CHAPTER 40

Cognitive rehabilitation

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Introduction

The rehabilitation of disorders of cognitive functions (language, spatial perception, attention, memory, calculation, praxis), following acquired neurological damage of different aetiology (in particular, stroke and traumatic brain injury [TBI]), is an expanding area of neurological rehabilitation, and has been the focus of considerable research interest in recent years. In 1999, a Task Force on Cognitive Rehabilitation was set up under the auspices of the European Federation of Neurological Societies (EFNS). The aim was to evaluate the existing evidence for the clinical effectiveness of cognitive rehabilitation in stroke and TBI, and provide recommendations for neurological practice. The results were published in 2003 in the European Journal of Neurology [1] and updated in 2005 [2]. The present chapter is an update and a revision of these guidelines.

For these guidelines, we have limited ourselves to a review of studies dealing with the rehabilitation of non-progressive neuropsychological disorders due to stroke and TBI. As a consequence, several important areas of ‘cognitive rehabilitation’ have been excluded, such as the rehabilitation of dementia, psychiatric, and developmental disorders. In addition, we have not considered studies of pharmacological treatments.

The prevalence and relevance of cognitive rehabilitation for stroke and TBI patients require the establishment of recommendations for the practice of cognitive rehabilitation, and these have been formally recognized by a subcommittee of the Brain Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine. The initial recommendations of the Committee were published in 1992 as the ‘Guidelines for cognitive rehabilitation’ [3] and were based on so-called expert opinion that did not take into account empirical evidence on the effectiveness of cognitive rehabilitation. More recently, a review of the scientific literature for cognitive rehabilitation in patients with TBI published from January 1988 through August 1998 (including 11 randomized clinical trials [RCTs]) noted that data on the effectiveness of cognitive rehabilitation programmes were limited by the heterogeneity of subjects, interventions, and outcomes studied [4].

As a preliminary consideration, we wish to underline that the present status of studies on the effectiveness of cognitive rehabilitation is still not satisfactory. We are fully convinced that the standards required for the evaluation of pharmacological and surgical interventions also apply to rehabilitation. In particular, it is necessary to show that rehabilitation is effective not only in modifying the impairment, but also in having sustained effects at the disability level. Unfortunately, the majority of RCTs in this area are of poor methodological quality, have insufficient sample size, and fail to assess the outcome at the disability level. Many other studies fail to compare intervention with placebo or sham treatment.

Before recommendations are advanced, a word of caution is necessary to alert the reader to the fact that there are differences in the classification schemes and rating systems used by different professional societies. Consequently, reviews and recommendations based on such systems may not always be directly comparable. Furthermore, inherent to each classification schema are grey zones, leeway of interpretation, and difficulties...
The rehabilitation of speech and language disorders following brain damage is the area of intervention for acquired cognitive deficits with the longest tradition, dating back to the nineteenth century [8]. A variety of approaches have been applied to the rehabilitation of aphasia, from stimulation approaches to the recent attempts to establish theory-driven treatment programmes based on the principles of cognitive neuropsychology [9]. The need to establish the effectiveness of aphasia rehabilitation has stimulated a number of investigations, dating back to the period after the Second World War, and has been based on a variety of methodologies. A meta-analysis of studies dealing with the effectiveness of language rehabilitation, limited to aphasia as a result of stroke, has been made available by the Cochrane collaboration. The review covers articles about speech and language rehabilitation after stroke up to January 1999 [10]. The conclusion of the review is that ‘speech and language therapy treatment for people with aphasia after a stroke has not been shown either to be clearly effective or clearly ineffective within an RCT. Decisions about the management of patients must therefore be based on other forms of evidence. Further research is required to find out if speech and language therapy for aphasic patients is effective. If researchers choose to do a trial, this must be large enough to have adequate statistical power, and be clearly reported’. This conclusion is based on a limited number of RCTs (12), all of which were considered of poor quality.

The reviews by Cicerone et al. [11] (updated in 2005) reached a different conclusion, i.e. that ‘cognitive-linguistic therapies’ can be considered as Practice Standard for aphasia after stroke; similar, positive conclusions for TBI are based on limited and less consistent evidence. The reasons for this discrepancy can be found in the different criteria used in the two reviews. Several studies classified as Class I by Cicerone et al. [11, 12] were excluded by the Cochrane reviewers. For example, one study by Hagen [13] was excluded because of the lack of true randomization (the patients being sequentially assigned to treatment or no treatment). Another study [14] was probably excluded because it dealt only with computer-assisted reading rehabilitation. Two small RCTs [15, 16], which reported positive treatment effects, were excluded from the Cochrane Review because they were devoted to communication disorders after TBI.

By definition, all Class II and III evidence is not included in the Cochrane review. This resulted in the exclusion of the three large studies by Basso et al. [17], Shewan and Kertesz [18] and Poeck et al. [19], all indicating significant benefits of treatment. An additional small Class II study by Carlomagno et al. [20] supported the usefulness of writing rehabilitation in patients in the post-acute stage. Additional evidence for treatment...
effects comes from investigations on small patient samples (Class II). A study comparing group communication treatment with ‘deferred treatment’ indicated positive effects on both linguistic and communication measures [21]. A randomized study compared semantic with phonological treatment of anomia. Both treatments resulted in a significant improvement in functional communication [22].

Single-case studies are also not considered in the Cochrane Reviews. This is particularly relevant because most of the treatment studies based on the cognitive neuropsychological approach make use of the single-case methodology. A review paper by Robey et al. [23] critically discussed this approach and concluded that generally large treatment effects have been found in aphasic patients. Moss and Nicholas [24] analysed the single-case studies in chronic aphasic patients, and did not find a relationship between treatment response and time post-onset.

Some of the available RCTs comparing therapy with unstructured stimulation were based on a very limited number of treatment sessions. Recent studies have addressed the crucial issue of the role of intensity and length of treatment. A meta-analysis by Bhogal et al. [25] showed that studies reporting a significant treatment effect provided 8.8 h of therapy per week for 11.2 weeks, while the negative studies only provided approximately 2 h per week for 22.9 weeks. The total length of therapy was significantly inversely correlated with a mean change in the Porch Index of Communicative Abilities scores. The number of hours of therapy provided in a week was significantly correlated to greater improvement on the Porch Index of Communicative Abilities and the Token Test. These results suggest that an intense therapy programme provided over a short amount of time can improve outcomes of speech and language therapy for stroke patients with aphasia (see, however, [26]). A small RCT comparing intensive (5 h/week) with conventional (2 h/week) intervention found similar effects of the two treatment schedules at 6 months [27]. On a similar line, several studies have assessed the effectiveness of ‘constraint-induced’ aphasia therapy (CIT), i.e. an approach based on the intensive stimulation of language modality, constraining the use of non-verbal communication strategies. A small RCT comparing ‘massed’ with conventional treatment showed a significant superiority of the ‘massed’ intervention [28]. A further study by Meinzer et al. [29] indicates that a similar programme is associated with a persistent improvement at a 6 months follow-up. The results of a small-scale, Class III study comparing CIT with a comparable schedule of multiple-modality treatment suggest that the effectiveness of the approach is more related to ‘massed practice’ than to the forced use of language modality [30]. A recent Class I study [31] compared the effectiveness of CIT alone, memantine alone, or combined CIT and pharmacological treatment. The best outcome, assessed with a functional communication scale, was found in the combined treatment group, and was persistent at long-term follow-up.

The use of computerized training as an adjunct to aphasia treatment is supported by the results of several Class III studies [12]. In particular, a study by Laganaro et al. [32] suggested that the number of treatment items rather than the number of repetitions plays an important role in recovery of naming. Additional data have been reported by Fridriksson et al. [33] (positive effects of visual speech training on naming abilities) and Manheim et al. [34] (positive effects of intensive computerized home training on communication abilities).

Recommendations

The conclusions of the Cochrane Review of aphasia rehabilitation after stroke are not compatible with Level A for aphasia therapy. Considerable evidence from Class II and III studies, as well as from rigorous single-case studies supports its probable effectiveness (Level B). There is a need for further investigations in the field, based on the definition of specific language targets (i.e. word comprehension, sentence production) in homogeneous samples of patients submitted to well-defined treatment approaches.

Rehabilitation of unilateral spatial neglect

The presence of hemineglect beyond the acute stage is associated with poor outcome in terms of independence [35, 36], and considerable effort is therefore devoted to its rehabilitation. Several reviews on the effectiveness of unilateral spatial neglect (ULN) rehabilitation are available [37–44].

A Cochrane Review [45] reported data from 12 studies and found evidence that cognitive rehabilitation resulted in significant and persisting improvements in performance in cancellation and line bisection tests. There was,
however, insufficient evidence to confirm or exclude an effect of cognitive rehabilitation at the level of disability, or on destination following discharge from hospital.

There is evidence for the effectiveness of multiple approaches in reducing ULN manifestations. Combined training of visual scanning, reading, copying, and figure description yielded a statistically significant improvement in neglect symptoms in one Class II [46] and two Class III studies [47, 48]. Visual scanning training alone was shown to improve neglect significantly in one Class I study [49]. Spatiomotor or visuo-spatiomotor cueing improved neglect significantly in one Class I [50] and two Class III studies [51, 52]. Visual cueing with kinetic stimuli was found to bring a significant, albeit transient, improvement in three Class III studies [53–55]. However, the use of optokinetic stimulation did not improve neglect in a recent Class III study [56].

Video feedback [57] and visuo-motor feedback [58] were shown to improve significantly performance on trained tasks in Class III and II studies, respectively. Training of sustained attention, increasing of alertness or cueing of spatial attention was shown to significantly improve neglect in Class III studies [59–62].

Several studies investigated the effects of influencing multisensory representations. These studies in general demonstrated transient effects, lasting little longer than the end of the appropriate stimulation. Vestibular stimulation by cold water infusion into the left outer ear canal showed significant effects on different aspects of the unilateral neglect in five Class III studies [63–66]. Galvanic vestibular stimulation significantly improved neglect symptoms in one Class III study [67]. Transcutaneous electrical stimulation of the left neck muscles showed significant effects in four Class III studies [68–71], and neck muscle vibration demonstrated an effect in one Class II study [72]. The latter is the only study of this group that showed a persistent effect after 2 months. Changes in trunk orientation had significantly positive effects in one Class II study [73].

The use of prism goggles deviating by 10 degrees to the right, introduced relatively recently, was shown to improve significantly, in a transient fashion, neglect symptoms in two Class II [74, 75] and one Class III study [76]. A Class III study applied the prism goggle treatment for a 2-week period and obtained statistically significant improvement in the long term [77]. Two further Class III studies [78, 79] have shown a persistence of the effects at, respectively, 3 and 6 months.

The forced use of the left visual hemifield or left eye showed a relative benefit in neglect in one Class II [80] and three Class III studies [81–83]. A negative result was reported by Fong et al. [84]. Computer training yielded mixed results. One Class I [85] and one Class III [86] study reported an absence of significantly positive effects, while a more recent Class II study showed a statistically significant improvement in wheelchair mobility [87].

### Recommendations

Several methods of neglect rehabilitation were investigated in Level I or II studies. The Cochrane Review concludes that, while there is evidence of persisting improvements in ULN symptoms, insufficient evidence is available to confirm or exclude an effect of cognitive rehabilitation at the functional level. With this caveat in mind, present evidence confers Level A recommendation to visual scanning training and to visuo-spatiomotor training, and Level B recommendation to the combined training of visual scanning, reading, copying, and figure description; to trunk orientation; to neck vibration; to forced use of the left eye; to the use of prism goggles; and to video feedback. Level B–C recommendation was made for training of sustained attention and alertness. Level C of recommendation is valid for transient effects due to caloric or galvanic vestibular stimulations, as well as transcutaneous electrical stimulation of the neck muscles.

### Rehabilitation of attention disorders

Attention deficits follow many types of brain damage, including stroke and TBI [88, 89]. A pioneering study by Ben-Yishay et al. [90] explored the treatment of deficits in focusing and sustaining attention in 40 brain-injured adults. There was not only an improvement in the attention-training tasks, but also a generalization to other psychometric measures of attention, both maintained at 6-month follow-up. Using a multiple-baseline design, with patients at 4–6 years after head injury, Wood [91] found that contingent token reinforcement was effective in increasing patients’ ability to sustain attention on a task. Several studies [92–94] have explicitly incorporated and evaluated therapeutic interventions such as feedback, reinforcement, and strategy teaching into the attention rehabilitation programmes.

The Cochrane Review by Lincoln et al. [95], having searched for controlled trials of attention training in stroke, identified only the study of Schoettke [96]
showing the efficacy of attention training in improving sustained attention.

Thirteen studies were reviewed by Cicerone et al. [11], including three prospective RCTs [93, 94, 97], four Class II controlled studies [90, 96–98], and six Class III studies [91, 101–105]. Most controlled studies compared attention training with an alternative treatment without including a no-treatment condition; a very important distinction is between studies conducted in the acute and post-acute stage. Cicerone et al. [11] concluded that evidence from two RCTs [93, 97] with a total of 57 subjects, and two controlled studies [98, 100] with a total of 49 subjects, supports the effectiveness of attention training beyond the effects of non-specific cognitive stimulation for subjects with TBI or stroke during the post-acute phase of recovery and rehabilitation. Cicerone et al. [11] recommended such a form of intervention as a practice guideline for these individuals. Interventions should include not only training with different stimulus modalities and complexity, but also therapist activities such as monitoring subjects’ performance, providing feedback, and teaching strategies. Attention training appears to be more effective when directed at improving the subject’s performance on more complex, functional tasks. However, the effects of treatment may be relatively small or task-specific, and an additional need exists to examine the impact of attention treatment on activities of daily living (ADLs) or functional outcomes.

Cicerone et al. [12] updated their previous evidence-based recommendations of the Brain Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine for cognitive rehabilitation of people with TBI and stroke, based on a systematic review of the literature from 1998 through 2002. They identified five further studies on rehabilitation of attention deficits after TBI. Two were Class I prospective randomized studies [106, 107] comparing attention treatment with alternative treatments; one was a Class II study [108] that compared attention treatment with no treatment; and two were Class III studies [109, 110]. Sohlberg et al. [106] used a crossover design to compare the effectiveness of ‘attention process training’ (APT) brain injury education and support for 14 patients with acquired brain injury. Self-reported changes in attention and memory functioning, as well as an improvement on neuropsychological measures of attention-executive functioning, were greater after APT than after therapeutic support. The second Class I study [107] taught 22 patients with severe TBI to compensate for slowed information-processing and the experience of ‘information overload’ in daily tasks. Participants were randomly assigned to receive either time pressure management or an alternative treatment of generic ‘concentration’ training. Participants receiving time pressure management showed a significantly greater use of self-management strategies and a greater improvement in attention and memory functioning than did participants who received the alternative treatment. Although the precise nature of the interventions in these 2 Class I studies differs, they share a common emphasis on the development of strategies to compensate for residual cognitive deficits (‘strategy training’) rather than attempting to directly restore the underlying impaired function (‘restoration training’). The results of these two studies and of an additional small Class II study [108] are therefore consistent with a strategy training model for attention deficits after TBI.

Stablin et al. [111] in a Class III study reported that the shift cost was greater for patients with severe TBI than controls: treatment consisted of five sessions, in which an endogenous task shift paradigm was used. When a subject is engaged in two speeded tasks, not simultaneously but with some form of alternation, the response is slower to an item of task A if it is preceded by an item of task B than if it was preceded by an item of task A. This shift cost is small when subjects can prepare in advance for the new task (endogenous task shift), whereas the cost is much greater when preparation is not possible (exogenous task shift). A significant reduction of the endogenous shift cost from assessment to retest was found. The reduction remained stable at the 4-month follow-up session. It seems that these results were not simply due to retesting, as the control patients did not show any improvement at retest. Interestingly, no reduction of exogenous task shift cost was found. The results showed also that the beneficial effect of the treatment generalizes to other executive functions.

TBI patients who successfully completed attentional training showed changes in attentional network activation on functional magnetic resonance imaging, namely decreased frontal lobe activity together with increased function of the anterior cingulated cortices and precuneus in comparison with the pre-training neuroimaging data showing, in the same patients, more activation in the frontal and temporoparietal lobes, and less activation
in the anterior cingulate gyrus and temporo-occipital regions compared with the healthy subjects [112]. Spontaneous blinking is considered to be influenced by basic cognitive processes, among them vigilance and attention. Therefore, from a methodological point of view, the monitoring of spontaneous blinking in chronic patients affected by various degrees of consciousness deficit after TBI and stroke has been shown to be useful to define the outcome of the syndrome [113].

**Acute studies**

One Class I and two Class II studies evaluated the effectiveness of attention treatment during the acute period of rehabilitation. The Class I study of Novack [94] compared the effectiveness of focused treatment consisting of sequential, hierarchical interventions directed at specific attention mechanisms versus unstructured intervention consisting of non-sequential, non-hierarchical activities requiring memory or reasoning skills. Both groups improved, but there were no intergroup differences: the observed improvements are probably due to spontaneous recovery. One Class II study [92] used a multiple baseline design across subjects and evaluated a programme for the remediation of processing speed deficits in 10 patients with severe TBI (6–34 weeks post-injury). The authors reported no benefit or generalization of effects of attention training; however, improvement did occur in some patients when practice on attention training tasks was combined with therapist feedback and praise. In the other Class II study [99], 35 subjects with lateralized stroke showed beneficial effects of attention training on five of 14 outcome measures, especially on measures of perceptual speed and selective attention in left hemisphere lesions.

Cicerone *et al.* [12], updating their previous review [11], stated that there was insufficient evidence to support the use of specific interventions for attention deficits during acute rehabilitation.

**Post-acute studies**

Two Class I and two Class II studies assessed the attention treatment effectiveness during the post-acute period of rehabilitation. Gray *et al.* [97] treated 31 patients with attention dysfunction, randomly assigned to receive either computerized attention retraining or an equivalent amount of recreational computer use. Immediately after training, the experimental group showed marked improvement on two measures of attention (although when premorbid intelligence score and time since injury were added as covariates, the treatment effect was no longer significant); at 6-month follow-up, the treatment group showed continued improvement and superior performance compared with the control group on tests involving auditory–verbal working memory. The authors suggested that the improvement, continuing over the follow-up period, was consistent with a strategy training model as it becomes increasingly automated and integrated into a wider range of behaviours [99]. In the second post-acute Class I study [93], community-dwelling patients with moderate to severe brain injury were screened for orientation, vision, aphasia, and psychiatric illness. The experimental attention training group improved significantly more than the alternative (memory) treatment group on four attention measures administered throughout the treatment period, although the effects did not generalize to the second set of neuropsychological measures.

Sohlberg and Mateer [100] employed a Class II multiple-baseline design with four patients to evaluate the effectiveness of a specific, hierarchical attention training programme. All subjects showed gain on a single attention outcome measure administered after the start of attention training but not after training on visuospatial processing; this improvement also generalized to cognitive and everyday problems. Strache [98] conducted a prospective Class II study on patients with mixed trauma and vascular aetiologies, and compared two closely related interventions for concentration with subjects in an untreated control group receiving general rehabilitation. After 20 treatment sessions, both attention treatments resulted in significant improvement on attention measures in respect of control subjects, with some generalization to memory and intelligence measures. Rath *et al.* [114], in three interrelated Class II controlled studies, examined the construct of problem-solving as it relates to the assessment of deficits in higher level outpatients with traumatic brain damage. The difference between the groups were significant first for timed attention tasks, then for psychosocial and problem-solving self-report inventories, then for patients’ self-report problem-solving, and also in self-report inventory. It means that it is necessary to have many different approaches to the construct of problem-solving (multidimensional approach) to obtain good rehabilitation.
Several attempts were made to establish the differential role for effectiveness of training of specific components of attention. Rios et al. [115] in a Class II controlled study on TBI consider attention as a basic cognitive function, a prerequisite for other cognitive processes. It is divided into four different subprocesses – cognitive flexibility, speed of processing, interference, and working memory – which must be taken into consideration. The results of the work support the view that these different subprocesses of attentional control can be differentiated between high and low level processes and may have implications for neuropsychological assessment and rehabilitation.

Cicerone et al. [12] reported evidence from two Class I studies [106, 107] with 36 subjects that supports the effectiveness of attention training for subjects with TBI during the post-acute period of rehabilitation. Considering such evidence, along with Cicerone et al.’s previous recommendation based on two Class I studies with 57 subjects [11], strategy training for attention deficits exhibited by subjects with TBI has been recommended as a practice standard during the post-acute period of rehabilitation [12]. Results of studies in this area suggest greater benefits on complex tasks requiring the regulation of attention, rather than on basic aspects of attention (e.g. reaction time, vigilance). These findings are consistent with the emphasis on strategy training to compensate for attention deficits in functional situations.

Pero et al. [116] evaluated the effectiveness of the Sohlberg and Mateer’s APT using a comprehensive assessment of different attentional processes. Two TBI patients were given the APT in a chronic phase: both showed some degree of recovery, particularly in attentional tasks with a selective component; lesser improvement was observed in tasks related to the intensity dimension of attention, namely those concerning alertness or vigilance. This Class IV study further supports selective training effects of APT on attentional deficits of patients with TBI.

Improvements in speed of processing appear to be less robust than improvements in non-speeded tasks [92, 101, 105]. Moreover, several studies also suggest greater benefits of attention training on more complex tasks requiring selective or divided attention than on basic tasks of reaction time or vigilance [97, 99, 105]. Wilson and Robertson [104], implementing a series of individualized interventions intended to facilitate voluntary control over attention during functional activities, effectively decreased the attention lapses that the subject experienced when reading novels and texts.

Rohling et al. [117] recently provided a meta-analysis of cognitive rehabilitation literature that was originally reviewed by Cicerone et al. [11, 12] for the purpose of providing evidence-based practice guidelines for TBI patients. The meta-analysis revealed sufficient evidence for the effectiveness of attention training after TBI.

### Recommendations

During the acute period of recovery and inpatient rehabilitation, evidence is insufficient to distinguish the effects of specific attention training from spontaneous recovery or more general cognitive interventions for patients with moderate to severe TBI and stroke. Therefore, specific interventions for attention during the period of acute recovery are not recommended. On the other hand, the availability of Class I evidence for attention training in the post-acute phase after TBI is compatible with a Level A recommendation. Moreover, the available evidence suggests that cognitive rehabilitation has differential effects on various components of attention; therefore, more research is needed to clarify the differential effects of interventions, and new methodologies are required for the assessment of related neural processes.

### Rehabilitation of memory

Memory impairment is a well-documented sequel following TBI. Nearly a fourth (25%) of those who have sustained TBI suffer from memory problems, and more than a third of patients who have suffered a stroke show cognitive impairments in one or more cognitive domains such as attention, memory, orientation, language, and executive functions. Generally, approaches to memory rehabilitation are either oriented towards restoring or optimizing damaged or residual functions, or focus on compensating for lost or deficient functions. Within these approaches, training techniques are oriented towards alleviating memory problems such as difficulties of learning and retrieval, or everyday functioning. Others focus on training specific contents such as orientation, dates, names, faces, routines, or appointments. Still others target specific memory systems such as working, episodic, declarative, or prospective memory, or modality-specific impairments such as visual or verbal problems. As cognitive domains frequently overlap, general cognitive training has also been attempted in order to
Rehabilitation Studies targeting intervention strategies include practice and rehearsal, domain-specific learning, mnemonics, and other strategies as well as the use of external memory aids and environmental supports. Whatever the technique used, the main question is how effective and long-lasting it is.

The current report on memory rehabilitation updates our previous reviews [118], literature from 2005 to January 2009, and considers various review or summary papers [12, 119–122]. Although we will not review pharmacological treatment, we would like to point the reader to some valuable reviews of the effects of pharmacological treatment in TBI [121, 123–126].

Studies targeting intervention strategies without the use of external memory aids

Early studies on the general use of compensatory memory strategies previously reported on showed partially contradictory findings, and it was difficult to draw a clear conclusion (for details, see [118]. For example, Doornhein and de Haan [127] did not find positive effects on memory impairment in stroke patients using compensatory strategies, whereas Berg et al. [128] reported positive effects, and Ryan and Ruff [129] found a training effect only for mild memory impairment. Later studies include a case report on three patients with TBI that found improved prospective memory and diary use using self-awareness and compensatory strategy training ([130]; Class IV study). A Class II study compared a control group receiving low-dose memory training with two high-frequency training groups that included process-oriented memory training and compensatory strategy training [131]. The study investigated 62 patients of mixed aetiologies with mild to moderate memory disorders; no conclusions can thus be drawn for specific pathologies or disease severity. The frequency or intensity with which a group was trained affected the degree to which verbal memory performance improved. Compared with strategy training, process-oriented memory training improved verbal memory performance and decreased the forgetting rate in the intensive memory trainings groups.

A series of Class III studies and a Class IV study targeting more specific memory strategies reported an advantage of errorless learning techniques (in which people are prevented from making errors) over errorful techniques (such as trial and error) in people with memory impairments. TBI and stroke patients benefited most when learning without errors was encouraged [132–134]. Findings indicated that any benefit of errorless learning may depend on the type of task used, the way in which memory is tested, and the severity of the memory impairment. Furthermore, pre-exposure to the target stimuli seemed to enhance the benefit of errorless learning [135–137]. Findings of a more recent Class II study also emphasized the dependency of the learning technique on the nature of the task. Mount and colleagues [138] investigated the effectiveness of errorless learning and trial and error learning for teaching ADLs during acute stroke rehabilitation in 33 patients with different levels of memory impairment. They did not find a difference between the two learning techniques when used to acquire two specific ADL skills (use of wheelchair and use of donning-sock). Only one of the techniques – the trial and error approach but not the errorless learning method – led to a carry-over effect of learning in one type of ADL task (the sock-donning task). It was also found that explicit memory impairment did not affect the effectiveness of either learning method. It is noteworthy that this study showed the effectiveness of the learning techniques in a natural instead of a ‘laboratory’ setting.

Another technique of learning and retaining information is based on a spacing effect that has been shown to improve learning and memory performance when information is distributed over time. Two Class III studies reported improved recall and recognition performance and learning of new information in TBI patients with different severity statuses when the material was presented in repeated trials distributed over time [139, 140]. Comparing spaced retrieval training with didactic strategy instructions (both over the telephone) in 38 severely impaired TBI patients, Bourgeois et al. [141] found that both techniques reduced memory problems but that the spaced retrieval technique was more effective (Class II study). However, these effects did not have an impact on quality of life measures.

The use of visual imagery to enhance memory performance has been reported by Kaschel et al. [142]. This Class III study compared nine target group patients with 12 control group patients of mixed aetiologies and in rehabilitation centres across different countries. The target group received imagery-based training, while the control group was trained with the standard programme.
in their respective rehabilitation centre. Positive effects of visual imagery training on memory functioning were reported at post-training and were maintained at the 3-month follow-up assessment.

In healthy people, memory performance is improved if items to be learned are self-generated. Two studies investigated the efficacy of self-generation in patients with TBI. Comparing 18 moderate to severe TBI patients with 18 healthy controls, Lengenfelder et al. [143] showed that self-generation of verbal material improved both subsequent recall and recognition compared with words that were provided to the subjects (Class III study). Another Class II study compared self-generation of verbal material with didactic presentation of material in two groups of 20 patients with TBI. The authors reported improvements in recognition memory but not in free recall [144]. Furthermore, self-generation procedures only improved recall performance when the newly learned material was supplemented with specific reminder cues.

A Class IV study has focused on a specific sequel frequently observed in patients with TBI – associating faces with names in a real-world context [145]. Five single cases with severe TBI were first trained with a traditional training programme (using name restating, phonemic cueing and visual imagery) followed by real-world training (actual, to-be-named people). Four of the five patients showed an improved recall of names, especially in real-world contexts, regardless of the type of cuing strategy. Unfortunately, the findings of this study are difficult to interpret as the effects of the traditional training and real-world training cannot be teased apart. It is also not clear whether any of the patients had visual or gnistic difficulties, which are frequently observed after TBI.

A Class III study investigated the effects of intense, adaptive working memory training in stroke patients. Fifteen patients who had had a mild to severe stroke (age 34–65 years, seen 12–36 months after the event) were divided into a treatment and a passive control group [146]. The treatment group was trained with a battery of visuospatial and auditory working memory tasks at home on a computer for 40 min daily for 5 days over 5 weeks. Eight neuropsychological tests served as baseline and outcome measures. Working memory and attention improved in the training but not the passive stroke group.

While the studies previously discussed generally focused on using some type of memory training to improve learning and specific aspects of memory, there are also studies that address a broader range of cognitive functions, motivated by the fact that patients with TBI often show impairments of several functional systems (such as attention, memory, executive functions, etc.) and the mounting problems to provide resources to treat all patients individually. Thickpenny-Davis and Barker-Collo [147] investigated the impact of eight learning modules (60-min sessions twice a week over 4 weeks) in a structured group format memory rehabilitation programme (Class III). The learning module consisted of didactic teaching about memory and memory strategies, small group activities, discussions, problem-solving, and practice implementing memory strategies. Ten patients with moderate to severe TBI and two stroke patients were divided into a waiting group and a memory group. Patients in the memory group showed an increased use of memory aids and strategies, an improved knowledge about memory and memory strategies, reduced self-rated behaviors indicative of memory impairment, and an improvement on neuropsychological assessment of memory. The improvements were maintained at 1-month follow-up assessment.

Another study aimed at improving planning skills in patients with TBI through a self-instructional technique involving self-cueing to recall specific autobiographical experiences [148]; Class II study). Thirty patients with severe TBI were randomly allocated to an (active) control group and a training group. While the control group was engaged in conversation, the experimental group underwent training in a procedure aimed at prompting autobiographical memory to support planning skills. Compared with the control group, the training group improved their planning skills, although the effect size indicated only a modest intervention effect. In addition, the authors found an effective increase in the number of specific memories recalled.

Another study aimed at improving planning skills in patients with TBI through a self-instructional technique involving self-cueing to recall specific autobiographical experiences [148]; Class II study). Thirty patients with severe TBI were randomly allocated to an (active) control group and a training group. While the control group was engaged in conversation, the experimental group underwent training in a procedure aimed at prompting autobiographical memory to support planning skills. Compared with the control group, the training group improved their planning skills, although the effect size indicated only a modest intervention effect. In addition, the authors found an effective increase in the number of specific memories recalled.

A Class I study evaluated the effect of everyday music listening on the recovery of cognitive functions and mood in 54 stroke patients at baseline and 3 and 6 months after the stroke [149]. Compared with a group listening to a non-music audio book or a group without listening material, patients who listened to their favourite music showed a greater improvement in focused attention and verbal memory, and were in a less depressed and confused mood.
In summary, there is some evidence that the frequency with which memory training is applied plays a role in having an effect on mild to moderate memory impairment. A process-oriented training approach is effective and improves verbal and prospective memory. It is, however, not clear whether patients who have had a TBI or stroke profit to the same degree from such training. Within the framework of specific training techniques, errorless learning is probably an effective intervention (Level B) in TBI and stroke patients. The effectiveness, however, depends on the nature of the task to be learned and the type of memory impairment. Exploiting the spacing effect to improve learning and memory performance is another probably effective intervention (Level B) in TBI patients, although other techniques, such as training visual-imagery strategies in patients of mixed aetiology, training working memory in stroke patients, using a wide variety of intervention material in structured group intervention, and training autobiographical memory, have shown beneficial effects. For these individual approaches, more evidence is, however, needed for a clear recommendation. Other approaches going beyond the mere training of memory functions have also shown beneficial effects on memory as well as on other cognitive functions. Regularly listening to music during the early recovery phase of stroke patients is an effective intervention technique (Level A) that improves attention and verbal memory. There is also evidence that training memory through self-instructional recall techniques affects not only memory, but also planning skills, and is evaluated as probably effective (Level B).

Studies targeting intervention techniques using non-electronic external memory aids
Keeping external aids such as a notebook or a diary is a common way to improve memory performance. Two Class III studies and a series of single-case Class IV studies support the use of external non-electronic memory aids such as a notebook or diary as a possibly effective (Level C) intervention [101, 150–155]. There is some indication that a combined treatment using an external memory aid (diary) with internal strategy training increases efficacy.

The use of assistive electronic technologies
The increasing availability of computers, the Internet, wireless connections, and other electronic devices opens a wide range of possibilities to incorporate these technologies into memory rehabilitation (for a review on assistive technology for cognition devices, see [156]).

Two Class III studies [157, 158] and some Class IV studies [159, 160] showed improved memory performance in patients with TBI after using computer-based memory training software. A comparison of computer-assisted memory training with a therapist memory training group and a control group without memory training in 37 patients with TBI showed that memory training was superior to no training but there was no difference in memory improvement between the computer and therapist training group [161]. Interpretation of this study is, however, difficult as the level of TBI severity is not clear, the group being very heterogeneous in terms of age and time post-surgery, and there also seem to be discrepancies in the reported results in the text and tables. Although there is (Level C) evidence that computer-based memory training is possibly effective, there is currently not sufficient evidence showing its superiority over non-computer-assisted training.

Besides computers, portable paging systems have been used to enhance memory performance. A randomized crossover-designed study [162] (Class III) showed the effectiveness of a portable externally programmed paging system (NeuroPage) in a large number of patients who were memory- and executive function-impaired as a result of TBI, stroke, and other aetiologies. Two studies followed using the same patient pool but separated out different aetiologies and controlled for demographic variables, thus upgrading the quality of the studies to Class II [163, 164]. Reporting on 36 patients with stroke [163] and 63 with TBI [164], it was shown that the paging system was effective in compensating for everyday memory and planning problems in the two patient groups. Comparing the stroke group with the TBI group at follow-up (cessation of pager use), it was found that the stroke group’s benefit had returned to baseline while the TBI group continued to profit from the system [163]. The authors suggested that this decline may have been due to poorer executive functions in the stroke group.

Another electronic memory aid device is the portable voice organizer. This device can be trained to recognize a patient’s individual speech patterns, store messages dictated by the user, and replay messages at prespecified time periods. It was shown that such a system facilitated the free and cued recall of therapy goals and plans in a...
controlled within-subject design study with TBI patients [165] (Class III study). The efficacy of the voice organizer has also been demonstrated in a Class IV study with patients of different aetiologies, including TBI [166]. Several single-case studies with TBI patients (Class IV) using personal digital assistants (PDAs) with data transmission via the mobile phone network [167], an alphanumeric paging system [168], and mobile phones that can be programmed to remind individuals to perform tasks at specific times [169] have shown mixed results concerning the successful use of these systems.

In summary, portable paging systems are probably effective (Level B) systems to enhance memory performance, while the effectiveness of other electronic memory devices (PDAs, mobile phones) still needs more empirical support.

The usefulness of a virtual environment for specific memory or learning skills has been investigated in two Class III studies [170, 171]; for a review of the use and possibilities of virtual reality in memory rehabilitation, see [172]. As reported previously, the studies indicated that patients with stroke or TBI could improve on spatial memory performance or verbal and visual learning in virtual environments, and memory training in virtual environments was rated as possibly effective (Level C evidence) (for details, see [118]). There are currently no newer controlled studies available that would update the previous findings.

Recommendations

Memory strategy training is one of the most common intervention techniques, and has been evaluated as effective for subjects with mild memory impairments after TBI or stroke by Cicerone and colleagues [12]. Comper and colleagues [119] arrive at a different conclusion. Reviewing the efficacy of cognitive training for patients with mild TBI, they concluded that there is very little evidence suggesting that cognitive rehabilitation therapy is effective in treating individuals with mild TBI. The differences in evaluation may be due to the heterogeneity of the patients and the types of cognitive function investigated. Besides severity of the TBI, other factors to consider are the frequency of training and the specific strategic approach applied. Errorless learning, spaced recall techniques, self-instructional recall techniques, and process-oriented training are supported by Level B evidence and are thus recommended as probably effective. Other techniques, such as training visual-imagery strategies in patients of mixed aetiology, training working memory in stroke patients, using structured group intervention with a wide variety of intervention material, and training autobiographical memory, have also shown positive effects. However, more supportive evidence for these individual techniques is needed before clear recommendations can be made. The use of non-electronic external memory aids such as a notebook or diary has shown a benefit and is evaluated as possibly effective (Level C).

A non-specific intervention approach to improve cognitive abilities after stroke has shown advantages in the cognitive as well as emotional domain. Regularly listening to music during the early recovery phase of stroke patients has shown effectiveness in improving attention and verbal memory (Level A evidence). Computer-assisted memory training is also possibly effective, although there is currently insufficient evidence to judge whether it is superior to non-computer-assisted training. Generally, the use of electronic external memory devices such as paging systems and portable voice systems is recommended as possibly effective (Level B evidence) in patients after stroke and TBI. Still more empirical support is, however, needed on the specific use of PDAs or mobile phones with reminder functions to arrive at evidence-based recommendation.

Memory training in virtual environments has shown positive effects on verbal, visual, and spatial learning in patients with stroke and TBI, and is rated as possibly effective (Level C evidence). A direct comparison of performing learning and memory training in virtual environments versus non-virtual environments is still lacking, and no recommendation can be made on the specificity of the technique.

More stringently controlled studies have appeared in recent years and thus facilitated evidence-based recommendations. There is, however, still a need to tease apart the effects that cognitive training has on specific aetiologies, the role that the severity of the impairment plays within these aetiologies, the lasting effect of the training and its ecological validity, and the effect of other non-memory-oriented intervention on memory functions (for a discussion, see [121]). It is conceivable that the type and intensity of training has different effects depending on the neural circuits damaged, the functional impairment profile, the age and gender of the patient, the time that has passed since injury, the education level of the patient, and other external factors (such as social and vocational situation). It would also be important to know whether a combination of interventions (including pharmacological therapy) is beneficial, and if so what the best combination would be. The number of variables involved makes generalization across individuals difficult and favours training programmes tailored to the individual circumstances.
Rehabilitation of apraxia

Although the incidence of apraxia after acquired brain damage is considerable, the literature on recovery and treatment is minimal. Several reasons for this lack of evidence can be identified [173]. First, patients with apraxia often seem to be unaware of their deficit and rarely complain; second, many researchers believe that recovery from apraxia is spontaneous and treatment is not necessary; third, some authors believe that apraxia only occurs when performance is requested of patients in testing situations, and that correct behaviour is displayed in natural settings. By now, however, there is agreement that apraxia hinders independence in ADLs. Goldenberg et al. [174] assessed complex ADLs in patients with apraxia and controls. They found that apraxic patients had more difficulties than patients with left brain damage without apraxia and healthy controls. In two other studies, comparable results were found: Hanna-Paddy et al. [175] found a significant relationship between severity of apraxia and dependency in physical functioning; Walker et al. [176] studied the impact of cognitive impairments on upper body dressing difficulties after stroke using video analysis – those patients who failed shirt-dressing showed neglect and apraxia at follow-up. Recently, the impact of apraxia on the dependence of patients with stroke in their ADLs has again been confirmed [177]. These results suggest that treatment of apraxia should be part of the overall neurorehabilitation programme after brain damage.

Recently, a Cochrane Review has been published that has determined which therapeutic interventions are effective for targetting disabilities due to motor apraxia following stroke [178]. The literature search was carried out up to November 2006 and revealed only three trials including a total of 132 participants [179–181]. The authors of the review conclude, on the basis of these three trials, that there is insufficient evidence to support or refute the effectiveness of specific interventions for motor apraxia following stroke. However, since there are more therapy studies conducted than the strict methodology of the Cochrane Collaboration for RCTs allows, a broader set of studies examining the effectiveness of treating apraxia will be reviewed in this brief summary. The studies are labelled either observational or experimental, and the quality of the studies is described. The reader is also referred to Buxbaum et al. [182] for a review on the treatment of limb apraxia.

There are two recent RCTs on the rehabilitation of apraxia. As the study by Edmans et al. [179] was on the treatment of perceptual problems, it will not be discussed here. Smania et al. [180] assessed in an RCT the effectiveness of a rehabilitative training programme for patients with limb apraxia. Thirteen patients with acquired brain injury and limb apraxia (lasting more than 2 months) as a result of lesions in the left cerebral hemisphere participated in the study. The study group underwent an experimental training for limb apraxia consisting of a behavioural training programme with gesture-production exercises. The control group received conventional treatment for aphasia. Assessments involved neuropsychological tests of apraxia, verbal comprehension, general intelligence, oral apraxia, and constructional apraxia, and three tests concerning limb praxic function (ideational and ideomotor apraxia and gesture recognition). Everyday activities related to each test were used to measure the outcome. The patients in the study group achieved a significant improvement of performance in both the ideational and ideomotor apraxia tests. They also showed a significant reduction of errors in ideational and ideomotor apraxia tests. The change in performance was not significant for the control group. The results show the possible effectiveness of a specific training programme for the treatment of limb apraxia.

Donkervoort et al. [181] determined in a controlled study the efficacy of strategy training in left hemisphere stroke patients with apraxia. A total of 113 patients who had suffered a stroke in the left hemisphere stroke and had apraxia were randomly assigned to two treatment groups: (1) strategy training integrated into the usual occupational therapy; and (2) usual occupational therapy only. The primary outcome measure was a standardized ADL observation by a blinded research assistant. Additional ADL measures were used as secondary outcome measures (Barthel ADL index, ADL judgement by occupational therapists and by patients). After 8 weeks of treatment, patients who received strategy training (n = 43) improved significantly more than patients in the usual treatment group (n = 39) on the ADL observations. This reflects a small to medium effect (effect size 0.37) of strategy training on ADL functioning. With respect to the secondary outcome measures, a medium effect (effect size 0.47) was found on the Barthel ADL index. No beneficial effects of strategy training were found after 5 months (at follow-up).
In addition, we performed secondary analyses on the data of Donkervoort et al. [181] to examine the transfer of the effects of cognitive strategy training for stroke patients with apraxia from trained to non-trained tasks. The analyses showed that, in both treatment groups, the scores on the ADL observations for non-trained tasks improved significantly after 8 weeks of training compared with the baseline score. Change scores of non-trained activities were larger in the strategy training group compared with the usual treatment group. These results suggest that transfer of training is possible, although further research should confirm these exploratory findings [183]. Recently, we performed a study specifically aiming to measure the transfer effects of the cognitive strategy training for apraxia [184]. In this study, we showed that patients performed trained and non-trained tasks at the same level of independency at the rehabilitation centre as well as at home, indicating a transfer of training effects that remained stable over time.

A promising approach has been brought forward by Sunderland et al. [185]. In a single-blind, randomized, multiple-baseline experiment, they showed that an ecological and individualized approach for dressing behaviour had a significant treatment effect for right hemisphere patients but not for left hemisphere patients; the benefits of this approach to dressing therapy are currently being evaluated further.

Several Class II studies also support the efficacy of apraxia rehabilitation. Goldenberg and Hagman [186] studied a group of 15 patients with apraxia who made fatal errors in ADLs: an error was rated as fatal if the patient could not proceed without help or if the error prohibited the patient from accomplishing the task successfully. The study design was as follows: each week an ADL test was performed; between tests, the patient was trained in one of three activities, whereas support, but no therapeutic advice, was given for two other activities. Each week, the patient was trained in a further activity, while the other activities were performed in daily life. Thus, in the following week, training was done in the second activity, and in the third week the remaining activity was trained. In case fatal errors were still seen during performance, another cycle of therapy was run. At the end of the therapy, 10 patients could perform all three activities without fatal errors. Three patients made only one fatal error. No generalization of training effects was found from trained to non-trained activities. Seven patients were re-examined after 6 months: only those patients who kept practising the activities in their daily life still showed the positive results of the training.

Van Heugten et al. [187] performed a study evaluating a therapy programme for teaching patients strategies to compensate for the presence of apraxia. The outcome was studied in a pre/post test design; measurements were conducted at baseline and after 12 weeks of therapy. Thirty-three stroke patients with apraxia were treated in occupational therapy departments in general hospitals, rehabilitation centres, and nursing homes. The patients showed considerable improvement in ADL functioning on all measures and slight improvements on the apraxia test and motor functioning test. The effect sizes for the disabilities, ranging from 0.92 to 1.06, were large compared with the effect sizes for apraxia (0.34) and motor functioning (0.19). The significant effect of treatment is also seen when individual improvement and subjective improvement are considered. These results suggest that the programme seems to be successful in teaching patients compensatory strategies that enable them to function more independently, despite the lasting presence of apraxia.

Poole [188] published a study examining the ability of participants with a left hemisphere stroke to learn one-handed shoe-tying. Participants with a left hemisphere stroke with and without apraxia and control participants were taught how to tie their shoelaces with one hand. Retention was assessed after a 5-min interval during which participants performed other tasks. All groups differed significantly with regard to the number of trials to learn the task. However, on the retention task, the control adults and the stroke patients without apraxia required a similar numbers of trial, whereas the participants with apraxia required significantly more trials than the other two groups. All groups required fewer trials on the retention task than on the learning task.

Further evidence is provided by single-case studies. Wilson [189] studied a female adolescent with extensive damage to her brain following an anaesthetic accident. One of the most disabling consequences of the damage was apraxia, which made her almost completely dependent in daily life. Wilson concluded that the step-by-step programme was successful in teaching the patient some tasks, but generalization to new tasks was not found at follow-up. Maher et al. [190] studied the effects of treatment on a 55-year-old man with ideomotor apraxia and
preserved gesture recognition. One-hour therapy sessions were given daily during a 2-week period. During therapy sessions, many cues were offered that were withdrawn systematically, while feedback and correction of errors were given as well. The production of gestures improved qualitatively. Ochipa et al. [191] subsequently developed a treatment programme aimed at specific error types. Praxis performance was studied in two stroke patients. It appeared that both patients achieved a considerable improvement in performance, but the observed effects were treatment specific: treatment of a specific error type did not improve across untreated gestures. Jantra et al. [192] studied a 61-year-old man with a right-sided stroke followed by apraxic gait. After 3 weeks of gait training supplemented with visual cues, the patient became independent with safe ambulating. Pilgrim and Humphreys [193] presented the case of a left-handed head injured patient with ideomotor apraxia of his left upper limb. The patient’s performance on the 10 objects was measured before and after training in three different modalities. A mixed-design analysis of variance was carried out showing a positive effect of therapy but little carry-over to everyday life. Bulter [194] presents a case study that explores the effectiveness of tactile and kinaesthetic stimulation as an intervention strategy, in addition to visual and verbal mediation, in the rehabilitation of a man with ideational and ideomotor apraxia following a head injury. The results indicated some improvement after a training period and limited evidence of the effectiveness of additional sensory input.

Goldenberg et al. [174] conducted a therapy study with six apraxic patients in which two methods of treatment were compared: direct training of the activity based on the guided performance of the whole activity, and exploration training aimed at teaching the patient the structure–function relationships underlying correct performance but not involving actual completion of the activity. Exploration training had no effect on performance, whereas direct training of the activity reduced errors and the need for assistance. Training effects were largely preserved at follow-up, but the rate of errors increased when the trained activities were tested with a partially different set of objects. Performance improved with repeated testing of untrained activities during initial baseline, but there was no reduction of errors or amount of assistance required for untrained activities during the training of other activities. As therapeutic results were restricted to trained activities and to some degree to trained objects, the authors concluded that therapy should be tailored to the specific needs of patients and their family and should be linked closely to the normal routines of daily life.

Recently, a single-case study was executed in which repetition of a newly designed facilitation exercise was used in a patient with corticobasal degeneration, leading to a decrease of difficulties in ADL performance [195].

**Recommendations**

There is Level A evidence for the effectiveness of apraxia treatment with compensatory strategies. Treatment should focus on functional activities that are structured and practised using errorless learning approaches. As transfer of training is difficult to achieve, treatment should focus on specific activities in a specific context close to the patients’ normal routines. Recovery of apraxia should not be the goal for rehabilitation.

**Rehabilitation of acalculia**

Acquired disorders of number processing and calculation (DNPC) are manifold and may occur after many types of brain damage. Depending on the underlying disease and lesion location, the frequency of calculation disorders in patients with neurological disorders has been estimated to range between 10% and 90% [196]. As with other cognitive deficits, subsets of number and calculation knowledge may be individually affected, requiring a profound assessment to define the profile of impairment. A review summarising the remediation of DNPC has to account for the variety of its clinical presentations and underlying causes [197], the frequent association with aphasia or other cognitive impairments, and the limited knowledge regarding its spontaneous recovery [198].

Most research designs and statistical evaluation procedures are taken from the field of single-subject research [199, 200]. Outcome measures typically consist of a comparison of an individual’s pre- and post-treatment performance, the decrease of error rates and response latencies, the confirmation of generalization or transfer, and the use of prior learning in new context. The amount of functional disability in daily life is rarely assessed or estimated in this corpus of studies. As a literature search based on databanks was unsatisfactory, the authors reviewed the existing literature themselves and used a pre-existing overview related to the topic [201, 202].
Two main types of treatment rationale have been applied to DNPC. One, the 'reconstitution' or 're-teaching' approach, consists of improvements to lost or damaged abilities by way of extensive practice and drill in order to improve efficiency and speed. The other, indirect approach promotes the use of 'back-up' strategies based on the patient’s residual resources [201]. In this case, the treatment would work not merely to restore the functionality of the impaired component, but rather to exploit preserved abilities to compensate for the deficit. Both types of remediation employ step-by-step training consisting of a presentation of problems of increasing difficulty, facilitation cues, and other types of assistance that eventually fade with progressive recovery; in all cases, direct feedback is provided to patients on their accuracy and errors.

Studies have been mostly ‘quasi-experimental’ using a single-case or small-group approach guided by the principles of cognitive neuropsychology [203–206] and single-subject research (Class II, III, and IV evidence). Group studies using control groups are considered inadequate by most authors due to known reasons (problems with patient selection, group homogeneity, heterogeneity of subjacent deficit and premorbid functional level). The group study of Gauggell and Billino [207] deals with the effects of motivation rather than of specific treatment.

Rehabilitation of DNPC may be grouped into several areas of intervention [208]. Rehabilitation of transcoding ability (the ability to translate numerical stimuli between different formats) has been successfully performed in several studies [209–213], mostly by re-teaching the patient the required set of rules. Impairments of arithmetical facts (simple multiplication, addition, subtraction, or division solved directly from memory) were the target of several rehabilitation studies [208, 214–220]. In all studies, extensive practice with the defective domain of knowledge, i.e. multiplication tables, determined significant improvement. A positive outcome was also reached by a rehabilitation programme based on the strategic use of the patient’s residual knowledge of arithmetic [215]. This specific case suggests that the integration of declarative, procedural, and conceptual knowledge critically mediates the reacquisition process. Miceli and Capasso [214] have successfully rehabilitated a patient with deficient arithmetical procedures (the knowledge required to solve multidigit calculations). Deficient arithmetical problem-solving (the ability to provide a solution for complex, multistep arithmetical text problems) has also been treated in one study [221]. The study was rated as partly successful by the authors, as patients benefited from the cueing procedure, engaged and generated a higher number of correct solution steps, but did not show a prominent effect on the actual execution process.

Recommendations

Overall, the available evidence suggests that rehabilitation procedures used to treat selected variants of DNPC have been successful (Level C). Notably, significant improvements were observed even in severely impaired and chronic patients. Several caveats, however, need to be mentioned in this context. At present, little is known about the prognosis and spontaneous recovery of DNPC; thus, the effects of different interventions in the early stages of numerical disorders may be difficult to evaluate. Moreover, different underlying neurological disorders (e.g. stroke, dementia, trauma) have only partly been compared in terms of their specific effects on DNPC. Furthermore, it has not been studied in detail how impairments of attention or executive functions influence the rehabilitation process of DNPC.

General recommendations

In our opinion, there is enough overall evidence to award a grade A, B, or C recommendation to some forms of cognitive rehabilitation in patients with neuropsychological deficits in the post-acute stage after a focal brain lesion (stroke, TBI). This general conclusion is based on a limited number of RCTs, and is supported by a considerable amount of evidence coming from Class II, III, and IV studies. In particular, the use of a rigorous single-case methodology has been considered by the present reviewers as a source of acceptable evidence in this specific field, in which the application of the RCT methodology is difficult for a number of reasons, related to the lack of consensus on the target of treatment, the methodology of the intervention, and the assessment of the outcomes. Similar conclusions were reached on the basis of a meta-analysis of effect sizes reported by Rohling et al. [117].

Future developments

There is clearly a need for large-scale RCTs evaluating well-defined methodologies of intervention in common
clinical conditions (e.g. assessment of the efficacy of an intervention for ULN after right hemispheric stroke on long-term motor disability). The main difficulty of this approach lies in the highly heterogeneous nature of cognitive deficits. For example, it is hard to believe that the same standardized aphasia treatment may be effective for a patient with a fluent neologistic jargon and another with agrammatic nonfluent production. Research in neuropsychology has focused on the assessment of specific, theoretically driven treatments in well-defined areas of impairment, usually by means of single-case methodology (e.g. the effect of a linguistically driven intervention compared with simple stimulation on the ability to retrieve lexical items belonging to a defined class). To the present panel, both approaches represent potentially fruitful avenues for research in this field.

Future studies should also aim at a better clinical and pathological definition of the patients included in the trials. The gross distinction between stroke and traumatic brain damage used in the present review is clearly insufficient: a separation of the main categories of cerebrovascular pathology and a subdivision on pathological grounds of the survivors of traumatic brain damage can be expected to improve the quality of rehabilitation studies.

Conflicts of interest

The authors report no conflicts of interest in connection with this chapter.

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References

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