REVIEW ARTICLE (META-ANALYSIS)

Evidence-Based Cognitive Rehabilitation: Updated Review of the Literature From 2003 Through 2008

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ABSTRACT. Cicerone KD, Langenbahn DM, Braden C, Malec JF, Kalmar K, Fraas M, Felicetti T, Laatsch L, Harley JP, Bergquist T, Azulay J, Cantor J, Ashman T. Evidence-based cognitive rehabilitation: updated review of the literature from 2003 through 2008. Arch Phys Med Rehabil 2011;92: 519-30.

Objective: To update our clinical recommendations for cognitive rehabilitation of people with traumatic brain injury (TBI) and stroke, based on a systematic review of the literature from 2003 through 2008.

Data Sources: PubMed and Infotrieve literature searches were conducted using the terms *attention*, *awareness*, *cognitive*, *communication*, *executive*, *language*, *memory*, *perception*, *problem solving*, and/or *reasoning* combined with each of the following terms: *rehabilitation*, *remediation,* and *training* for articles published between 2003 and 2008. The task force initially identified citations for 198 published articles.

Study Selection: One hundred forty-one articles were selected for inclusion after our initial screening. Twenty-nine studies were excluded after further detailed review. Excluded articles included 4 descriptive studies without data, 6 nontreatment studies, 7 experimental manipulations, 6 reviews, 1 single case study not related to TBI or stroke, 2 articles where the intervention was provided to caretakers, 1 article redacted by the journal, and 2 reanalyses of prior publications. We fully reviewed and evaluated 112 studies.

Data Extraction: Articles were assigned to 1 of 6 categories reflecting the primary area of intervention: attention; vision and visuospatial functioning; language and communication skills; memory; executive functioning, problem solving and awareness; and comprehensive-holistic cognitive rehabilitation. Articles were abstracted and levels of evidence determined using specific criteria.

Data Synthesis: Of the 112 studies, 14 were rated as class I, 5 as class Ia, 11 as class II, and 82 as class III. Evidence within each area of intervention was synthesized and recommendations for *Practice Standards*, *Practice Guidelines*, and *Practice Options* were made.

Conclusions: There is substantial evidence to support interventions for attention, memory, social communication skills, executive function, and for comprehensive-holistic neuropsychologic rehabilitation after TBI. Evidence supports visuospatial rehabilitation after right hemisphere stroke, and interventions for aphasia and apraxia after left hemisphere stroke. Together with our prior reviews, we have evaluated a total of 370 interventions, including 65 class I or Ia studies. There is now sufficient information to support evidence-based protocols and implement empirically-supported treatments for cognitive disability after TBI and stroke.

Key Words: Brain injuries; Practice guidelines as topic; Rehabilitation; Stroke.

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THE COGNITIVE REHABILITATION Task Force of the American Congress of Rehabilitation Medicine Brain Injury Interdisciplinary Special Interest Group has previously conducted 2 systematic reviews of cognitive rehabilitation after TBI or stroke, which served as the basis for specific practice recommendations. The first of these articles represents the initial application of an evidence-based, systematic review to the literature concerning the effectiveness of cognitive rehabilitation.[1] The second article provided an update to the cognitive rehabilitation literature through 2002 publications.[2] Since then, a number of systematic reviews have been conducted.

Rees et al[3] conducted a systematic review of 64 studies addressing cognitive rehabilitation for attention, learning or memory, executive functioning, and general cognitive rehabilitation approaches including pharmacologic interventions. Most of their conclusions were based on moderate or limited evidence. They found strong evidence supporting the use of external memory aides to compensate for functional memory problems, without necessarily improving underlying memory abilities. They also

List of Abbreviations

ANCDS	Academy of Neurologic Communication Disorders and Sciences
APT	attention process training
CIAT	constraint induced aphasia therapy
IADLs	instrumental activities of daily living
RCT	randomized controlled trial
TBI	traumatic brain injury
VRT	visual restoration therapy

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found strong evidence that internal strategies are effective in improving recall performance for people with mild impairment, but ineffective for those with severe memory impairment. These conclusions are consistent with our earlier recommendations. They also noted moderate evidence that methylphenidate improved overall cognitive functioning and strong evidence that methylphenidate improves processing speed after TBI.

The ANCDS has conducted 3 systematic reviews of cognitive rehabilitation. Sohlberg et al[4] reviewed 9 studies and developed evidence-based practice guidelines for direct attention training after TBI. The review was based on 5 key questions regarding participants, nature of interventions, outcomes, methodologic concerns, and clinically applicable trends across studies. Direct attention training was defined as the repeated stimulation of attention via graded exercises to improve the underlying neurocognitive system and attention functioning. The authors recommended use of direct attention training in conjunction with metacognitive training (feedback, self-monitoring, strategy use) for postacute or mildly impaired clients with intact vigilance. The ANCDS also reviewed 21 studies addressing the effectiveness of external aids for memory compensation, using the key questions noted above.[5] The most common type of external aid was a written memory notebook or daily planner (9 studies), while other studies evaluated various electronic devices. The authors concluded that treatment to establish the use of external aids for memory compensation might be considered a *Practice Guideline* as a means of improving day-to-day functioning for people with brain injury. Finally, the ANCDS[6] conducted a systematic review and meta-analysis of 15 studies addressing interventions for executive functions after TBI. Ten of the studies (including 5 RCTs) utilized metacognitive strategy instructions (eg, for self-monitoring and control of cognitive processes). These studies supported metacognitive strategy training to improve problem solving for personally relevant activities, based on significant effect sizes for activity and participation outcomes compared with control treatments. The review led to the recommendation of a practice standard for the use of metacognitive strategy training with young to middle-age adults with TBI in chronic stages of disability for difficulties with problem solving, planning, and organization.

Two reviews were based directly on the task force's earlier systematic reviews. One of these evaluated the methodologic quality of 53 comparative effectiveness studies (32 RCTs and 21 observational studies) involving exclusively or primarily participants with TBI.[7] There were several high-quality studies that supported the effectiveness of interventions for attention, communication skills, executive functioning, and comprehensive-holistic rehabilitation after TBI, including improvements on participation outcomes. This analysis also noted the value of non-RCTs in providing evidence for the effectiveness of cognitive rehabilitation for people with TBI.

Rohling et al[8] conducted a meta-analytic reexamination of the task force's prior systematic reviews. They found a small significant overall treatment effect that was directly attributable to cognitive rehabilitation, after controlling for improvements in nontreatment control groups. The meta-analyis revealed sufficient evidence for the effectiveness of attention training after TBI, language treatment for aphasia, and visuospatial treatment for neglect syndromes after stroke. Treatment effects were moderated by the targeted cognitive domain, time since injury, etiology, and age. Differing conclusions between this meta-analysis and the systematic reviews may reflect differences in methodology. For example, the meta-analysis did not partial out the effect of impairment severity on memory interventions, critical to the conclusions of our and other systematic reviews. When assessing comparative effectiveness, the meta-analysis did not distinguish between studies comparing active with sham treatment conditions, and those comparing 2 alternative, active cognitive interventions. The meta-analysis also excluded noncontrolled and single-case studies that might elucidate innovative and potentially effective treatments.

Among the systematic reviews discussed above,[3-6] only 2 articles were not included in our prior reviews. We therefore identified the need to review the literature since 2002 and update our previous practice recommendations accordingly. The current study is an updated review of the literature published from 2003 through 2008 addressing cognitive rehabilitation for people with TBI or stroke. We systematically reviewed and analyzed studies that allowed us to evaluate the effectiveness of interventions for cognitive limitations. We integrated these findings in our current practice recommendations.

METHODS

The development of evidence-based recommendations followed our prior methodology for identification of the relevant literature, review and classification of studies, and development of recommendations. These methods are described in more detail in our initial publication.[1] For the current review, online literature searches using PubMed and Infotrieve were conducted using the terms *attention*, *awareness*, *cognitive*, *communication*, *executive*, *language*, *memory*, *perception*, *problem solving*, and *reasoning* combined with each of the terms *rehabilitation*, *remediation*, and *training* for articles published between 2003 and 2008. Articles were assigned to 1 of 6 possible categories (based on interventions for attention, vision and visuospatial functioning, language and communication skills, memory, executive function, or comprehensive-integrated interventions) that specifically address the rehabilitation of cognitive disability. Articles were reviewed by 2 task force members who were experienced in the process of conducting a systematic review of cognitive rehabilitation studies, and classified as providing Level I, Level II, or Level III evidence.

The task force initially identified citations for 198 published articles. The abstracts or complete articles were reviewed in order to eliminate articles according to the following exclusion criteria: (1) nonintervention articles, including nonclinical experimental manipulation, (2) theoretical articles or descriptions of treatment approaches, (3) review articles, (4) articles without adequate specification of interventions, (5) articles that did not include participants primarily with a diagnosis of TBI or stroke, (6) studies of pediatric subjects, (7) single case reports without empirical data, (8) nonpeer reviewed articles and book chapters, (9) articles describing pharmacologic interventions, and (10) non-English language articles. One hundred forty-one articles were selected for inclusion following this screening process. Twenty nine studies were excluded following further detailed review (4 descriptive studies without data, 6 nontreatment studies, 7 experimental manipulations, 6 reviews, 1 single case study of a patient not diagnosed with TBI or stroke, 2 articles where the intervention was provided to a caretaker, and 1 article that was redacted by the journal). Two studies were reanalyses of a prior publication; these were not classified as new studies but were evaluated and the findings are discussed.

We fully reviewed and evaluated 112 studies. For these 112 studies, the level of evidence was determined based on criteria used in our prior reviews.[1,2] Well-designed, prospective, RCTs were considered class I evidence; studies using a prospective design with quasi-randomized assignment to treatment conditions were designated as class Ia studies. Given the inherent difficulty in blinding rehabilitation interventions, we did not

Table 1: Definition of Levels of Recommendations

Practice Standards	Based on at least 1, well-designed class I study with an adequate sample, with support from class II or class III evidence, that directly addresses the effectiveness of the treatment in question, providing substantive evidence of effectiveness to support a recommendation that the treatment be specifically considered for people with acquired neurocognitive impairments and disability.
Practice Guidelines	Based on 1 or more class I studies with methodologic limitations, or well-designed class II studies with adequate samples, that directly address the effectiveness of the treatment in question, providing evidence of probable effectiveness to support a recommendation that the treatment be specifically considered for people with acquired neurocognitive impairments and disability.
Practice Options	Based on class II or class III studies that directly address the effectiveness of the treatment in question, providing evidence of possible effectiveness to support a recommendation that the treatment be specifically considered for people with acquired neurocognitive impairments and disability.

consider this as criterion for class I or Ia studies, consistent with our prior reviews. Class II studies consisted of prospective, nonrandomized cohort studies; retrospective, nonrandomized case-control studies; or multiple-baseline studies that permitted a direct comparison of treatment conditions. Clinical series without concurrent controls, or single-subject designs with adequate quantification and analysis were considered class III evidence. Studies that were designed as comparative effectiveness studies but did not include a direct statistical comparison of treatment conditions were considered class III; this occurred for 4 articles. Disagreements between the 2 primary reviewers (as occurred for 3 articles) were first addressed by discussion between reviewers to correct minor sources of disagreement, and then by obtaining a third review.

Of the 112 studies, 14 were rated as class I, 5 as class Ia, 11 as class II, and 82 as class III. The overall evidence within each predefined area of intervention was synthesized and recommendations were derived from the relative strengths of the evidence. The level of evidence required to determine *Practice Standards*, *Practice Guidelines*, or *Practice Options* was based on the decision rules applied in our initial review (table 1). All recommendations were reviewed for consensus by the entire task force through face-to-face discussion.

Remediation of Attention

We reviewed 2 class I studies[9,10] and 6 class III studies[11-16] addressing remediation of attention. A class I study[9] investigated the effectiveness of cognitive remediation and cognitive-behavioral psychotherapy for participants with persisting complaints after mild or moderate TBI. The cognitive remediation consisted of direct attention training along with training in use of a memory notebook and problem-solving strategies. Cognitive-behavioral therapy was used to increase coping behaviors and reduce stress. Participants demonstrated improved performance on a measure of complex attention and reduced emotional distress compared with a wait-list control group, although there was no effect on community integration. This study supports the findings from a previous RCT,[17] demonstrating the beneficial effects of APT on complex attention. Unlike the earlier study, this study combined APT with compensatory strategy training and psychotherapeutic treatment. While it is therefore not a pure test of APT, it is representative of clinical practice.

Two studies evaluated direct attention training after stroke or TBI, based on the assumption that training would increase working memory capacity, which would then generalize to other cognitive systems. A class I study[10] utilized an automated, computerized training program to treat adults who had sustained a stroke 1 to 3 years earlier. The treatment protocol required home use of computer software, completing 90 trials (taking about 40min) daily, 5 days a week for 5 weeks. Weekly telephone feedback was provided, with no other therapist involvement. When compared with an untreated control group, participants who completed the computerized intervention demonstrated improvements on untrained working memory and attention tests, as well as a decrease in self-rated cognitive symptoms. A class III study[15] compared general stimulation with repeated administration of working memory tasks to remediate central executive deficits after TBI. No improvements in neuropsychologic performance were seen after general stimulation; following the working memory training there were significant improvements on executive aspects of attention and self-reported everyday functioning.

Although improvements in attention-executive functioning have been related to self-reported improvements in attention and memory, there is limited evidence of improvement in everyday functional activities after attention training. Three class III studies[11-13] used single-subject methods to investigate the effects of direct attention training for individuals with mild aphasia after stroke. In 2 cases, improvements in reading comprehension were seen after APT.[11,12] In 1 case,[13] improvement

Table 2: Remediation of Attention

Intervention	Level of Recommendation
Remediation of attention is recommended during postacute rehabilitation after TBI. Remediation of attention deficits after TBI should include direct attention training and metacognitive training to promote development of compensatory strategies and foster generalization to real world tasks. Insufficient evidence exists to distinguish the effects of specific attention training during acute recovery and rehabilitation from spontaneous recovery or from more general cognitive interventions.	Practice Standard
Computer-based interventions may be considered as an adjunct to clinician-guided treatment for the remediation of attention deficits after TBI or stroke. Sole reliance on repeated exposure and practice on computer-based tasks without some involvement and intervention by a therapist is not recommended.	Practice Option

Table 3: Remediation of Visuospatial and Praxic Deficits

Intervention	Level of Recommendation
Visuospatial rehabilitation that includes visual scanning training is recommended for left visual neglect after right hemisphere stroke.	Practice Standard
The use of isolated microcomputer exercises to treat left neglect after stroke does not appear effective and is not recommended.	Practice Guideline
Inclusion of limb activation or electronic technologies for visual scanning training may be included in the treatment of neglect after right hemisphere stroke.	Practice Option
Systematic training of visuospatial deficits and visual organization skills may be considered for persons with visual perceptual deficits, without visual neglect, after right hemisphere stroke as part of acute rehabilitation.	Practice Option
Computer-based interventions intended to produce extension of damaged visual fields may be considered for people with TBI or stroke.	Practice Option
Specific gestural or strategy training is recommended for apraxia during acute rehabilitation for left hemisphere stroke.	Practice Standard

was limited to trained attention tasks with nominal change in auditory comprehension.

Recommendations. This recent evidence is consistent with our recommendation of strategy training for attention deficits during postacute rehabilitation for people with TBI (*Practice Standard*) (table 2) and with ANCDS evidence-based practice guidelines for direct attention training. Remediation of attention deficits after TBI should include direct attention training and metacognitive training to promote development of compensatory strategies and foster generalization to real world tasks. Direct attention training through repeated practice using computer-based interventions may be considered as an adjunct to treatment when there is therapist involvement (*Practice Option*) (see table 2). Consistent with the task force's prior recommendations, sole reliance on repeated use of computer-based tasks without some involvement and intervention by a therapist is not recommended.

Remediation of Vision and Visuospatial Functioning

We reviewed 3 class I[18,19] or class Ia[20] studies, 1 class II study,[21] and 11 class III studies[22-32] addressing the remediation of visuoperceptual deficits after TBI or stroke. One class I study[18] evaluated the effectiveness of visual attention training on the driving performance for 97 patients with stroke, extending a prior class III study by these investigators using the useful field of view.[33] Training with useful field of view to address attention and processing speed was compared with traditional computerized visuoperceptual training. There were no significant differences between groups on measures of attention, visuoperception, or resumption of driving. The authors suggested that there was no benefit from targeting visual attention skills, but patients with right hemisphere stroke might benefit from specific skill training (eg, using a driving simulator).

One class I study with 22 stroke patients[20] investigated whether it is possible to strengthen the rehabilitation of visual hemineglect by combining a standard scanning intervention[34,35] with optokinetic stimulation. Results replicated the beneficial effects of scanning training, but the addition of optokinetic stimulation did not further enhance visual scanning or attention.

A class I study[19] investigated whether the use of a visuospatial cue to focus attention improved performance in areas of partially-defective residual vision during VRT. Visuospatial cuing extended the topographic pattern of recovery and improved vision within the cued area. This finding suggests that increased attention to the areas of partially-defective vision helps to compensate for the visual defect. Five class III studies[22,23,26,28,29] also investigated the effects of VRT on reducing the extent of visual field deficits, with some evidence that these changes are associated with subjective improvements in visual function and reading speed.[26,28,29]

Table 4: Remediation of Language and Communication Deficits

Intervention	Level of Recommendation
Cognitive-linguistic therapies are recommended during acute and postacute rehabilitation for language deficits secondary to left hemisphere stroke.	Practice Standard
Specific interventions for functional communication deficits, including pragmatic conversational skills, are recommended for social communication skills after TBI.	Practice Standard
Cognitive interventions for specific language impairments such as reading comprehension and language formulation are recommended after left hemisphere stroke or TBI.	Practice Guideline
Treatment intensity should be considered a key factor in the rehabilitation of language skills after left hemisphere stroke.	Practice Guideline
Group based interventions may be considered for remediation of language deficits after left hemisphere stroke and for social-communication deficits after TBI.	Practice Option
Computer-based interventions as an adjunct to clinician-guided treatment may be considered in the remediation of cognitive-linguistic deficits after left hemisphere stroke or TBI. Sole reliance on repeated exposure and practice on computer-based tasks without some involvement and intervention by a therapist is not recommended.	Practice Option

Table 5: Remediation of Memory Deficits

Intervention	Level of Recommendation
Memory strategy training is recommended for mild memory impairments from TBI, including the use of internalized strategies (eg, visual imagery) and external memory compensations (eg, notebooks).	Practice Standard
Use of external compensations with direct application to functional activities is recommended for people with severe memory deficits after TBI or stroke.	Practice Guideline
For people with severe memory impairments after TBI, errorless learning techniques may be effective for learning specific skills or knowledge, with limited transfer to novel tasks or reduction in overall functional memory problems.	Practice Option
Group-based interventions may be considered for remediation of memory deficits after TBI.	Practice Option

Recommendations. The task force previously identified 9 class I studies demonstrating the efficacy of visual scanning training for visual neglect after right hemisphere stroke, providing strong support for this intervention as a *Practice Standard* (see table 3). Inclusion of limb activation or electronic technologies for visual scanning training was recommended as a *Practice Option*, but a current class I study does not support the addition of optokinetic stimulation as a component of visual scanning treatment.[20]

The task force previously recommended that visual restoration training to reduce the extent of damaged visual fields should be considered a *Practice Option.* In the current review, this recommendation is supported by class III evidence. A class I study suggests that a combination of top-down (cuing attention) and bottom-up (VRT) interventions, linking visual and attentional neuronal networks, may enhance conscious visual perception.[19] We previously noted[1] that the observed reductions in visual field defects were insufficient to explain the associated reduction in functional impairments after VRT, and that functional improvement was associated with increased compensation rather than change in the underlying visual field deficit. The current class I study is consistent with this interpretation. We continue to recommend that interventions intended to reduce the extent of damaged visual fields should be considered a *Practice Option* (see table 3).

The task force previously identified the need for class I studies to improve complex visuospatial abilities required for functional activities (eg, driving). In the current review, one class I study suggests limited benefit from targeting visual attention deficits skills and the need for specific, functional skill training to improve driving ability after stroke.[18]

Remediation of Language and Communication Skills

We reviewed 6 class I[36-40] or Ia[41] studies, 3 class II studies,[42-44] and 32 class III studies[45-76] in the area of cognitive-linguistic rehabilitation. As in past reviews, most of the studies involved persons with stroke, although 4 of the class I studies investigated interventions for communication deficits resulting from TBI.[38-41]

Language remediation after stroke. One class I study[36] examined whether the amount of speech and language therapy influenced recovery from aphasia after a single, first stroke. Participants were randomly allocated to receive either intensive therapy (5h/wk) or standard therapy (2h/wk); an additional group of patients were clinically assigned to standard therapy. There was no effect of therapy intensity on a standardized assessment of aphasia, although few of the patients in the intensive therapy condition could tolerate the prescribed therapy, and only 80% received the prescribed treatment. Of interest, there was a significant difference between the 2 standard treatment groups, which may have reflected the amount of treatment actually received (averaging 1.6 vs 0.6h/wk). The authors posited that there may be a critical threshold of treatment intensity required to improve acute recovery after stroke, and emphasized the need for future research to address the optimal timing for starting intensive therapy after acute stroke. Two class II[42,43] studies addressed the intensity of aphasia treatment after stroke. One study[42] suggests that the effectiveness of contextually-based language treatment may not depend on therapy intensity. The second study[43] compared constraint-induced aphasia therapy with constraint-induced aphasia therapy combined with additional training in everyday communication. There was greater improvement in communication effectiveness among participants who received additional communication exercises.

One class I study[37] investigated the effects of semantic versus phonologic treatment on verbal communication in 55 patients with aphasia after left hemisphere stroke. Both groups improved on a measure of verbal communication, with no difference between groups. Treatment-specific effects were related to type of impairment, with semantic treatment related to improved semantic processing and phonologic treatment related to improvement of phonologic processing. The authors

Table 6: Remediation of Executive Function Deficits

Intervention	Level of Recommendation
Metacognitive strategy training (self-monitoring and self-regulation) is recommended for deficits in executive functioning after TBI, including impairments of emotional self-regulation, and as a component of interventions for deficits in attention, neglect, and memory.	Practice Standard
Training in formal problem-solving strategies and their application to everyday situations and functional activities is recommended during postacute rehabilitation after TBI.	Practice Guideline
Group-based interventions may be considered for remediation of executive and problem solving deficits after TBI.	Practice Option

Table 7: Comprehensive-Holistic Neuropsychologic Rehabilitation

Intervention	Level of Recommendation
Comprehensive-holistic neuropsychologic rehabilitation is recommended during postacute rehabilitation to reduce cognitive and functional disability for persons with moderate or severe TBI.	Practice Standard
Integrated treatment of individualized cognitive and interpersonal therapies is recommended to improve functioning within the context of a comprehensive neuropsychologic rehabilitation program, and facilitate the effectiveness of specific interventions.	Practice Option
Group-based interventions may be considered as part of comprehensive-holistic neuropsychologic rehabilitation after TBI.	Practice Option

suggest that improvement in either linguistic route may contribute to improved verbal communication patterns.

Treatment of cognitive communication disorders after TBI. Dahlberg et al[38] conducted a class I study to investigate the efficacy of social communication skills training for 52 participants with TBI who were at least 1 year postinjury. Training incorporated pragmatic language skills, social behaviors, and cognitive abilities required for successful social interactions. Between-group analyses demonstrated a significant treatment effect on 7 of 10 scales on the Profile of Functional Impairment in Communication and on the Social Communication Skills Questionnaire, as well as improved quality of life at 6-month follow-up.

Another class Ia study[41] investigated social communication skills training among 51 participants with acquired brain injury, predominantly TBI, who were at least 12-months postinjury and residing in the community. Participants either received social skills training, an equivalent amount of group social activities (eg, cooking, board games), or no treatment. The social skills training was devoted to pragmatic communication behaviors (listening, starting a conversation) and social perception of emotions and social inferences, along with psychotherapy for emotional adjustment. When compared with both control conditions, social communication skills training produced significant improvement in participants' ability to adapt to the social context of conversations. Two class I studies conducted a more detailed investigation of the intervention for social and emotional perception. Improvements were noted in recognition of emotional expressions but these improvements were not reflected on a more general measure of psychosocial functioning.[39] A subsequent study compared errorless learning and self-instructional training strategies for treating emotion perception deficits.[40] Both interventions resulted in modest improvements in judging facial expressions and drawing social inferences, with some advantage for self-instructional training.

Recommendations. There is a continued need to investigate the aspects of intensive language treatment (eg, timing, dosage) that contribute to therapy effectiveness. Although, therapy intensity should continue to be considered as a factor in the rehabilitation of language skills after left hemisphere stroke (*Practice Guideline*) (table 4).

Four class I or Ia studies[38-41] support the task force's recommendation of social communication skills interventions for interpersonal and pragmatic conversational problems for people with TBI (*Practice Standard*) (see table 4). An additional class III study[55] suggests that incorporation of cognitive-linguistic therapies in postacute rehabilitation is related to cognitive and functional progress for patients with language impairment after TBI.

Remediation of Memory

We reviewed 3 new class I[77] or Ia studies,[78,79] 1 class II study,[80] and 11 class III studies.[81-91] We also reviewed 2 reanalyses of an earlier RCT[92] restricted to participants with TBI[93] or stroke.[94]

Errorless learning. One class Ia study,[78] a class II study,[80] and 4 class III studies[82,86,87,90] investigated the benefits of errorless learning in memory remediation. The class Ia study[78] compared computer-assisted and therapist-assisted memory training with a no-treatment control condition for participants with TBI. Both active treatment conditions utilized an errorless learning method and consisted of 20 sessions of memory skills training, management of daily tasks that utilize memory skills, and the consolidation and generalization of those skills. Both treatments produced improvement on neuropsychologic tests of memory functioning compared with no treatment.

The class II study[80] evaluated an instructional sequence for people with severe memory and executive function impairments resulting from chronic TBI. Participants were taught to use a simple e-mail interface through a combination of errorless learning and metacognitive strategy training. Results showed a strong relationship between the instructional program and learning the e-mail procedures, replicated across all 4 subjects and maintained at 30-day follow-up. Positive transfer was seen on a slightly revised procedure, but not to a novel task with different content.

A preliminary study suggested that errorless learning can be used to teach compensatory strategies for specific memory problems, such as taking medications at mealtime or keeping keys in a consistent location.[86] In a subsequent class I study,[77] adults with chronic TBI were trained to use compensatory strategies for personally-relevant memory problems through errorless learning or didactic strategy instruction. Participants trained with errorless learning reported greater use of strategies after training, with limited generalization of strategy use. There was no difference between treatments in generalized strategy use or frequency of memory problems reported by participants or caregivers.

These studies support potential benefits of errorless learning for treatment for teaching new knowledge, including knowledge of compensatory strategies, to people with severe memory deficits resulting from TBI. Errorless learning techniques appear to be effective for teaching specific information and procedures to patients with mild executive disturbance as well as memory impairment. However, the presence of severe executive dysfunction may limit effectiveness of this form of memory rehabilitation.[87]

Compensatory strategy training. Several studies investigated group administered memory remediation. A class Ia study[79] investigated type and intensity of memory training to treat mild memory impairment after recent onset stroke. Treatment consisted of process-oriented memory training (20h), an equivalent amount of strategy training, or control treatment of low dose, process-oriented memory training (7h). Process-oriented training included mass practice, training to manage interference between acquisition and recall, and use of simple principles to optimize memory performance. Strategy training was aimed at teaching strategies adapted to different situations with memory requirements. Results indicated that frequency and intensity of memory training were critical in improving memory performance. A class III study[91] demonstrated increased knowledge of memory strategies and use of memory aids, reduced behaviors indicative of memory impairment, and improved performance on neuropsychologic assessment of memory following a 4-week structured, group format memory training program.

Externally directed assistive devices. There were 2 reanalyses of an RCT[92] studying the benefits of a paging system for subjects with acquired brain injury. Wilson et al[93] examined the results for 63 people with chronic TBI with memory and/or planning problems. A randomized cross-over design was used to examine the impact of pager use on successful achievement of target behaviors. Results demonstrated significantly increased task behavior in each group when using the pager, and a carryover effect for the first group after removing the pager. This analysis supports the initial findings that a paging system was effective in reducing everyday memory and planning problems experienced by persons with TBI. Fish et al[94] analyzed the effectiveness of the paging system for 36 participants with stroke. As found with TBI participants, introduction of the paging system produced immediate benefits in compensating for memory and planning deficits. Unlike TBI participants, the behavior of stroke participants returned to baseline levels after removal of the pager. Further analyses suggested that maintenance of treatment benefits was associated with executive functioning, and the stroke participants had poorer executive functioning.

Recommendations. The task force previously recommended the use of compensatory strategy training for subjects with mild memory impairment as a *Practice Standard* (table 5). For patients with severe memory impairments after TBI, errorless learning techniques may be effective for learning specific skills or knowledge, with limited transfer to novel tasks or reduction in overall functional memory problems. We now recommend this as a *Practice Option* (see table 5). The use of externally-directed assistive devices, such as pagers, appears to be beneficial for persons with moderate to severe memory impairments after TBI or stroke. The presence of significant executive dysfunction appears to limit the effectiveness of these interventions for severe memory deficits. The task force continues to recommend training in the use of external compensations (including assistive technology) with direct application to functional activities for persons with moderate or severe memory impairment after TBI or stroke as a *Practice Guideline* (see table 5).

Remediation of Executive Functioning

We reviewed 3 class I[95,96] or Ia[97] studies, 2 class II studies,[98,99] and 14 class III studies[100-113] addressing the remediation of executive functioning, including training in metacognitive strategies to increase awareness. Two of the class I and Ia studies[95,97] compared an awareness-training protocol with conventional occupational therapies after moderate or severe TBI (n=33) or stroke (n=8). In 1 of these studies,[97] the awareness-training protocol incorporated feedback to increase participants' awareness of their abilities, with experiential exercises requiring participants to predict, self-monitor, and self-evaluate their performance. Improvements in awareness, performance of IADLs, and overall function were evident for both groups. The awareness intervention was associated with greater increase in self-awareness of deficits after treatment, but not with better performance of IADLs or general functioning compared with conventional rehabilitation. The second class I study[95] employed self-awareness and verbal self-regulation strategies during performance of IADLs tasks. Participants were asked to define their performance goals, predict task performance, anticipate difficulties, select a strategy to circumvent difficulties, assess the amount of assistance required to successfully perform the task, and self-evaluate performance. Participants in the control condition performed the same IADLs tasks as the treatment group, but received conventional practice without the awareness intervention. Participants who received the awareness intervention demonstrated significant improvements in self-regulation skills and cognitive aspects of IADLs performance when compared with participants receiving conventional therapy, whose performance either did not improve or decline. No differences between groups were evident on either general or task-specific measures of awareness or a measure of community integration after the 6 treatment sessions. A number of single-case studies support the benefits of metacognitive training and suggest that the most consistent benefits of this treatment are apparent on participants' online monitoring, awareness of errors, and error management.[104,108]

One class I study[96] evaluated the use of autobiographical memory cuing to improve performance on a planning task by people with TBI. Participants in the experimental group received a single session of instruction on the use of specific examples from their memory of similar activities in order to solve a functional problem situation (eg, planning a vacation). The intervention was successful in increasing the recall of specific memories and effectiveness of functional planning, suggesting that this procedure might be an effective component of training on problem-solving techniques.

A notable study[110] evaluated an innovative social problem-solving intervention after TBI, compared with conventional neuropsychologic rehabilitation. Participants, who were an average of 4 years postinjury, were described as being "higher functioning" but with persistent impairments in social/vocational functioning (eg, job loss, marital difficulties). In the problem-solving intervention, emotional self-regulation was taught as the basis for effective problem-orientation and a necessary precursor to support training in the clear thinking underlying problem-solving skills. Role play was used to promote internalization of self-questioning, use of self-regulations strategies, and systematic analysis of real-life problem situations. Only the problem-solving treatment resulted in significant beneficial effects on measures of executive functioning, self-appraisal of clear thinking, self-appraisal of emotional self-regulation, and objective observer-ratings of interpersonal problem solving behaviors in naturalistic simulations.

Recommendations. The studies in this area are consistent with the task force's recommendation of training in formal problem-solving strategies, including problem orientation (emotional regulation), and their application to everyday activities and functional situations during postacute rehabilitation for people with TBI (*Practice Guideline*) (table 6). A number of studies indicate that interventions directed at improving metacognitive skills (ie, self-monitoring and self-regulation) have particular value and effectiveness over conventional rehabilitation in treating patients with impaired self-awareness after moderate or severe TBI.[95,97,110] There also is continued evidence that the incorporation of interventions, including training in metacognitive strategies, can facilitate the treatment of attention,[114-116] memory,[80,85,87] language deficits,[56] and social skills[40,41] after TBI or stroke. Based on the current evidence, the task force now recommends the use of metacognitive strategy training for people with deficits in executive functioning (including impaired self-awareness) after TBI as a *Practice Standard* (see table 6).

Comprehensive-Integrated Neuropsychologic Rehabilitation

There were 2 class I studies,[117,118] 4 class II studies,[119-122] and 8 class III studies[123-130] of comprehensive-holistic rehabilitation after TBI or stroke. Vanderploeg et al[117] conducted an RCT comparing cognitive-didactic and functional-experiential treatment approaches among 360 service members with moderate or severe TBI at 4 Veterans Administration acute inpatient rehabilitation programs. Participants received 1.5 to 2.5 hours daily of protocol-specific therapy along with 2 to 2.5 hours of occupational and physical therapy. The cognitive-didactic group showed better immediate posttreatment cognitive function but the 2 groups did not differ on functional or employment outcomes at 1-year follow-up.

Cicerone et al[118] conducted an RCT to evaluate the effectiveness of comprehensive-holistic neuropsychologic rehabilitation compared with standard, multidisciplinary rehabilitation for 68 participants with TBI. Most participants (88%) had sustained moderate or severe TBI and over half were more than 1-year postinjury. Standard neurorehabilitation consisted primarily of individual, discipline-specific therapies (physical therapy, occupational therapy, and speech therapy) along with 1 hour of individual cognitive rehabilitation. The holistic neuropsychologic intervention included individual and group therapies that emphasized metacognitive and emotional regulation for cognitive deficits, emotional difficulties, interpersonal behaviors, and functional skills. Neuropsychologic functioning improved in both conditions, but the holistic neuropsychologic rehabilitation produced greater improvements in community functioning and productivity, self-efficacy, and life satisfaction. An earlier (class II) study compared these interventions for clinical referrals.[119] The study found that participants, despite being more severely disabled and further postinjury, receiving comprehensive-holistic rehabilitation were twice as likely to make clinically significant gains in community functioning than those receiving conventional rehabilitation. Several class II studies of comprehensive-holistic rehabilitation demonstrated reductions in symptoms, improvements in community functioning, and better quality of life compared with conventional treatment[120] or no treatment.[121,122]

Recommendations. Results from a class I study,[118] several class II studies,[119-122] and class III studies,[123-125,128,129] are consistent with prior findings suggesting that comprehensive-holistic neuropsychologic rehabilitation can improve community integration, functional independence, and productivity, even for patients who are many years postinjury.[118,119,124] The task force recommends that postacute, comprehensive-holistic neuropsychologic rehabilitation should be provided to reduce cognitive and functional disability after moderate or severe TBI (*Practice Standard*) (table 7). Within this context, interventions should address the cognitive, emotional, and interpersonal difficulties of people with acquired brain injury. Comprehensive-holistic programs typically incorporate a combination in individual and group therapies. There is also evidence for the effectiveness of group treatment for memory deficits,[79,91] social communication skills,[38,41] aphasia,[131] and executive functioning and problem solving.[109,110] Based on this evidence, the task force recommends that group interventions be considered for treating cognitive and communication deficits after TBI and left hemisphere stroke (*Practice Option*) (see tables 4–7).

DISCUSSION

In this systematic review, we evaluated 112 studies of cognitive rehabilitation after TBI or stroke. Based on our current review, we recommend 2 new *Practice Standards* and the strengthening or refinement of several *Practice Standards* previously advanced. There is substantial evidence to support the use of direct attention training and metacognitive training after TBI to promote the development of self-directed strategies during postacute rehabilitation and foster generalization to real-world tasks. Self-directed strategy training is recommended for the remediation of mild memory deficits after TBI. For impairments of higher cognitive functioning after TBI, interventions that promote self-monitoring and self-regulation for deficits in executive functioning (including impaired self-awareness) and social communication skills interventions for interpersonal and pragmatic conversational problems are recommended after TBI. Comprehensive-holistic neuropsychologic rehabilitation is recommended to improve postacute participation and quality of life after moderate or severe TBI. A number of recommended *Practice Standards* reflect the lateralized nature of cognitive dysfunction that is characteristic of stroke. Visuospatial rehabilitation that includes visual scanning training for left visual neglect is recommended after right hemisphere stroke. Cognitive-linguistic interventions for aphasia and gestural strategy training for apraxia are recommended after left hemisphere stroke.

The *Practice Standards* for metacognitive strategy training for executive deficits and comprehensive-holistic neuropsychologic rehabilitation after TBI represent upgraded recommendations from our prior reviews. The *Practice Options* for errorless learning for memory deficits after TBI and for group treatments for cognitive and communication deficits after TBI or left hemisphere stroke represent new recommendations since our prior reviews.

Together with our prior reviews, we now have evaluated a total of 370 interventions (65 class I or Ia, 54 class II, and 251 class III studies) that provide evidence for the comparative effectiveness of cognitive rehabilitation. Among the 65 class I and Ia studies, there were 15 comparisons (which included 550 participants) of cognitive rehabilitation with no active treatment. In every one of these comparisons, cognitive rehabilitation was shown to be of benefit. There were 17 comparisons (with 696 participants) between cognitive rehabilitation and conventional forms of rehabilitation. Cognitive rehabilitation was shown to be of greater benefit than conventional rehabilitation in 94.1% of these comparisons. Examining this evidence base, there is clear indication that cognitive rehabilitation is the best available form of treatment for people who exhibit neurocognitive impairment and functional limitations after TBI or stroke. Additional research needs to elucidate the mechanisms of change underlying the efficacy of cognitive rehabilitation and the comparative effectiveness of different interventions.

Although not the primary focus of our reviews, there are some indications regarding consideration of patient characteristics in cognitive rehabilitation. Most notable, remediation of memory should be tailored to the severity of memory impairment, with different interventions for mild versus severe impairment. The presence of executive functioning deficits may moderate the response to treatment, and metacognitive strategy training may need to be incorporated in these interventions. Finally, there is evidence from numerous studies indicating that cognitive rehabilitation is effective during the postacute period, even many years after the initial injury. Additional research is needed to investigate the patient characteristics that influence treatment effectiveness.

In our initial review, we indicated that cognitive rehabilitation should be directed at achieving changes that improve persons' functioning in areas of relevance to their everyday lives. The majority of studies have relied on changes in cognitive functioning, assessed by standardized neuropsychologic testing or other cognitive measures, as proximal outcomes of cognitive rehabilitation. Our reviews are consistent with the view that cognitive rehabilitation is effective in helping patients learn and apply compensations for residual cognitive limitations, although several studies suggest that intervention may directly improve underlying cognitive functions.[10,15,99] Our systematic reviews provide more limited evidence regarding improvements at the level of functional activities, participation, or life satisfaction after cognitive rehabilitation. Although improvements at the level of social participation and quality of life are valued as the distal health-related outcomes of cognitive rehabilitation, it is often not possible to observe improvements on these more global outcomes within the limited timeframes used in most investigations of cognitive rehabilitation. The possible reasons for this include the relatively brief periods of intervention, limited opportunity to address the application of interventions to everyday functioning, lack of follow-up assessing community functioning, or failure to include the relevant outcome measures. A number of studies have evaluated treatment effects based on observations of everyday functioning or performance on tasks derived from activities of daily living, which provide evidence for the effects on daily functioning. Studies of comprehensive-holistic cognitive rehabilitation provide the best evidence for improvements in health-related outcomes, such as social participation and quality of life.

Study Limitations

Since our prior reviews, more sophisticated criteria have been developed for evaluating the level of evidence beyond basic study design (eg, blinding of outcome assessments). We recognize that the failure to employ these additional criteria has influenced the classification of studies and is a limitation of this review. We elected to retain our initial criteria in order to be consistent with our prior reviews. Many of the studies in this review and our 2 prior reviews have been evaluated according to additional methodologic criteria and this information is available in another publication.[7]

CONCLUSIONS

The Cognitive Rehabilitation Task Force has systematically reviewed 370 studies of cognitive rehabilitation published from 1971 through 2008, in order to establish recommendations for the practice of cognitive rehabilitation. There is now sufficient information to support evidence-based clinical protocols, and to design and implement a comprehensive program of empirically-supported treatments for cognitive disability after TBI and stroke.

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