in the r-CRP retained gains in cognitive functioning at follow-up, but patients in the aCG, on the other hand, presented greater reductions in post-traumatic stress symptoms at this stage. Furthermore, Peers et al. (2021) found no changes between patients that underwent the r-CRP and the passive control condition at this stage, and both Välimäki et al. (2018) and van der Linden (2021) identified specific improvements at follow-up that were exhibited by patients enrolled on the r-CRP and the other groups (i.e., aCG or pCG). As a result, the reviewed class I studies assessing ABI patients cognitive and noncognitive-related outcomes offer inconclusive evidence on r-CRP's long-term effects. The only class II study (Lawson et al., 2020) found that the therapist-delivered compensatory memory rehabilitation in telehealth (EG) and face-to-face (aCG) formats led to similar results in 100% of the objective cognitive domains, with both groups of patients improving in prospective memory at post- and follow-up assessments, while revealing declines in new learning and delayed memory at post-intervention and follow-up. On the other hand, the telehealth delivery of the program led to better results in noncognitive domains, more specifically in subjective everyday memory failures and internal compensation strategies adoption, than the face-to-face delivery. Noteworthy, results on goal attainment and subjective memory failures were the same for both groups. For these outcomes, follow-up gains were maintained, except for internal compensation strategies use. Five out of six class III studies reported significant improvements in specific cognitive outcomes, and all indicated significant gains on noncognitive outcomes immediately after the r-CRP with CT as the only intervention technique. Among these, two studies measured the long-term effect of the r-CRP, and results were, once again, inconsistent. One study provided inconclusive results following Lumosity training (Withiel et al., 2018) in objective (e.g., verbal and visual memory) and subjective memory-related variables (e.g., subjective everyday and prospective memory failures), with some patients maintaining the improvements at follow-up, while others exhibiting maintenance of the declines at this stage. In contrast, the other study (Choi et al., 2018) found maintenance of language-related gains (e.g., auditory comprehension, fluency) at one month-follow up. Finally, irrespective of the studies' class, almost all studies reported the high feasibility and acceptability of r-CRP among participants.

In sum, this systematic review identified limited and inconclusive evidence for the efficacy of r-CRP in ABI patients-related cognitive and noncognitive outcomes, both in the short and in the long-term.

Limitations

This systematic review is not without limitations. Firstly, we only considered studies published in English, Portuguese and Spanish, and consequently can have disregarded studies with robust results published in other languages. Secondly, while we employed Cicerone et al. (2000) criteria to assess the studies' quality, the absence of a formal risk-of-bias assessment could have potentially impacted the reliability and interpretability of our findings. Additionally, the substantial heterogeneity across clinical populations, interventions and assessment protocols precluded meaningful comparisons between studies, significantly limiting our ability to conduct a meta-analysis that could have provided more comprehensive insights on interventions efficacy. Fourthly, the non-inclusion of qualitative data from semi-structured interviews narrows our understanding of patient experiences during r-CRP. Lastly, this systematic review did not capture the perspectives of caregivers and healthcare providers regarding the application of r-CRP in real-world settings. Notably, the studies included in this review did not report on these perspectives. Consequently, our ability to identify key facilitators and barriers that may have influenced the successful implementation and dissemination of these r-CRP remains limited.

Conclusions

With the advent of technological advances in CR and the influence of the COVID-19 pandemic, resulting in the rapid transformation in the delivery of healthcare services, r-CR has been emerging as a complementary or even substitutive approach to face-to-face CR. The present review synthesized the current state of the art in the field of r-CRP, and provided a comprehensive overview of the assessment and intervention protocols of studies reporting on the use of available r-CRP. The characterization of the assessment and intervention protocols used in studies describing r-CRP can be useful for therapists working with ABI patients. Indeed, systematizing this information can provide therapists with the knowledge and tools necessary to make informed decisions regarding the identification and implementation of the most suitable interventions in their clinical practice, considering the specificities of their ABI clients.

The findings of this review suggest that r-CRP is feasible and widely accepted among participants with ABI.

Nonetheless, results from Class I studies provide inconsistent evidence on the effects of r-CRP in cognitive and noncognitive domains, in result of considerable methodological heterogeneity among studies, preventing us from determining if these approaches lead to actual benefits for ABI patients.

Hence, this review highlights the need for developing sufficiently powered clinical trials able to detect differences between EG and aCG, and to demonstrate the noninferiority of r-CRP compared to face-to-face CRP to establish the efficacy of r-CRP compared to conventional in-presence methods. Thus, in light of the aforementioned limitations, we present the following recommendations for future research, namely: (a) provision of a detailed description of the clinical population characteristics (e.g., stage of ABI, severity of ABI, years of formal education, time post-ABI, digital literacy, pre-morbid functioning) to facilitate the identification of subgroups that are likely to be more or less responsive to these interventions; (b) development of clinical trials with larger and more homogenous samples; (c) analysis of the efficacy of r-CRP at different stages of ABI, and comparison between a r-CRP and a face-to-face counterpart; (d) enhancement of the ecological validity of the assessment protocols by integrating, apart from performance-based and self-report cognitive instruments, measures of quality of life, functionality, emotional, and neurobehavioral functioning; (e) establishment of the neural correlates of r-CRP, through the use of functional connectivity measures such as the electroencephalogram (EEG) and functional magnetic resonance imaging (fMRI); (f) provision of a detailed description of the method section to allow replication – this means adding information on inclusion and exclusion criteria, assessment (instruments and timings of assessment) and intervention protocol (e.g., number of sessions, frequency, duration, type of program, training content); (g) inclusion of a follow-up assessment to explore the maintenance of gains/effects; (h) integration of aCG and pCG to account for the placebo effect of having an intervention and the impact of spontaneous recovery in initial stages of recovery; (i) exploration of individual and external factors influencing response to r-CRP in order to recruit more adequate candidates; and (j) explore the perspectives of ABI caregivers and healthcare providers on facilitators and barriers to r-CRP adoption in order to both develop effective implementation strategies and optimize r-CRP delivery in clinical and community settings, ultimately improving patient-related outcomes. In sum, these recommendations can inform future research, guiding researchers and therapists in developing more rigorous methodologies, ultimately strengthening the body of evidence supporting r-CRP.

Acknowledgements We want to thank the authors who shared their research for inclusion in the present review and for all the clarifications provided.

Author contributions Conceptualization, J.C. and A.G.; methodology, J.C. and A.G.; software, J.C. and A.G; validation, J.C., A.G., M.V. and E.F.; formal analysis, J.C. and A.G.; investigation, J.C., A.G., M.V. and E.F.; writing—original draft preparation, J.C.; writing—review and editing, J.C., A.G., M.V and E.F; supervision, M.V and E.F. All authors have read and agreed to the published version of the manuscript.

Funding This work was supported by the FCT (*Fundação para a Ciência e a Tecnologia*, Portugal) under two PhD Grants awarded to Joana Câmara [SFRH/BD/145919/2019] and Andreia Geraldo [SFRH/BD/138723/2018]. Additionally, this work was partially supported by the same funding agency through NOVA LINCS: UID/CEC/04516/2019, PTDC/CCI-COM/30990/2017, PTDC/CCI-COM/4464/2020, UIDB/04516/2020 (https://doi.org/10.54499/UIDB/04516/2020) and UIDP/04516/2020 (https://doi.org/10.54499/UIDP/04516/2020).
Open access funding provided by FCT|FCCN (b-on).

Data availability Not applicable.

Declarations

Informed consent Not applicable.

Conflict of interest The authors declare no conflict of interest.

Institutional review board statement Not applicable.

References

Allott, K., & Lloyd, S. (2009). The provision of neuropsychological services in rural/regional settings: Professional and ethical issues. *Applied Neuropsychology, 16*(3), 193–206. https://doi.org/10.1080/09084280903098760

Barnett, S. D., Heinemann, A. W., Libin, A., Houts, A. C., Gassaway, J., Sen-Gupta, S., Resch, A., & Brossart, D. F. (2012). Small N designs for rehabilitation research. *Journal of Rehabilitation Research & Development, 49*(1), 175–186. https://doi.org/10.1682/JRRD.2010.12.0242

Bennett, T. L. (2001). Neuropsychological evaluation in rehabilitation planning and evaluation of functional skills. *Archives of Clinical Neuropsychology, 16*(3), 237–253. https://doi.org/10.1093/arclin/16.3.237

Bergquist, T., Gehl, C., Mandrekar, J., Lepore, S., Hanna, S., Osten, A., & Beaulieu, W. (2009). The effect of internet-based cognitive rehabilitation in persons with memory impairments after severe

traumatic brain injury. *Brain Injury, 23*(10), 790–799. https://doi.org/10.1080/02699050903196688

Bogdanova, Y., Yee, M. K., Ho, V. T., & Cicerone, K. D. (2015). Computerized cognitive rehabilitation of attention and executive function in Acquired brain injury: A systematic review. *Journal of Head Trauma Rehabilitation, 31*(6), 419–433. https://doi.org/10.1097/HTR.0000000000000203

Bombardier, C. H., Bell, K. R., Temkin, N. R., Fann, J. R., Hoffman, J., & Dikmen, S. (2009). The efficacy of a scheduled telephone intervention for ameliorating depressive symptoms during the first year after traumatic brain injury. *The Journal of Head Trauma Rehabilitation, 24*(4), 230–238. https://doi.org/10.1097/HTR.0b013e3181ad65f0

Braley, M., Pierce, J. S., Saxena, S., De Oliveira, E., Taraboanta, L., Anantha, V., Lakhan, S. E., & Kiran, S. (2021). A virtual, randomized, control trial of a digital therapeutic for speech, language, and cognitive intervention in post-stroke persons with aphasia. *Frontiers in Neurology, 12*, 626780. https://doi.org/10.3389/fneur.2021.626780

Brasure, M., Lamberty, G. J., Sayer, N. A., Nelson, N. W., MacDonald, R., Ouellette, J., & Wilt, T. J. (2013). Participation after multidisciplinary rehabilitation for moderate to severe traumatic brain injury in adults: A systematic review. *Archives of Physical Medicine and Rehabilitation, 94*(7), 1398–1420. https://doi.org/10.1016/j.apmr.2012.12.019

Buckingham, S. A., Anil, K., Demain, S., Gunn, H., Jones, R. B., Kent, B., Logan, A., Marsden, J., Playford, E. D., & Freeman, J. (2022). Telerehabilitation for people with physical disabilities and movement impairment: A survey of United Kingdom practitioners. *Journal of Medical Internet Research, 3*(1), e30516. https://doi.org/10.2196/30516

Cacciante, L., Pietà, C. D., Rutkowski, S., Cieślik, B., Szczepańska-Gieracha, J., Agostini, M., & Kiper, P. (2022). Cognitive telerehabilitation in neurological patients: Systematic review and meta-analysis. *Neurological Sciences, 43*, 847–862. https://doi.org/10.1007/s10072-021-05770-6

Câmara, J., Ferreira, L., Faria, A. L., Vilar, M., & Bermúdez i Badia, S. (2022). Feasibility, acceptability, and preliminary impact of full-body interaction on computerized cognitive training based on instrumental activities of daily living: A pilot randomized controlled trial with chronic psychiatric inpatients. *Games for Health Journal*, *11*(6), 435-446. https://doi.org/10.1089/g4h.2021.0228

Campbell, M. (2004). Acquired brain injury: Trauma and pathology. In M, Bates (Eds.), *Physical management in neurological rehabilitation* (2nd ed., pp. 103–124). Elsevier.

Cernich, A. N., Kurtz, S. M., Mordecai, K. L., & Ryan, P. B. (2010). Cognitive rehabilitation in traumatic brain injury. *Current Treatment Options in Neurology, 12*(5), 412–423. https://doi.org/10.1007/s11940-010-0085-6

Chen, J., Jin, W., Zhang, X. X., Xu, W., Liu, X. N., & Ren, C. C. (2015). Telerehabilitation approaches for stroke patients: Systematic review and meta-analysis of randomized controlled trials. *Journal of Stroke and Cerebrovascular Diseases, 24*(12), 2660–2668. https://doi.org/10.1016/j.jstrokecerebrovasdis.2015.09.014

Chen, P., Zanca, J., Esposito, E., & Barrett, A. M. (2021). Barriers and facilitators to rehabilitation care of individuals with spatial neglect: A qualitative study of professional views. *Archives of Rehabilitation Research and Clinical Translation, 3*(2), 100122. https://doi.org/10.1016/j.arrct.2021.100122

Cherney, L. R., Kaye, R. C., & Hitch, R. S. (2011). The best of both worlds: Combining synchronous and asynchronous telepractice in the treatment of aphasia. *Perspectives on Neurophysiology and Neurogenic Speech and Language Disorders, 21*(3), 83–93. https://doi.org/10.1044/nnsld21.3.83

Choi, Y. H., Park, H. K., & Paik, N. J. (2016). A telerehabilitation approach for chronic aphasia following stroke. *Telemedicine and e-Health, 22*(5), 434–440. https://doi.org/10.1089/tmj.2015.0138

Cicerone, K. D., Dahlberg, C., Kalmar, K., Langenbahn, D. M., Malec, J. F., Bergquist, T. F., Felicetti, T., Giaciano, J. T., Harley, J. P., Harrington, D. E., Herzog, J., Kneipp, S., Laatsch, L., & Morse, P. A. (2000). Evidence-based cognitive rehabilitation: Recommendations for clinical practice. *Archives of Physical Medicine and Rehabilitation, 81*(12), 1596–1615. https://doi.org/10.1053/apmr.2000.19240

Cicerone, K. D., Goldin, Y., Ganci, K., Rosenbaum, A., Wethe, J. V., Langenbahn, D. M., Malec, J. F., Bergquist, T. F., Kingsley, K., Nagele, D., Trexler, L., Fraas, M., Bogdanova, Y., & Harley, J. P. (2019). Evidence-based cognitive rehabilitation: Systematic review of the literature from 2009 through 2014. *Archives of Physical Medicine and Rehabilitation, 100*(8), 1515–1533. https://doi.org/10.1016/j.apmr.2019.02.011

Cogollor, J. M., Rojo-Lacal, J., Hermsdörfer, J., Ferre, M., Waldmeyer, M. T. A., Giachritsis, C., Armstrong, A., Martinez, J. M. B., Loza, D. A. B., & Sebastián, J. M. (2018). Evolution of cognitive rehabilitation after stroke from traditional techniques to smart and personalized home-based information and communication technology systems: Literature review. *JMIR Rehabilitation and Assistive Technologies, 5*(1), e8548. https://doi.org/10.2196/rehab.8548

Dores, A. R., Geraldo, A., Carvalho, I. P., & Barbosa, F. (2020). The use of new digital information and communication technologies in psychological counseling during the COVID-19 pandemic. *International Journal of Environmental Research and Public Health, 17*(20), 7663. https://doi.org/10.3390/ijerph17207663

Eilam-Stock, T., George, A., & Charvet, L. E. (2021). Cognitive telerehabilitation with transcranial direct current stimulation improves cognitive and emotional functioning following a traumatic brain injury: A case study. *Archives of Clinical Neuropsychology, 36*(3), 442–453. https://doi.org/10.1093/arclin/acaa059

Entwistle, H., & Newby, G. (2013). The very basic basics: Definitions, prevalence and consequences. In G. Newby, R. Coetzer, A. Daisley, & S. Weatherhead (Eds.), *Practical neuropsychological rehabilitation in acquired brain injury: A guide for working clinicians* (pp. 3–11). Karnac Books.

Fasotti, L. (2017). Mechanisms of recovery after acquired brain injury. In B. Wilson, J. Winegardner, C. M. van Heugten, & T. Ownsworth (Eds.), *Neuropsychological Rehabilitation: The international handbook* (pp. 25–35). Routledge.

Fish, J., & McKnight, P. (2021) Cognitive rehabilitation. In: *Reference module in neuroscience and biobehavioral psychology.* Elsevier. https://doi.org/10.1016/B978-0-12-819641-0.00140-7

Geraldo, A., Dores, A. R., Coelho, B., Ramião, E., Castro-Caldas, A., & Barbosa, F. (2018). Efficacy of ICT-Based neurocognitive rehabilitation programs for acquired brain injury. *European Psychologist, 23*(3). https://doi.org/10.1027/1016-9040/a000319

Geraldo, A., Dores, A. R., Castro-Caldas, A., & Barbosa, F. (2022). Functional connectivity as a neural correlate of cognitive rehabilitation programs' efficacy: A systematic review. *Current Psychology*, 1–17. https://doi.org/10.1007/s12144-022-02989-0

Gil-Pagés, M., Solana, J., Sánchez-Carrión, R., Tormos, J. M., Enseñat-Cantallops, A., & García-Molina, A. (2022). Functional improvement in chronic stroke patients when following a supervised home-based computerized cognitive training. *Brain Injury, 36*(12–14), 1349–1356. https://doi.org/10.1080/02699052.2022.2140832

Higgins, J., & Green, S. (2011). Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0). Retrieved from: http://handbook.cochrane.org

Jehkonen, M., Laihosalo, M., & Keetuenen, J. E. (2006). Impact of neglect on functional outcome after stroke: A review of

methodological issues and recent research findings. *Restorative Neurology and Neuroscience, 24*, 209–215.

Juengst, S. B., Hart, T., Sander, A. M., Nalder, E. J., & Pappadis, M. R. (2019). Mobile health interventions for traumatic brain injuries. *Current Physical Medicine and Rehabilitation Reports*, *7*(4), 341–356. *Frontiers in Neurology*, 926. https://doi.org/10.3389/fneur.2020.00926

Kiran, S., Des Roches, C., Balachandran, I., & Ascenso, E. (2014). Development of an impairment-based individualized treatment workflow using an iPad-based software platform. *Seminars in Speech and Language, 35*(1), 38–50. https://doi.org/10.1055/s-0033-1362995

Lawson, D. W., Stolwyk, R. J., Ponsford, J. L., McKenzie, D. P., Downing, M. G., & Wong, D. (2020). Telehealth delivery of memory rehabilitation following stroke. *Journal of the International Neuropsychological Society, 26*(1), 58–71. https://doi.org/10.1017/S1355617719000651

Lawson, D. W., Stolwyk, R. J., Ponsford, J. L., Baker, K. S., Tran, J., & Wong, D. (2022). Acceptability of telehealth in post-stroke memory rehabilitation: A qualitative analysis. *Neuropsychological Rehabilitation, 32*(1), 1–21. https://doi.org/10.1080/09602011.2020.1792318

Lebowitz, M. S., Dams-O'Connor, K., & Cantor, J. B. (2012). Feasibility of computerized brain plasticity-based cognitive training after traumatic brain injury. *Journal of Rehabilitation Research & Development, 49*(10), 1547–1556. https://doi.org/10.1682/JRRD/2011.07.0133

León-Carrión, J., Machuca-Murga, F., Solís-Marcos, I., León-Domínguez, U., & Domínguez-Morales, M. D. R. (2013). The sooner patients begin neurorehabilitation, the better their functional outcome. *Brain Injury, 27*(10), 1119–1123. https://doi.org/10.3109/02699052.2013.804204

Maggio, M. G., De Luca, R., Manuli, A., & Calabrò, R. S. (2020). The five 'W' of cognitive telerehabilitation in the Covid-19 era. *Expert Review of Medical Devices, 17*(6), 473–475. https://doi.org/10.1080/17434440.2020.1776607

Mahncke, H. W., DeGutis, J., Levin, H., Newsome, M. R., Bell, M. D., Grills, C., French, L. M., Sullivan, K. W., Kim, S. J., Rose, A., Stasio, C., & Merzenich, M. M. (2021). A randomized clinical trial of plasticity-based cognitive training in mild traumatic brain injury. *Brain, 144*(7), 1994–2008. https://doi.org/10.1093/brain/awab202

Man, D. W., Soong, W. Y. L., Tam, S. F., & Hui-Chan, C. W. (2006). A randomized clinical trial study on the effectiveness of a tele-analogy-based problem-solving programme for people with acquired brain injury (ABI). *NeuroRehabilitation, 21*(3), 205–217. https://doi.org/10.3233/NRE-2006-21303

Mantovani, E., Zucchella, C., Bottiroli, S., Federico, A., Giugno, R., Sandrini, G., Chiamulera, C., & Tamburin, S. (2020). Telemedicine and virtual reality for cognitive rehabilitation: A roadmap for the COVID-19 pandemic. *Frontiers in Neurology, 11*, 926. https://doi.org/10.3389/fneur.2020.00926

Maresca, G., Maggio, M.G., Latella, D., Cannavò, A., De Cola, M.C., Portaro, S., Stagnitti, M. C., Silvestri, G., Torrisi, M., Bramanti, A., De Luca, R., & Calabrò, R. S. (2019). Toward Improving poststroke aphasia: A pilot study on the growing use of telerehabilitation for the continuity of care. *Journal of Stroke and Cerebrovascular Diseases, 28*(10), 104303. https://doi.org/10.1016/j.jstrokecerebrovasdis.2019.104303

Mendes, L., Reis, L. P., & Barbosa, F. (2021). Effectiveness of a holistic neuropsychological rehabilitation program using virtual reality. *PsychTech & Health Journal, 5*(1), 20–41. https://doi.org/10.26580/PTHJ.art34-2021

Mitchell, C., Gittins, M., Tyson, S., Vail, A., Conroy, P., Paley, L., & Bowen, A. (2021). Prevalence of aphasia and dysarthria among inpatient stroke survivors: Describing the population, therapy provision and outcomes on discharge. *Aphasiology, 35*(7), 950–960. https://doi.org/10.1080/02687038.2020.1759772

Moher et al, 2009 Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Prisma Group. (2009). Reprint—preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Physical Therapy*, *89*(9), 873-880. https://doi.org/10.1093/ptj/89.9.873

Norman, R. S., Swan, A. A., Jenkins, A., Ballard, M., Amuan, M., & Pugh, M. J. (2021). Updating and refining prevalence rates of traumatic brain injury–related communication disorders among post-9/11 veterans: A chronic effects of neurotrauma consortium study. *Perspectives of the ASHA Special Interest Groups, 6*(5), 1060–1072. https://doi.org/10.1044/2020_PERSP-20-00011

O'Neil, J., van Ierssel, J., & Sveistrup, H. (2020). Remote supervision of rehabilitation interventions for survivors of moderate or severe traumatic brain injury: A scoping review. *Journal of Telemedicine and Telecare, 26*(9), 520–535. https://doi.org/10.1177/1357633X19845466

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan—a web and mobile app for systematic reviews. *Systematic Reviews, 5*(1), 1–10. https://doi.org/10.1186/s13643-016-0384-4

Parsons, T. D. (2016). *Clinical neuropsychology and technology*. Springer.

Peers, P. V., Astle, D. E., Duncan, J., Murphy, F. C., Hampshire, A., Das, T., & Manly, T. (2020). Dissociable effects of attention vs working memory training on cognitive performance and everyday functioning following fronto-parietal strokes. *Neuropsychological Rehabilitation, 30*(6), 1092–1114. https://doi.org/10.1080/09602011.2018.1554534

Peers, P. V., Punton, S. F., Murphy, F. C., Watson, P., Bateman, A., Duncan, J., Hampshire, A., & Manly, T. (2021). A randomized control trial of the effects of home-based online attention training and working memory training on cognition and everyday function in a community stroke sample. *Neuropsychological Rehabilitation*, 1–25. https://doi.org/10.1080/09602011.2021.1972817

Pinto, J. O., Pontes, D., Peixoto, B., Dores, A.R., & Barbosa, F. (2024). Ecological validity of neuropsychological interventions: A systematic review. Applied Neuropsychology Adult. Epub ahead of print, 1–20. https://doi.org/10.1080/23279095.2024.2328694

Ponsford, J. L., & Dymowski, A. R. (2017). Adults with non-progressive brain injury: Traumatic brain injury. In B. Wilson, J. Winegardner, C. M. van Heugten, & T. Ownsworth (Eds.), *Neuropsychological rehabilitation: The international handbook* (pp. 61–64). Routledge.

Rogers, J. M., Foord, R., Stolwyk, R. J., Wong, D., & Wilson, P. H. (2018). General and domain-specific effectiveness of cognitive remediation after stroke: Systematic literature review and meta-analysis. *Neuropsychology Review, 28*, 285–309. https://doi.org/10.1007/s11065-018-9378-4

Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *British Medical Journal*, *349*. https://doi.org/10.1136/bmj.g7647

Shochat, G., Maoz, S., Stark-Inbar, A., Blumenfeld, B., Rand, D., Preminger, S., & Sacher, Y. (2017). Motion-based virtual reality cognitive training targeting executive functions in acquired brain injury community-dwelling individuals: A feasibility and initial efficacy pilot. *Proceedings of the International Conference on Virtual Rehabilitation (ICVR)*, 1–8. https://doi.org/10.1109/ICVR.2017.8007530

Small, R., Wilson, P. H., Wong, D., & Rogers, J. M. (2022). Who, what, when, where, why, and how: A systematic review of the quality of post-stroke cognitive rehabilitation protocols. *Annals*

of Physical and Rehabilitation Medicine, 65(5), 101623. https://doi.org/10.1016/j.rehab.2021.101623

Solana, J., Cáceres, C., García-Molina, A., Opisso, E., Roig, T., Tormos, J. M., & Gómez, E. J. (2014). Improving brain injury cognitive rehabilitation by personalized telerehabilitation services: Guttmann neuropersonal trainer. *IEEE Journal of Biomedical and Health Informatics, 19*(1), 124–131. https://doi.org/10.1027/1016-9040/a000319

Stephenson, A., Howes, S., Murphy, P. J., Deutsch, J. E., Stokes, M., Pedlow, K., & McDonough, S. M. (2022). Factors influencing the delivery of telerehabilitation for stroke: A systematic review. *PLoS One*, *17*(5), e0265828. https://doi.org/10.1371/journal.pone.0265828

Tagliaferri, F., Compagnone, C., Korsic, M., Servadei, F., & Kraus, J. (2006). A systematic review of brain injury epidemiology in Europe. *Acta Neurochirurgica, 148*(3), 255–268. https://doi.org/10.1007/s00701-005-0651-y

Torrisi, M., Maresca, G., De Cola, M. C., Cannavò, A., Sciarrone, F., Silvestri, G., Bramanti, A., De Luca, R., & Calabrò, R. S. (2019). Using telerehabilitation to improve cognitive function in post-stroke survivors: Is this the time for the continuity of care? *International Journal of Rehabilitation Research, 42*(4), 344–351. https://doi.org/10.1097/MRR.0000000000000369

Tsai, Y. C., Liu, C. J., Huang, H. C., Lin, J. H., Chen, P. Y., Su, Y. K., Chun-Ting, C., & Chiu, H. Y. (2021). A meta-analysis of dynamic prevalence of cognitive deficits in the acute, subacute, and chronic phases after traumatic brain injury. *Journal of Neuroscience Nursing, 53*(2), 63–68. https://doi.org/10.1097/JNN.0000000000000570

Tsaousides, T., & Ashman, T. (2017). Technology-based delivery of neuropsychological rehabilitation. In B. Wilson, J. Winegardner, C. M. van Heugten, & T. Ownsworth (Eds.), *Neuropsychological rehabilitation: The international handbook* (pp. 447–457). Routledge.

Välimäki, M., Mishina, K., Kaakinen, J. K., Holm, S. K., Vahlo, J., Kirjonen, M., Pekurinen, V., Tenovuo, O., Korkeila, J., Hämäläinen, H., Sarajuuri, J., Rantanen, P., Orenius, T., & Koponen, A. (2018). Digital gaming for improving the functioning of people with traumatic brain injury: Randomized clinical feasibility study. *Journal of Medical Internet Research, 20*(3), e7618. https://doi.org/10.2196/jmir.7618

van der Linden, S. D., Rutten, J. M., Dirven, L., Taphoorn, J. B., Satoer, D. D., Dirven, M. F., Sitskoorn, M. M., & Gehring, K. (2021). eHealth cognitive rehabilitation for brain tumor patients: Results of a randomized controlled trial. *Journal of Neuro-Oncology, 154*(3), 315–326. https://doi.org/10.1007/s11060-021-03828-1

Van Heugten, C. M. (2017). Adults with non-progressive brain injury: Stroke. In B. Wilson, J. Winegardner, C. M. van Heugten, & T. Ownsworth (Eds.), *Neuropsychological rehabilitation: The international handbook* (pp. 65–68). Routledge.

Wilson, B. (1987). Single-case experimental designs in neuropsychological rehabilitation. *Journal of Clinical and Experimental Neuropsychology, 9*(5), 527–544. https://doi.org/10.1080/01688638708410767

Wilson, B. A., & Betteridge, S. (2019). *Essentials of neuropsychological rehabilitation*. The Guilford Press.

Withiel, T. D., Wong, D., Ponsford, J. L., Cadilhac, D. A., & Stolwyk, R. J. (2018). Feasibility and effectiveness of computerised cognitive training for memory dysfunction following stroke: A series of single case studies. *Neuropsychological Rehabilitation, 30*(5), 829–852. https://doi.org/10.1080/09602011.2018.1503083

World Health Organization (WHO) & International Telecommunication Union (ITU) (2022). *WHO-ITU global standard for accessibility of telehealth services*. Retrieved from: https://www.who.int/publications/i/item/9789240050464

Zhou, Q., Lu, X., Zhang, Y., Sun, Z., Li, J., & Zhu, Z. (2018). Telerehabilitation combined speech-language and cognitive training effectively promoted recovery in aphasia patients. *Frontiers in Psychology, 9*, 2312. https://doi.org/10.3389/fpsyg.2018.02312