Efficacy of ICT-based neurocognitive rehabilitation programs for Acquired Brain Injury: a systematic review on its assessment methods

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Abstract

This systematic review aims to analyze the methods used in the assessment of the efficacy of Neurocognitive Rehabilitation Programs (NRPs) based on Information and Communication Technologies in patients with Acquired Brain Injury, namely platforms and online rehabilitation programs. Studies with the main purpose of evaluating the efficacy of those programs were retrieved from multiple literature databases, accordingly to inclusion and exclusion criteria. The inclusion and analysis of the studies followed PRISMA-P and Cochrane Collaboration Guidelines. Thirty-one studies were included in this review. Results showed that most studies used a pre-post methodological design, with few studies performing assessment moments during intervention or follow-up. Attention, memory and executive functions were the cognitive variables considered by a larger number of studies at the assessment of NRPs efficacy. Despite that, there is a growing evidence on the inclusion of variables related to everyday functioning in this process, increasing its ecological validity. Concerning the instruments used, the studies presented a large heterogeneity of the instruments and methods used, even for the same assessment purpose, highlighting a lack of consensus regarding assessment protocol. Psychophysiological and neuroimaging techniques are seldom used on this field. This review identifies the main characteristics of the methodology used at the assessment of NRPs and potential limitations, providing useful information to guide the practice of the health care professionals in rehabilitation of Acquired Brain Injury. It also suggests new directions for future studies.

Efficacy of ICT-based neurocognitive rehabilitation programs for Acquired Brain Injury: a systematic review on its assessment methods

Acquired brain injury (ABI) is a clinical condition characterized by the occurrence of a cerebral damage, non-related to congenital or degenerative medical conditions, that causes temporary or permanent deficits, triggering functional disability and psychosocial maladjustment (WHO, 1996). The damage occurs more frequently as a result of a Traumatic Brain Injury (TBI) or a stroke, although it can have multiple causes (Feigin, Barker-Collo, Krishnamurthi, Theadom, & Starkey, 2010). It is considered one of the main causes of death and disability at western countries (Tagliaferri, Compagnone, Korsic, Servadei, & Kraus, 2006) and has a significant impact at daily life of the disabled person, and at his social support network (Truelle, Fayol, Montreuil, & Chevignard, 2010). ABI may have a negative influence at the cognitive, physical, behavioral and socioemotional dimensions of the person's life (Entwistle & Newby, 2013). Therefore, it may cause marked changes regarding the functionality and quality of life of the person (Cernich, Kurtz, Mordecai, & Ryan, 2010; Truelle et al., 2010).

Advances at medical technology and emergency assistant have caused a decrease at the mortality rate related to TBI and strokes in the last years (Entwistle & Newby, 2013). In addition, technology contributed to the improvement of health care and the development of new interventions in order to minimize the damage caused by the injury (e.g., physical and cognitive impairments).

As part of the neuropsychological rehabilitation, neurocognitive rehabilitation practices have a considerable impact on the recovery process of the patient. The chosen practice will influence the future levels of functionality and quality of life of the patient. Thus, it is

important for the professionals to be sure that they are using the best methods to that specific problematic and the deficits that characterizes it.

Along with the cognitive rehabilitation techniques that already existed, rehabilitation programs started to use techniques based on new information and communication technologies (ICTs). These techniques are currently enabling the design of new intervention programs, allowing the administration of rehabilitation services at distance, through online connections between therapists and patients (Rossi, 2006). Thus, this type of interventions is contributing to reduce healthcare costs and increase both the efficiency and efficacy of the rehabilitation services. These advantages are due to the decrease of hospital admission, the extension of the rehabilitation care to patients with reduced mobility, and the involvement of the patients' social support network on the rehabilitation process (Caltagirone, & Zannino, 2008; Musiat, & Tarrier, 2014; Rossi, 2006; Schoenberg et al., 2008).

Rehabilitation techniques based on ICT that can be subdivided in three major categories of resources – online programs and platforms, virtual reality and serious games. This type of programs is contributing to overcome one of the greatest limitations of traditional interventions - a rigid and not personalized rehabilitation design - by enabling the customization of the rehabilitation process to the patients' characteristics, their deficits and potentialities (Rees, Marshal, Hartridge, Mackie, & Weiser, 2007). This assumes a greater relevance in health conditions with a broad and diverse spectrum of deficits, as it is ABI. Additionally, it facilitates planning the intervention, monitoring the patient's performance and store the results for a later access by the health professional. Characteristics as the previous establishment of increasing levels of complexity of the tasks, evolving at the rhythm of the patient, provides a greater autonomy and allows patients to get an accurate real-time feedback based on their performance. The broad task diversity, the concerns with motivation, and the

ecological validity that many of these programs present, offer the opportunity of rehabilitate multiple cognitive domains at the same time, using tasks closer to daily life activities. These characteristics are facilitating the learning process and the generalization of the acquired capacities (Cruz et al., 2013; Dores et al., 2016; Joseph, Mazaux, & Sorita, 2014).

Evidence-based practice is a process that seeks to link healthcare practices and policies with scientific knowledge. It considers three major components to provide the best healthcare to the patient, which comprises the clinical expertise of the healthcare provider, the patients' characteristics, including their values, and the scientific evidence (Bauer, 2007; Institute of Medicine, 2001; Victora, Habitch, & Bryce, 2004). The component of "scientific evidence" aims to provide health care professionals the opportunity to make a conscious choice, in an explicitly and judicious way, by the clinical practices that gathers the best current evidence regarding a specific problematic (Bauer, 2007; Sacket, Rosenberg, Gray, Haynes, & Richardson, 1996). According to the Institute of Medicine (2001), the best research evidence refers to clinically relevant research that cares about the patient, examining the validity of diagnostic tests and prognostic markers and the efficacy of healthcare practices regarding prevention and rehabilitation of certain deficits.

It is important to assess the efficacy of rehabilitation programs, i.e. the capacity of a program to provide positive outcomes when applied under ideal conditions (Andrews, 1999), in order to produce knowledge that allows the practitioners to choose between different rehabilitation approaches. Currently, there is a growing number of studies focused on assessing the efficacy of neurocognitive rehabilitation programs (NRP) in ABI (Bodagnova, Yee, Ho, & Cicerone, 2015; Cicerone et al., 2000; Cicerone et al., 2005; Cicerone et al., 2011; van Heughten, Gregório, & Wade, 2012). Despite of the promising results of NRP, some of them raise methodological issues (e.g., small sample sizes) and the comparison between them

is often difficult (e.g., the instruments used to do the assessment are distinct and not consensual). Furthermore, some practitioners have been recognizing difficulties in assessing outcomes of NRP, due to the large range of variables that must be considered in the assessment of the efficacy of the programs (Beaumont, Connolly, & Rogers, 1999).

The main purpose of this systematic review is to analyze the methodology used in the assessment of the efficacy of NRPs for patients with ABI. In this review there will not be considered the efficiency of the NRPs, i.e., "what level of resources are required to produce benefit" (Andrews, 1999, p. 316). Considering the increasing interest in cognitive rehabilitation programs based on ICTs, we will focus on the assessment of such rehabilitation programs and platforms. This description can be useful to identify potential gaps on the processes and provide future guidance to research and clinical practice. We aim to respond at the following research questions:

How is the efficacy of NRP assessed?

Which variables are more frequently considered in the assessment of the efficacy of NRP?

Method

General stages and protocols of this study have followed the recommendation from PRISMA (Shamseer et al., 2015).

Search Strategy

A systematic literature search was performed in order to identify studies that assessed the efficacy of NRP for ABI patients.

Studies were identified through the search at multiple literature databases at EBSCOhost and Web of Science. The literature databases in EBSCOhost comprised

MEDLINE, MEDLINE with full text, Academic Search Complete, PsycInfo, CINAHL Plus with full text and Psychology, and Behavioral Sciences Collection. The categories considered at Web of Science were Rehabilitation, Neurosciences, Clinical Neurology, Psychology, Psychology Multidisciplinary, Medicine Research Experimental, Psychology Clinical, Health Care Sciences Services and Psychology Experimental. This search was complemented by additional hand searching to prevent publication and source selection bias.

The key words and search string were: Neurorehabilitat* OR Cognitive rehabilitat* OR Cognitive train* OR Neuropsychologic* Rehabilitat* - AB abstract; AND Comput* assist* rehabilitat* OR Platform* OR Program* OR Telepractic* OR Online OR Web OR New technolog* OR Technolog* of information and communication"- AB abstract; AND Head injur* OR Brain injur* OR Cerebrovascular accident* OR Stroke* - AB abstract; AND Evaluat* OR Efficac* OR Effect* OR Assess* OR Impact* - TX All text; NOT Child* - AB abstract. At WEB of Science, the search of all terms was conducted at the "Topic field".

The search was constrained from January 2006 to November 2016 and to English, Spanish and Portuguese languages only. Additionally, there were only considered documents from scientific and academic journals.

Study Selection

Studies were included accordingly to the following inclusion criteria: (a) participants were adults (+ 18 years) with ABI; (b) the main purpose of the paper was testing the efficacy of a NRP based on ICTs. Articles were excluded if: (a) were written in a different language; and (b) were reviews of the literature.

The selection of studies for eligibility and data extraction was undertaken by two independent reviewers, accordingly to Cochrane Collaboration's recommendations (Higgins &

Green, 2011). Any disagreements were solved with the help of a third reviewer, expert in the area.

Results

A total of 993 studies, published between 2006 and 2016, were identified from the database search. Additionally, 6 studies were included through hand search. After duplicate removal, the titles and abstracts of 424 studies were screened. A total of 335 articles were excluded and 91 studies remained for further eligibility assessment. Sixty studies were excluded for the following reasons: NRP were not based on ICTs (n = 33), or had motor, vocational or other purposes, that not cognitive rehabilitation (n = 9); the article consisted of a description of programs and study protocols, or the assessment of the usability of programs, not presenting intervention results (n = 13); the study was presented only as a poster (n = 3); and two studies had the abstract in english, but full-text in Chinese (see fig. 1).

[INSERT FIGURE 1]

After the full-text analysis, 31 studies were included in this systematic review. The inter-rater agreement was calculated after the titles and abstracts screening and after the full-text assessment. The values found for Cohen's Kappa Coefficient were 0.891 and 0.897, respectively, indicating an almost-perfect agreement between reviewers (Landis & Koch, 1977).

Two independent reviewers made the final review. The analysis of the first 12 articles were conducted by both (38.7%). Once confirmed that the inter-rater agreement of the analysis was high, only one reviewed the remaining articles.

Studies characteristics

Each of the 31 articles that were reviewed (see Table 1) was assigned to a class, accordingly to the classification of Cicerone et al. (2000) regarding the strength of the research methodology (see Table 1). Class I included 15 studies with a prospective, randomized controlled design. Three studies were assigned to Class Ia, because they presented a prospective design with "quasi-randomized" assignment to treatment conditions. Class II included studies that consisted of prospective and nonrandomized cohort studies; of retrospective and nonrandomized case-control studies; or of clinical series with a control group that allows between subject comparisons of clinical or treatment conditions. Four studies were included at this class. Nine studies were assigned to Class III, in which are comprised clinical series without controls or case-study designs. Nine papers did not have control groups and five papers did use passive control groups or control groups with other interventions, which did not aim to stimulate or rehabilitate cognitive functions.

Across studies, the total number of participants was 806 (M = 26.00; SD = 22.61; Min = 1; Max = 103). A total of 478 participants were male (59.3%) and 312 were female (38.7%). One study did not report the participants' gender (Kang et al., 2009). The age of the participants ranged between 20 and 80 years old. Regarding etiology of ABI, Stroke was the most frequent (n=509; 63.2%), followed by Traumatic Brain Injury (n=208; 25.8%). Twenty-seven participants (3.3%) had Arterioventricular Malformation (Man, Soong, Tam, & Hui-Chan, 2006), six participants (0.7%) had Encephalitis (Hauke, Fimm, & Sturm, 2011), one participant (0.1%) had Hypoxic Brain Damage (Hynes, Fish, & Manly, 2014), eight participants (1%) had a brain tumor (Johansson & Tornmalm, 2012; Lundqvist, Grundström, Samuelsson, & Rönnberg, 2010), two participants (0.2%) had subarachnoidal hemorrage (Lundqvist, Grundström, Samuelsson, & Rönnberg, 2010) and the cause of ABI was not specified to forty-five (5.6%) of the participants (Man et al., 2006; Yip & Man, 2013).

Studies were published in sixteen different journals. The two journals with a higher number of publications were *Brain Injury* (*n* = 6) and *Journal of Physical Therapy Science* (*n* = 5).

Assessment moments

All studies analyzed have comprised, at least, two assessment moments despite the class in which they were assigned: pre-intervention and post-intervention (see Table 1). Nine of them conducted more than two assessments, namely during the intervention period and follow-up assessments (studies 1, 3, 8, 9, 12, 14, 15, 16, and 21).

Three of the studies comprised more than one kind of intervention, and assessed the effects of each one separately. Separate evaluations, allowed the assessment of the efficacy of each intervention performed (studies 3, 9 and 15). One study assessed the performance of the participants at 5th session of the NRP (study 12) and another study did two pre-intervention assessments and three assessments during the NRP (study 16).

Regarding the follow-up, only five studies did a follow-up assessment to evaluate the maintenance of the improvements resulting from the programs (studies 1, 8, 9, 14, and 21). Two studies conducted follow-up assessments after six months of the end of the training (studies 1 and 14), one study after one month (study 8), and another study after three weeks (study 9). One of the articles reported two follow-up assessments, one month and five months after the completion of the training (study 21).

Variables Considered

The NRP used in the studies targeted different cognitive domains and, consequently, considered different variables while assessing the efficacy of the programs (see Table 1).

Nine of the studies presented a screening or comprehensive assessment of cognitive functioning, through a screening instrument or an assessment battery (studies 7, 8, 10, 18, 24, 25, 26, 27, and 31). Despite that, at the most part of the studies, this kind of instruments were not used or were complemented with specific assessment of other domains.

Attention is considered in 16 studies. Being a multidimensional construct, different studies targeted different aspects of it, including focused attention, sustained attention, selective attention and divided attention. Additionally, there were studies targeting executive attention and attention functioning in daily tasks (studies1, 2, 4, 7, 9, 10, 11, 12, 13, 14, 20, 21, 26, 28, 29, and 30).

Another variable that was widely considered is Memory, being referred in 13 studies. Similar to attention, different models and memory components were targeted by the assessment, such as working memory and long-term memory, including declarative and prospective memory (studies 2, 4, 7, 8, 11, 12, 13, 15, 16, 17, 20, 21, and 30).

Different components of executive functioning were also assessed in 15 studies. The components considered in the studies were cognitive flexibility, behavioral flexibility, processing speed, planning, problem solving, reasoning, time management and perception, goal management, visual and spatial processing, and inhibition (studies 1, 2, 7, 9, 15, 18, 20, 21, 22, 23, 25, 26, 28, 29, and 30).

Spatial neglect and visuo-spatial gnosis were variables considered in three of the studies (studies 2, 19, and 26), verbal fluency in two studies (studies 7 and 30), navigation ability in one of the studies (study 6), and reading capacity in another study (study 2).

Fifteen studies have considered functionality-related variables as an important measure of the efficacy of the NRP, comprising functional disability, functional independence,

participation, occupational performance, frequency of compensation techniques and cognitive failure in daily life (studies 2, 3, 7, 17, 18, 19, 20, 21, 22, 23, 26, 28, 29, 30, and 31).

As a complement to cognitive and functional assessments, nine studies had evaluated subjective experiences of the participants, such as training experiences and perceptions, progress and problems, interest degree, self-efficacy, satisfaction with results, subjectively experienced attention deficits and generalization of attention gains (studies 6, 9, 14, 17, 18, 22, 26, 28, and 30).

Only two studies assessed brain activity through relative beta activation in addition to cognitive and functional domains (studies 4 and 5).

A total of five studies have also considered variables related to the impact of ABI on emotional and daily life, including physical, cognitive, behavioral and emotional symptoms and quality of life (studies 3, 7, 15, 26, and 28).

Instruments

The screening and neuropsychological instruments used by the studies analyzed in this review were very diverse, even when measuring the same functions. Most of the studies used distinct instruments, so that many instruments were used only in one study but not in the others (See Table 1).

The Mini Mental State Examination (MMSE), a cognitive functioning screening instrument, gathered more consensus between researchers, as it was used in five studies (studies 7, 10, 18, 24, and 26).

The Instrumental Activities of Daily Living test (IADL) was used in four of the studies, despite two of them used an adapted version of it (studies 7, 22, 23, and 26).

The Barthel index, Paced Auditory Serial Addition Task (PASAT), Weschler Memory Scale (WMS) and Cognitive Failures Questionnaire (CFQ) were used in three studies each, either the original or an adapted version (studies 7, 10, 11, 13, 18, and 19).

Additionally, a number of instruments were used in two studies each, such as QEEG-8, Catherine Bergego Scale, Community Integration Questionnaire, Computerized Neurocognitive Function Test, Functional Independence Measure, Hong Kong List Learning Test, Ruff 2&7, Test of Everyday Attention, Rey Complex Figure, Toulouse-Piéron, Raven's Standard Progressive Matrices, Hospital Anxiety and Depression Scale, Canadian Occupational Performance Measure, Line Bisection Test, Motor-free Visual Perception Test, Category Test for Adults (I-VIII) from the Halstead-Reitan Neuropsychological Test Battery and Frontal Assessment Battery (studies 1, 3, 4, 5, 8, 9, 11, 13, 15, 17, 18, 19, 21, 22, 23, 25, 26, 28, 29, 30, and 31).

None of the other outcome measures was used in more than one study.

[INSERT TABLE 1]

Discussion

The main purpose of this literature review was to investigate the methodology used in the assessment of the efficacy of NRPs for patients with ABI. The assessment moments, the variables considered and the instruments used in that process were explored.

Regarding the class of the study, according to the classification of Cicerone et al. (2000), only 16 studies were included at Class I. Class I studies are the ones that presents the stronger methodological design, building a more solid theoretical evidence based on the results reported. The existence of numerous studies within Class II and III represents one of the biggest methodological issues regarding rehabilitation studies with ABI patients. These issues might be explained by difficulties in designing randomized and double blind controlled studies regarding neurocognitive rehabilitation. Additionally, this kind of studies represent a large investment of time to researchers and patients, which is rarely possible.

In what concerns to the sample characteristics, the main causes of ABI that were identified were Stroke and Traumatic Brain Injury, as reported by the literature (Feigin et al., 2010), and there was a higher prevalence of male patients in the samples of the studies.

Regarding the assessment of the efficacy of NRPs, it consisted, at least, of two moments of assessment in all the studies analyzed. The assessment of the participants' performance in two moments – pre- and post-intervention – allowed the comparison of the results obtained and, through that, the assessment of the program efficacy. Despite that, only five studies performed a follow-up assessment (Akinwuntan et al., 2010; Dou et al., 2006; Dymowski et al., 2016; Hauke et al., 2011; Lundqvist et al., 2010). A follow-up assessment allows the evaluation of the maintenance of the gains that resulted from the NRP, which provides relevant evidence about the duration of the effects and the retraining needs.

Furthermore, not all the studies presented a control group (Claessen et al., 2016; Dymowski et al., 2015; Férnandez et al., 2012; Hauke et al., 2011; Jang et al., 2013; Johansson et al., 2012; Lebowitz et al., 2012; Satish et al., 2008; Gamito et al., 2011). In studies with ABI patients, a control group assumes greater relevance, especially at acute phase, once it allows to examine whether the improvements are due to the NRP or to spontaneous recovery effects (Carey & Seitz, 2007; Chen, Epstein, & Stern, 2010).

The variables considered at the assessment of the efficacy of cognitive rehabilitation programs were diverse. This diversity might provide difficulties in assessing the efficacy and outcomes of NRP, reported by health care professionals (Beaumont, Connolly, & Rogers, 1999). All studies had assessed at least one cognitive function, highlighting the relevance of the cognitive improvements as an indicator of the efficacy of NRPs. Memory, attention and executive function were the cognitive functions assessed by a larger number of studies. These cognitive functions are reported as the main cognitive deficits after ABI (Gartland, 2004; Lezak, Howieson, & Loring, 2004; Virk, Williams, Brundson, Suh, & Morrow, 2015).

Additionally, most studies complemented the assessment of cognitive functions with other measures, related to functionality, quality of life and emotional well-being of the patients. Considering the role of neuropsychological assessment at clinical practice, as it allows the health care professionals to make informed decisions regarding rehabilitation and everyday functioning, it has been registered a growth of the importance of the ecological validity of the assessment process (Chaytor & Schmitter-Edgecombe, 2003). The ecological validity is being improved, as seen on the studies, through the combination of cognitive measures with functioning measures in real-life environments.

Respectively to the instruments of assessment used in research, a large range of instruments was identified in the studies analyzed, even when the purpose was the same. The

most part of the instruments were used at only one study, which highlights the lack of consensus regarding the decision about the assessment protocol. This diversity raises difficulties on comparing the efficacy of NRPs to make an evidence-based decision for one of them.

The most used instruments for cognitive assessment provide behavioral measures (neuropsychological and functionality instruments). Despite that, two studies used electroencephalography to measure electrical activity of the brain (Cho et al., 2015; Cho et al., 2016). The results of both studies showed significant differences between pre- and post-intervention assessment of brain activity, reporting significant improvements on brain activation after the NRP. Additionally, one study used functional magnetic brain imaging techniques (De Luca et al., 2014), but only at pre-intervention assessment and not as an outcome measure. The use of these methods in order to assess the efficacy of NRPs provides information about the neural correlates, and increased accuracy regarding the identification of the type of neuropathologies or location of brain lesions (Chaytor & Schmitter-Edgecombe, 2003; Cho et al, 2016; Stathopoulou & Lubar, 2004; Thornton & Carmody, 2005). The data provided could be used to modify and improve NRPs accordingly to the patients' brain functioning, enhancing the probability of success of the rehabilitation programs. Electroencephalography and functional neuroimaging should be considered as useful methods for the assessment of the efficacy of NRP in future studies.

The heterogeneity observed regarding the methods used to assess the efficacy of the NRPs was also evident in the characteristics of the programs. Twenty-two of the thirty-one studies reviewed used online-computerized programs or rehabilitation platforms. Six studies used virtual reality environments, one used a driving simulator, one used a video game and other used a tablet application to rehabilitate cognitive functions. The NRPs comprised 4 to

60 sessions, lasting between 20 to 120 minutes and with a frequency from 1 to 5 times a week for 2 to 12 weeks. Therefore, we can conclude that the duration, length, and frequency of the NRPs sessions are highly variable.

All ICT-based NRPs allowed the automatic adjustment of the difficulty to the performance of the patient and provided feedback to them, although through different methods, improving the autonomy level of the patient in the rehabilitation process. Additionally, the errorless learning approach, as well as interactive and ecological tasks have been pointed as means of improving the motivation and the investment of the patient in the program.

The diversity of the ICT-based NRPs and the methodologies used for the assessment of the efficacy of those programs highlights the need for multicentric studies in order to standardize those procedures and, based on the results, provide new guidelines to the neuropsychological rehabilitation of patients with ABI. This conclusion is in line with a literature review by Bodagnova et al. (2015), focused on computer-assisted rehabilitation for attention and executive function in ABI patients (Bodagnova et al., 2015).

Summing up, this systematic review provides an analysis of the methodology used in the assessment of the efficacy of ICT-based NRPs designed for patients with ABI. The large heterogeneity observed in the studies makes it difficult to take strong and coherent conclusions about future decisions, emphasizing the need of multicentric studies to standardize these procedures. Although, there are some conclusions that should be considered in the methodological design of future studies regarding neurocognitive rehabilitation of patients with ABI: (1) variables related with functionality, quality of life, and emotional well-being should be considered at the assessment of the efficacy of NRPs, improving the ecological validity of the protocols; (2) a follow-up assessment provides relevant information about the

duration of the effects resulted from NRPs; (3) the existence of a control group allows to explore if the results are due to NRP or to spontaneous recovery effects; (4) techniques as electroencephalography and functional neuroimaging may be important add-ups to the assessment protocols, in order to provide brain-based evidences that could improve rehabilitation programs.

This review has some limitations, although it had followed the PRISMA-P and Cochrane Collaboration guidelines regarding the development protocol of systematic reviews and efforts to diminish publication bias. The inclusion of studies of Class II and III may represent a limitation at the comparison of the methodologies (assessment moments, instruments and variables) used in the assessment of the efficacy of NRPs. In fact, most of the studies highlighted methodological issues, such as lack of control groups and reduced sample sizes. Despite of that, due to the high prevalence of these study designs and the aim of the current review we decided for the inclusion of Class II and III studies. Future reviews should use the methodological strength of the studies in order to provide evidence-based guidelines to assess NCPs.

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Figure 1.

Flow Diagram of the literature search

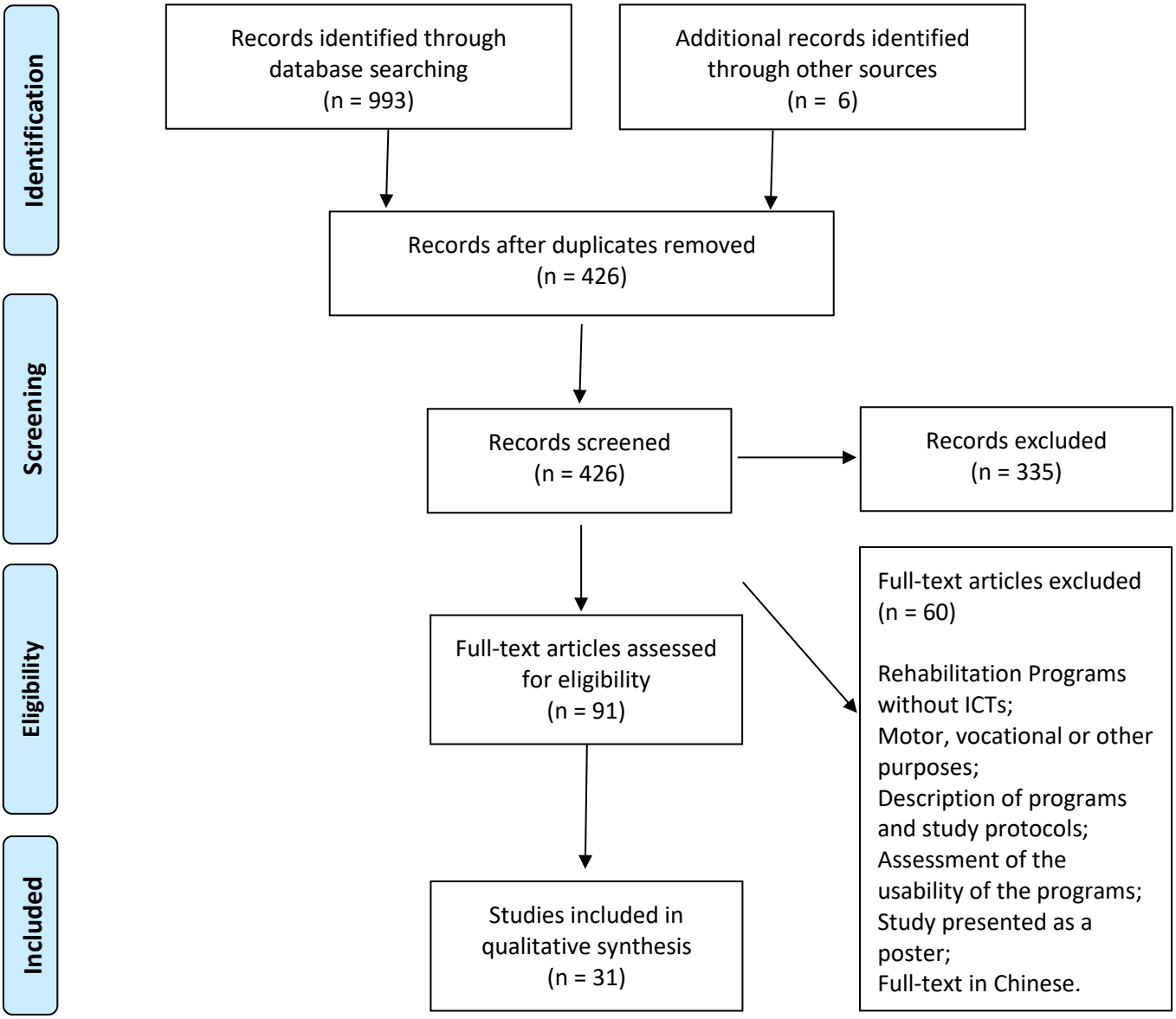

Table 1.

Methodology used at the assessment of the efficacy of NRPs: assessment moments, variables considered and instruments used.

Nr.	First Author	Class	Time after injury	Assessment moments	Variables measured	Instruments
1	Akinwuntan, A. et al. (2010)	I	< 6 months	Pre-intervention; Post-intervention; Follow-up (6 months after).	Visual attention Processing speed	Useful Field of View
2	Aparicio-López, C. et al. (2016)	I	< 6 months	Pre-intervention; Post-intervention.	Attention Memory Executive Functions Spatial Neglect Reading capacity Functional Disability	Bell Cancelation Test Figure Copy of Ogden Line Bisection Test Baking Tray Task Reading Test (Designed for the study) Catherine Bergego Scale
3	Bergquist, T. et al. (2009)	Ia	> 1 year	Cross-over design: Pre-intervention; Post-1st intervention: Final assessment.	Physical, cognitive, behavioral and emotional symptoms of TBI Participation Frequency of compensation techniques	Neurobehavioral Functioning Inventory Community Integration Questionnaire Compensation Techniques Questionnaire
4	Cho, H. et al. (2015)	I	< 6 months - 1 year	Pre-intervention; Post-intervention.	Brain activity Attention and Memory	QEEG-8 (electroencephalography) Computerized Neurocognitive Function Test
5	Cho, H. et al. (2016)	I	< 6 months - 1 year	Pre-intervention; Post-intervention.	Brain activity Functional Independence	QEEG-8 (electroencephalography) Functional Independence Measure
6	Claessen, M. et al. (2016)	III	1 – 5 years	Pre-intervention; Post-intervention.	Navigation ability Training experiences of participants	Virtual Tübingen Test Evaluation form

7	De Luca, R. et al. (2014)	I	< 6 months	Pre-intervention; Post-intervention.	Cognitive Functioning (screening) Verbal Fluency Behavioral Flexibility Selective and Sustained Attention Verbal Memory Functional disability Anxiety and Depression	Mini Mental State Examination Category Verbal Fluency Letter Verbal Fluency Reversal Motor Learning Attentive Matrices Rey Auditory Verbal Learning Test Basic Activities of Daily Living Instrumental Activities of Daily Living Levels of Cognitive Functioning Barthel Index Hamilton Rating Scale
8	Dou, Z. L. et al. (2006)	I	6 months – 1 year	Pre-intervention; Post-intervention; Follow-up (1 month).	Cognitive Functioning Memory	Neurobehavioral Cognitive Status Examination Rivermead Behavioral Memory Test, cantonese version Hong Kong List Learning Test
9	Dymowski, A. R. et al. (2015)	III	1 –10 years	Pre-intervention; Post-1st intervention; Post- 2nd intervention; Follow-up (3 weeks)	Information Processing Speed Speed and Selective Attention Generalization of Attention gains Functional attention Participants' training perceptions	Symbol Digit Modalities test Ruff 2&7 Selective Attention Test of Everyday Attention Rating Scale of Attentional Behavior Semi-structured interview
10	Férnandez, E. et al. (2012)	III	1 – 5 years	Pre-intervention; Post-intervention.	Cognitive Functioning (screening) Simple Attention Executive Attention Memory	Mini Mental State Examination Trail Making Test – A Trail Making Test – B Wechsler Memory Scale
11	Gamito, P. et al. (2015)	I	NR	Pre-intervention; Post-intervention	Memory	Weschler Memory Scale Rey Complex Figure

					Attention and concentration	Toulouse-Piéron
12	Gamito, P. et al. (2011)	III	< 6 months – 1 year	Pre-intervention; Post-5th session; Post-intervention.	Working Memory and Attention	Paced Auditory Serial Addition Task
13	Gamito, P. et al. (2014)	Ia	< 6 months	Pre-intervention; Post-intervention.	Memory Attention and Concentration	Weschler Memory Scale Rey Complex Figure Toulouse-Piéron
14	Hauke, J. et al. (2011)	III	1 – 5 years	Pre-intervention; During intervention; Post-intervention (4 weeks); Follow-up (6 months).	Attention Divided Attention Subjectively experienced attention deficits	WAF subtests from Vienna Test System. Test of Attentional Performance Self-report questionnaire (Fragebogen Erlebter Defizite der Aufmerksamkeit)
15	Hynes, S. et al. (2014)	III	1 – 5 years	Pre-intervention; Post-1st intervention; Post-2nd intervention.	Time Perception Planning, task schedulling, problem solving Memory Reasoning/novel problem-solving Time management/problem-solving Goal Management Anxiety and Depression	Time perception task Modified 6-elements subtest of Behavioral Assessment of Dyexecutive Syndrome Story recall subtest of the Rivermead Behavioral Memory Test II Raven's Standard Progressive Matrices Games Evaluation Task Goal Management Questionnaire Hospital Anxiety and Depression Scale
16	Jang, S. et al. (2013)	III	6 months – 1 year	1 month pre-intervention; Pre-intervention 3 times during intervention (1 per month).	Memory	Memory Assessment Scale

17	Johanson, B. & Tornmalm, M. (2012)	II	1 - > 10 years	Pre-intervention; Post-intervention.	Working memory Rank cognitive failure in daily life Occupational Performance Progress and problems Subjective experiences	QM Cognitive Failures Questionnaire Canadian Occupational Performance Measure Diary Semi-structured interview
18	Kang, S. et al. (2009)	I	< 6 months	Pre-intervention; Post-intervention.	Cognitive Functioning (screening) Visual perception Functional Disability Patients interest degree	Mini Mental State Examination Motor-Free Visual Perception Test Modified Barthel Index (Korean) Interest scale
19	Kim, Y. et al. (2011)	I	< 6 months	Pre-intervention; Post-intervention.	Unilateral Spatial Neglect Functional Disability Unilateral Spatial Neglect Functional Disability	Star Cancellation Test Catherine Bergego Scale Line Bisection Test Barthel Index (Korean Version)
20	Lebowitz, M. et al. (2012)	II	5 – 10 years	Pre-intervention; Post-intervention.	Processing speed and efficiency Working memory Attention and concentration Encoding and Memory Spatial Processing Visuospatial working memory. Rank cognitive failure in daily life Behavioral symptoms from frontal lobe injury	Automated-Neuropsychological Assessment Metrics Version 4 Cognitive Failures Questionnaire Frontal Systems Behavior Scale
21	Lundqvist, A. et al. (2010)	II	1 – 5 years	Cross-over design: Pre-intervention; Post-intervention;	Working Memory and Attention Inhibition & Cognitive Flexibility Working Memory	Paced Auditory Serial Addition Task Colour Word Interference Test condition 4-Inhibition/Switching Block-Span-board from WAIS-R-NI

				Follow-up (1 & 5 months).		Listening Span Task The Picture Span
					Occupational Performance	Canadian Occupational Performance Measure
					Health related quality-of-life	EQ-5D questionnaire
22	Man, D. et al. (2006)	I	1 – 5 years	Pre-intervention; Post-intervention.	Problem Solving Skills	16 analogous target insight problems to the training sessions
					Self-efficacy at Problem Solving Skills	13-item questionnaire
					Problem Solving Skills	Category Test for Adults (I-VIII) from the Halstead-Reitan Neuropsychological Test Battery
					Functional Independence	Lawton Instrumental Activities of Daily Living Scale (Chinese)
23	Man, D. et al. (2006a)	II	1 – 5 years	Pre-intervention; Post-intervention.	Problem Solving Skills	Quizzes on daily behavioral problem-solving-session-based scoring
						Category Test for Adults (I-VIII) from the Halstead-Reitan Neuropsychological Test Battery
					Functional Independence	Lawton Instrumental Activities of Daily Living Scale (Chinese)
24	Park, S. et al. (2013)	Ia	< 6 months	Pre-intervention; Post-intervention.	Cognitive Functioning (screening)	Mini Mental State Examination
					Cognitive Functioning	Seoul Computerized Neuropsychological Test
25	Park, J. & Park, J. (2015)	I	< 6 months	Pre-intervention; Post-intervention.	Cognitive Functioning	Lowenstein Occupational Therapy Cognitive Assessment
					Visual Perception	Motor-Free Visual Perception Test

26	Prokopenko, S. et al. (2013)	I	< 6 months	Pre-intervention; Post-intervention.	Cognitive Functioning (screening) Cognitive Functioning (screening) Executive functions Visuo-spatial gnosis Attention Anxiety and Depression Quality of Life Functional Independence Satisfaction with results (Practicioner) Satisfaction with results (Patient)	Mini Mental State Examination Montreal Scale of Cognitive Assessment Frontal Assessment Battery Clock Drawing Test Schulte's tables Hospital Anxiety and Depression Scale Stroke Specific Quality of Life Scale Instrumental Activities of Daily Living Clinical Global Impressions Scale Personal Growth Initiative Scale
27	Satish, U. et al. (2008)	III	1 – 5 years	Pre-intervention; Post-intervention.	Cognitive Functioning	Strategic Management Simulation Test (Woodline County Scenario)
28	Vakili, A. & Langdon, R. (2016)	II	1 – 5 years	Pre-intervention; Post-intervention.	Attention and processing speed Attention Quality of Life Self-Efficacy Executive Functions	Game performance Attentional Blink task Test of Everyday Attention Comprehensive Quality of Life Scale (5th Ed) for Cognitive Disability General Self-Efficacy Scale Behavior Rating Inventory of Executive Functioning-Adult Version
29	Westerberg, H. et al. (2007)	I	1 – 5 years	Pre-intervention; Post-intervention.	Cognitive Failures in daily life Visuo-spatial & auditory Working Memory Inhibition Learning and Declarative memory Non-verbal reasoning abilities Memory Working Memory and attention	Cognitive Failures Questionnaire Span Board & Digit Span (WAIS-R NI) Stroop Interference Test Claeson-Dahl test (word list) Raven's Standard Progressive Matrices Word List Delayed Recall Paced Auditory Serial Addition Task (A)

					Selective Attention	RUFF 2&7 selective attention task
30	Yip, B. & Man, D. (2013)	I	< 6 months	Pre-intervention; Post-intervention.	Prospective Memory (PM)	Virtual Reality-based test of everyday Prospective Memory (PM) tasks Behavioral Checklist of PM task Cambridge PM Test (chinese version)
					Memory	Hong Kong List Learning Test
					Executive Functions	Frontal Assessment Battery
					Verbal Fluency	Word Fluency Test (Chinese version)
					Cognitive Flexibility, Attention, Sequencing, Visuomotor speed	Color Trails Test
					Participation	Community Integration Questionnaire (Chinese version)
					Self efficacy related to PM	Self-efficacy questionnaire in performing everyday PM tasks
31	Yoo, C. et al. (2015)	I	6 months – 1 year	Pre-intervention; Post-intervention.	Cognitive Functioning	Computerized Neurocognitive Function Test
					Functional Disability	Functional Independence Measurement