NEUROPSYCHOLOGICAL REHABILITATION
i*First*, 1–43

Psychology Press
Taylor & Francis Group

Intervention for executive functions after traumatic brain injury: A systematic review, meta-analysis and clinical recommendations

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A systematic review of studies that focused on the executive functions of problem solving, planning, organising and multitasking by adults with traumatic brain injury (TBI) was performed through 2004. Qualitative and quantitative methods were used to evaluate the 15 studies that met inclusion criteria. Demographic variables, design and intervention features, and impairment and activity/participation outcomes (ICF) (World Health Organization, 2001) were documented. Five randomised control treatment (RCT) studies used step-by-step, metacognitive strategy instruction (MSI) and outcomes were evaluated in a meta-analysis. Effect sizes (ESs) from immediate impairment outcomes after MSI and "control" intervention were similar to each other, and both were significantly larger than chance. ESs from immediate activity/participation outcomes after MSI were significantly larger than the ESs from

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This project was funded by the Academy of Neurologic Communication Disorders and Sciences (ANCDS), with additional support from American Speech-Language-Hearing Association (ASHA), ASHA's Division 2: Neurophysiology and Neurogenic Speech and Language Disorders, the Veterans Administration, and numerous universities. The authors want to especially thank graduate students, Miriam Krause, Sarah Linhart and Sharon Spencer, in the Department of Speech-Language-Hearing Sciences at the University of Minnesota for their contributions to this project.

http://www.psypress.com/neurorehab DOI:10.1080/09602010701748644

control intervention, and both were significantly larger than chance. These results, along with positive outcomes from the other group, single-subject design and single case studies, provided sufficient evidence to make the clinical recommendation that MSI should be used with young to middle-aged adults with TBI, when improvement in everyday, functional problems is the goal (Level A) (American Academy of Neurology, 2004). Although maintenance effects were generally positive, there was insufficient data quantitatively to evaluate this. Furthermore, there was insufficient evidence to make clinical recommendations for children or older adults. Intervention that trained verbal reasoning and multi-tasking was promising, although the evidence is insufficient to make clinical recommendations at this time. Additional research needs were highlighted.

Keywords: Brain injury; Executive functions; Intervention; Problem solving; Systematic review.

INTRODUCTION

Traumatic brain injury (TBI) is the leading cause of unintentional death in children and young adults, although no age group is spared. In the US alone, the Centers for Disease Control (CDC) report that there are approximately 5.3 million individuals living with disability from TBI in the United States with 1.4 million injured annually (http://www.cdc.gov/ncipc). Of the various disabilities that are the result of TBI, cognitive, communication and psychosocial deficits keep individuals from independently returning to their home, school, community and job.

Various rehabilitation professionals, including speech-language pathologists, neuropsychologists, occupational therapists, special education instructors and vocational rehabilitation counsellors work with individuals with TBI, by assessing and managing their abilities and disabilities. The purposes of this document are to report: (1) results of a systematic review of the research evidence on the treatment of executive functions, specifically problem solving, planning, organisation, and multi-tasking; (2) results of a meta-analysis used to answer specific questions about interventions that have similar underlying constructs; and (3) clinical recommendations for rehabilitation professionals treating these individuals. Thus, a hybrid approach of both qualitative and quantitative methods was used to evaluate and make practice recommendations for treating these executive functions.

Executive functions have been traditionally defined as "integrative cognitive processes that determine goal-directed and purposeful behavior and are superordinate in the orderly execution of daily life functions includ[ing]: the ability to formulate goals; to initiate behavior; to anticipate the consequences of actions; to plan and organize behavior according to the spatial, temporal, topical or logical sequences; and to monitor and adapt behavior to fit a particular task or context" (Cicerone et al., 2000, p. 1605). Stuss (1991) positioned executive functions in the middle of a hierarchical framework in which the results of these executive activities (planning, problem solving, reasoning, etc.) are relayed to a higher level of "self" (e.g., self-awareness) and to lower level systems (e.g., memory, comprehension) where updating can occur.

Other fields such as educational, developmental, and cognitive psychology consider self-regulation skills to be at the core of executive functions (e.g., Butterfield & Belmont, 1977). When self-regulation is applied to cognition, it is called "metacognition" or thinking about your thinking which includes "self-awareness or *metacognitive beliefs*, as well as *self-monitoring* and *self-control* of cognition while performing an activity" (Kennedy & Coelho, 2005, p. 243). Each aspect of metacognition is used during highly complex behaviour (e.g., solving everyday problems) and is organised around skill sets that include: (1) setting goals; (2) comparing performance with goals or outcomes (i.e., self-monitoring); (3) making decisions to change one's behaviour in order to reach the desired outcome (i.e., self-control) (e.g., selecting an alternative solution); and (4) executing the change in behaviour (e.g., implementing an alternative solution). Thus, highly complex behaviours are byproducts of self-regulation or an executive function system that includes a set of skills, not a single skill (Kennedy & Coelho, 2005). Although divergent views about the central executor exist, a convergence of evidence from numerous fields is rather clear; the central executor regulates more basic cognitive systems (e.g., attention, memory, social behaviour, comprehension), the frontal lobes – in particular the prefrontal cortex – are instrumental to these processes, and these areas of cortex are likely to be injured by blunt trauma.

Disorders of executive functions are as heterogeneous as the TBI population itself; however, the focus of this paper is on the intervention for improving everyday problem solving, planning, organising and multitasking. For example, individuals may have difficulty solving everyday problems because they cannot generate alternative solutions that adhere to time and resource constraints. Others may be able to generate alternative solutions to problems, but cannot predict when problems will arise and therefore are not prepared with alternatives when they are needed. Still others could have difficulty organising and prioritising the steps that it takes to solve a problem. It is not surprising then that intervention for these kinds of executive functions typically targets a specific set of skills, such as identifying realistic goals, establishing priorities and time frames, weighing pros and cons of solutions, selecting and gathering the necessary materials, carrying out the steps and monitoring the outcomes of each, and modifying next steps based on results of earlier ones (Kennedy & Coelho, 2005; Marlowe, 2000). Being able to solve everyday, functional problems relies not only on the integrity of each skill set, but also on the integration of these skills. Rehabilitation researchers have provided evidence spanning three decades indicating that intervention for these executive functions are efficacious for some subgroups of the TBI population, while leaving much yet to be investigated. The strength of this evidence is evaluated in this paper.

Systematic reviews of intervention for executive functions

"Systematic reviews follow a rigorous methodology to address focused questions, apply explicit eligibility criteria, conduct exhaustive literature searches and critically appraise the evidence" (American Academy of Neurology, 2004, p. 56). Few researchers have systematically reviewed the cognitive rehabilitation research literature, specifically the intervention research on executive functioning and only recently have these reviews included clinical recommendations. The earliest systematic review was by Coelho, DeRuyter, and Stein (1996). These authors summarised 28 intervention studies of efficacy of cognitive rehabilitation for survivors of TBI of which seven intervention studies aimed at improving executive functions. Tables of evidence were provided although the studies were not evaluated or critiqued. The authors concluded that interventions aimed at improving various executive functions appear to result in positive outcomes when intervention procedures included self-monitoring, self-control procedures and explicit feedback.

Cicerone et al. (2000) searched Medline through 1998 and found 171 intervention studies for deficits in cognition, language, and visual perception for adults post-stroke or post-TBI. Fourteen studies with goals of improving executive functions (including problem solving) were identified: one randomised control trial (RCT); two group studies; and 11 case reports or single-subject design studies. In 2005, Cicerone et al. reporting nine additional studies published between 1998 and 2002 that were aimed at improving executive functions, awareness or self-monitoring. In both reviews, studies with children, studies without data or studies published only in book chapters were excluded. Tables of evidence were not provided although the authors made clinical recommendations. These authors concluded that there was sufficient research evidence to make intervention for problem solving a practice guideline when intervention used functional activities and everyday situations (Cicerone et al., 2000; 2005). Thus, these prior reviews summarised the intervention research using a qualitative approach and made general and, for some kinds of disability, specific recommendations (Kennedy, 2007).

In the current paper, we used qualitative and quantitative approaches to evaluating the evidence for intervention for problem solving, planning, organisation and multitasking. Quantitatively, effect sizes were estimated and a meta-analysis was conducted on the treatment effects of a subset of group intervention studies, whose intervention techniques included step-by-step, metacognitive strategy instruction (MSI). We conclude with a discussion of the methodological issues, followed by recommendations that are reflective of three fundamental clinical questions: (1) What should intervention look like to be efficacious or effective? (2) Who is the best candidate for this intervention, as described by the research evidence? (3) What outcomes should be expected from this intervention, are they maintained over time and generalised to untrained activities or other contexts?

METHODS

Methodological transparency is as critical to the integrity of systematic reviews as it is to primary intervention studies. Thus, initial methodological and inclusion/exclusion decisions were made a priori and are identified here.[1] First, we agreed that no particular cognitive rehabilitation approach would be excluded from this systematic review, although it was agreed that a modular approach best reflected the current state of research. Thus, separate systematic reviews addressing attention training, memory therapy, and intervention for behavioural problems would be generated (Kennedy et al., 2002). Studies in which participants were children or adolescents would be included although evaluated separately from studies with only adults. Additionally, "Tables of evidence" that typically accompany technical reports would be accessible to readers or be published with the summary and critique of evidence. Finally, the treatment outcomes would be classified using the International Classification Framework for Enablement (ICF) from the World Health Organization (2001) at the impairment level (e.g., most standardised tests) and at the activity/participation level (Bilbao et al., 2003). Outcomes would be classified using this framework because of the lack of research evidence that performance on impairment-level tasks generalise or transfer to functional, everyday activities (e.g., Kennedy, 2004), and because of the clinical need to identify functional goals rather than to simply document impairment (e.g., Wilson, 2003). Studies that included individuals with diagnoses other than TBI could be included in the review, but only if individuals with TBI had participated as well. Descriptive studies, such as those with no quantifiable outcomes, and studies published solely in chapters or books would be excluded.

Identifying, gathering and extracting intervention studies

Searches of available databases were completed in 2005 of studies through 2004. MEDLINE, PsychInfo, the Cumulative Index to Nursing and Allied

[1]This work is from the Writing Subcommittee on Evidence-based Practice for Cognitive-Communication Disorders after TBI, established by the Academy of Neurologic Communication Disorders and Sciences (ANCDS). See www.ancds.org/practice.shtml for other publications from this and other subcommittees.

Health Literature (CINAHL), and ERIC were searched as far back as possible, for intervention studies published in English. Searches were performed using the following keywords: *traumatic brain injury, brain injury, closed head injury*, and *head trauma* for the population; *executive functions, metacognition, awareness, self-awareness, planning, problem solving, self-monitoring, self-control, strategies, self-instruction, self-regulation, metamemory, goals*, and *reasoning* for the disability of interest; and *intervention, treatment, compensation, therapy, training, remediation, rehabilitation* for therapy. In addition, reference lists from published reviews, books, and chapters were checked to identify intervention studies that may not have been found when searching databases. These search methods resulted in a combined total of 2509 published articles.

The first author and graduate students reviewed and excluded the majority of articles because they were review articles, theoretical articles, studies identifying types of executive functions but not intervention studies, descriptive intervention studies with no objective outcomes, or reports of pharmacological intervention. Single case reports and single-subject design studies were included. From this, 35 quantitative intervention studies were identified. Twenty studies focused on general self-awareness or self-regulated attention, behaviour, or memory and learning. Reviews of intervention studies on these parts of executive functions can be found elsewhere (Fleming & Ownsworth, 2006; Kennedy & Coelho, 2005; Ylvisaker et al., 2007). The remaining 15 studies focused on intervention for improving executive functions that included aspects of problem solving, planning, organisation and multi-tasking. Because executive functions are a collection of processes and skill sets we did not impose a priori definitions of executive functions and include or exclude studies accordingly.

This document was reviewed externally prior to its submission for publication to determine if: (1) any studies had been missed; (2) the process was thorough and transparent to readers; and (3) studies were adequately and accurately described. Research and clinical experts in cognitive rehabilitation reviewed the document. Fifteen reviewers were ANCDS members and five were authors of studies cited in the review. From this process, one study was added and one study was deleted from the review. A study by Delazer, Bodner, and Benke (1998) met the inclusion criteria and it was integrated into this review, whereas two reviewers commented that one study in the review did not clearly meet the inclusion criteria (Hux, Reid, & Lugert, 1994); the child had had a TBI as the result of brain surgery for chronic epilepsy. We agreed and removed it from the review. Thus, there remained 15 studies in the review.

Classifying studies and creating clinical recommendations

Clinical recommendations are in part created by first determining the strength of the research evidence. Therefore, each study was rated according to the initial classification system used by the Quality Standards Subcommittee of the American Academy of Neurology (AAN) (Miller et al., 1999). The AAN revised this classification system by expanding its three levels (I, II, and III) into four (I, II, III, and IV) (www.aan.com). In 1999, *practice standards*, *guidelines*, and *options* were used to describe clinical recommendations (Miller et al.) whereas in 2004 the AAN began using more descriptive language in its clinical recommendations (e.g., should be done, should be considered, may be considered, data are insufficient). Because this review was started using the former classification system, it is the one used here, although both types of language have been included to make the clinical recommendations clearer. The Appendix provides definitions for each class, with criteria for creating clinical recommendations.

Reviewing and coding studies

Creating a table of evidence

Important features of studies were identified a priori: 26 demographic characteristics; 13 variables that described studies' design and intervention; and four variables that described outcomes. Each study was read and codes were assigned to each variable reported, creating a Table of Evidence available at www.ancds.org/practice.shtml#TBI. A "1" was entered if that information was provided, although for many characteristics, it was more informative to provide the actual information, such as participants' ages. Cells remained empty if the information was not provided. Readers are encouraged to use the Table of Evidence as a detailed supplement to this review.

The first author reviewed and coded all 15 intervention studies. Consensus was reached by having the second author independently review and code eight studies, or 53%. Of these, there were four points of disagreement, which were related to the amount of detail in the description of a variable. These were resolved after discussion.

Estimating effect sizes and preparing data for meta-analysis

Reporting the size of a treatment effect, or effect size (ES), improves the strength of studies and helps researchers and clinicians determine whether or not the "significant difference" is small, medium, or large (small = .20, medium = .50, large = .80, Cohen, 1988). As it is now best practice to report ESs along with tests of statistical significance, we estimated ES using Cohen's d (Cohen, 1988) and Hedges' g (Rosenthal, 1994) for the eight group studies. Most readers are familiar with Cohen's d, although Hedges' g is recommended when the ESs from within and between-subject comparisons across studies are going to be combined in a meta-analysis because studies can be weighted based on their methodological rigor (Rosenthal, 1994). Hedges' g is the difference between population means divided by average population standard deviation:

$$\text{Hedges's } g = \frac{M_1 - M_2}{S_{pooled}}$$

ESs were calculated when sufficient raw data were available; when raw data were not available, ESs were estimated from t-tests or other statistics that provided the number of participants, *df*, the value reached, and the p-value using equations provided by Rosenthal (1994). Hedges' g effect sizes were further converted into Hedges' unbiased estimator g^U: $g^U = c(m)g$. For a subset of the 15 studies (5 group studies) that used step-by-step metacognitive strategy instruction (MSI), a fixed effects model was used to answer specific questions about its treatment effects.

RESULTS

Fifteen studies met the established criteria that focused on the executive functions of problem solving, planning, organisation, and multi-tasking. Two documents display the results of analysing and coding these studies. The Table of Evidence contains detailed population sample demographics, study design and intervention, and treatment outcomes of each study and is available at www.ancds.org/practice.shtml#TBI. The second document summarises the number and percentage of studies that reported these characteristics and are found in Table 1.

Classification of studies

The strength of the evidence is typically determined by the number and quality of intervention studies. Of the 15 studies in this review, all were prospective studies that were published from 1987 to 2004 and involved persons with TBI. The goals of all 15 studies were to improve some aspect of problem solving, planning, organisation, or multi-tasking. The studies were classified as follows in chronological order:

- Class I: von Cramon, Matthes-von Cramon, and Mai (1991); Webb and Gluecauf (1994); Fasotti, Kovacs, Eling, and Brouwer (2000); Levine et al. (2000); Rath, Simon, Langenbahn, Sherr, and Diller (2003).
- Class II: Fox, Martella, and Marchand-Martella (1989); Stablum, Umiltà, Mogentale, Carian, and Guerrini (2000); Manly, Hawkins, Evans, Woldt, and Robertson (2001).

TABLE 1

Summary table of evidence for intervention studies to improve problem solving, planning, organising and multitasking: The number and percentage of studies that reported demographic variables, study design, intervention characteristics and data analysis and types of outcomes by order of occurance ($N = 15$). The more detailed Table of Evidence that accompanies this document is accessible at www.ancds.org/practice.shtml#TBI

Type of evidence	*Number (%) of studies reported*
Class I	5 (33.33)
Class II	3 (20.00)
Class III	7 (46.67)
Demographic variable	
Number of participants	15 (100)
Gender	15 (100)
Time post-injury	15 (100)
Age in years	15 (100)
Neuropsychological tests	14 (93.33)
Subject pool	14 (93.33)
Aetiology	13 (86.67)
Evidence of severity (GCS, Glasgow Outcome Score, LOC, PTA, imaging)	12 (80.00)
Severity at study	10 (66.67)
Education in years	9 (60.00)
Exclusion criteria	8 (53.33)
Initial severity	6 (40.00)
Treatment history	6 (40.00)
Post-injury living situation	4 (26.67)
Motor function	3 (20.00)
Language spoken	3 (20.00)
Pre-morbid occupations, pre-injury IQ, pre-injury living situation, family status, socioeconomic status, race, vision, hearing status, medications, control occupations	2 or < reported
Study design, intervention characteristics and data analysis	
Rationale	15 (100)
Evidence of experimental control	15 (100)
Statistics - p values	9 of 10 (90.00)
Tx type - individual	13 (86.67)
Duration	13 (86.67)
Frequency	11 (73.33)
Replicability: manual or reference	11 (73.33)
Tx setting	8 (53.33)
Who delivered tx	4 (26.67)
Tx type - group	3 (20.00)

(*Table continued*)

TABLE 1 Continued

Type of evidence	*Number (%) of studies reported*
Generalisation tx	2 (13.33)
Maintenance tx	2 (13.33)
Statistics - effect size	1 of 10 (10.00)
Outcomes	
Activity and/or participation	12 (80.00)
Impairment	9 (60.00)
Maintenance	9 (60.00)
Generalisation	9 (60.00)

Some variables were not applicable for all types of studies. In these cases, the number reported was divided by the number of studies for which the variable was appropriate.

- Class III: Cicerone and Wood (1987); Burke, Zencius, Wesolowski, and Doubleday (1991); Cicerone and Giacino (1992); Suzman, Morris, Morris, and Milan (1997); Delazer, Bodner, and Benke (1998); Turkstra and Flora (2002); Marshall et al. (2004).

Of particular importance are the five studies that randomised participants across conditions. von Cramon et al. (1991) randomly assigned participants with TBI to treatment conditions in which one group received problem-solving therapy and the other group received memory skills training. Webb and Gluecauf (1994) randomly assigned participants to one of two treatment conditions: high involvement in setting goals or low involvement in setting goals. Fasotti et al. (2000) randomly assigned participants with TBI to receive time pressure management training or concentration training, whereas Levine et al. (2000) assigned participants to goal management training or motor skills training. In an RCT by Rath et al. (2003), participants received either therapy organised in two modules (problem orientation and problem solving) or conventional cognitive rehabilitation.

Of the Class II studies, Fox et al. (1989) compared the performance of those who received problem-solving intervention in multiple steps to those who received no intervention. Manly et al. (2001) compared performance of those with brain injury to those without brain injury, when trained with auditory tones to prompt behaviour in a complex task. Stablum et al. (2000) compared the speed of response of those with acquired brain injury (including TBI) to healthy controls when trained to respond to a computerised dual task.

Of the Class III studies, Suzman et al. (1997), Burke et al. (1991) and Cicerone and Giacino (1992) used single-subject designs with multiple baselines across participants. Turkstra and Flora (2002) and Cicerone and Wood

(1987) used case examples to demonstrate the effectiveness of intervention for planning, problem solving and organisation. Delazar et al. (1998) provided cues to assist three adults with TBI in figuring out mathematical word problems. Marshall et al. (2004) determined the effects of a brief period of an interactive strategy-modelling training (ISMT) procedure on solving of Twenty Question problems in a group of chronic TBI participants. No control group was included, yielding this as Class III evidence.

Population sample characteristics

Number of participants, age and gender

Because of the varied types of designs, the number of participants varied widely across studies, ranging from 1 to 60. There was a total of 268 participants across studies, averaging 17.9 per study ($SD = 16.77$). When the number of participants was calculated for group studies only ($N = 9$), the average increased to 21.92 ($SD = 16.38$).

All but one study (Webb & Gluecauf, 1994) reported the ages of participants. Of these, 13 (93%) included participants who ranged in age from young to middle-aged adults. Suzman and colleagues (1997) investigated the effects of cognitive-behavioural therapy on the problem-solving abilities of five children ranging in ages 6 to 11 years. Older adults did not participate in any studies.

All 15 studies reported the gender of participants: 169 males and 99 females participated; a ratio of 1.7 to 1.

Education

Nine studies (60%) reported the participants' level of education. Across studies the range was wide. Some individuals had as little as 9 years of formal education whereas others had completed college. The average years of education reported was between 12 and 13 years.

Time post-onset (TPO) and aetiology

All authors reported the amount of time between the injury and the study (100%). The average number of years or months reported indicated that in general, participants were long past an acute stage of recovery, i.e., they had chronic disabilities. Three studies included individuals who could be considered in an acute recovery stage: von Cramon et al. (1991) included a participant who was 2 months post-injury, and Suzman et al. (1997) and Fasotti et al. (2000) included six participants who were at a subacute recovery phase, i.e., 3–6 months post-injury.

All 15 studies reported the aetiology of the participants which included individuals with brain injury, such as closed head injury (CHI) or TBI.

Exclusion criteria

Eight of the 15 studies included explicit descriptions or lists of exclusion criteria (53.3%). It could be argued that exclusion criteria are not necessary in single case studies and indeed, none of the case studies included them. Of the 13 studies that included multiple participants, eight reported exclusion criteria (61.5%). All Class I and II studies published since 2000 included exclusion criteria. Examples of exclusion criteria were as follows: presence of aphasia, amnesia or chemical dependency (Fasotti et al., 2000; Levine et al., 2000; Marshall et al., 2004); unawareness of deficits (Fasotti et al., 2000; Webb and Gluecauf, 1994); motor impairment (Stablum et al., 2000); severe intellectual impairment (Fasotti et al., 2000); and co-morbid behavioural problems (Levine et al., 2000; Rath et al., 2003; Stablum et al., 2000).

Severity of injury, severity of impairment at the time of the study, and evidence of severity

The initial severity of injury was explicitly reported in six of the 15 studies (40%) (Delazer et al., 1998; Fasotti et al., 2000; Manly et al., 2001; Rath et al., 2003; Stablum et al., 2000; Suzman et al., 1997), whereas Cicerone and Wood (1987), Burke et al. (1991), and Marshall et al. (2004) implied severity by reporting Glasgow Coma Scale (GCS) scores, and summarised neuroimaging results for their chronic sample but did not report initial severity explicitly. Of the six studies that reported severity of injury, participants ranged from mild to severe and very severe. Some studies included participants with mild, moderate, or severe injuries (Manly et al., 2001; Rath et al., 2003; Stablum et al., 2000), whereas others narrowed the sample to those with injuries that were moderate to severe (Suzman et al., 1997) or severe to very severe (Fasotti et al., 2000). Importantly, 12 studies (80%) included some type of evidence of injury severity (e.g., loss of consciousness, GCS scores).

Severity of impairment or disability at the time of the study was reported in 10 studies (66.7%). Most of these used test results to indicate severity (e.g., Delazer et al., 1998), although some included reports from family or clinicians (e.g., Cicerone & Giacino, 1992). Importantly, participants were described as having poor problem-solving or planning skills, identified through a combination of test results and reports from reliable persons, but with generally "good recovery" (e.g., Levine et al., 2000) or "high-level skills" (e.g., Rath et al., 2003).

Treatment history

Six of the 15 studies (40%) reported participants' treatment history (Burke et al., 1991; Cicerone & Wood, 1987; Delazer et al., 1998; Fox et al., 1989; von Cramon et al., 1991; Webb & Gluecauf, 1994), and five studies provided sufficient information about the participant pool that the treatment history could be inferred (Cicerone & Giacino, 1992; Delazer et al., 1998; Fasotti et al., 2000; Turkstra & Flora, 2002). For example, Marshall et al. (2004) reported that subjects were participating in a support group and not receiving rehabilitation services at the time of the study. Therefore, 73.3% of the studies included sufficient description of the type of treatment participants had received prior to the study or during the study.

Living situation

Four studies reported on participants' post-injury living situations (26.7%) (Delazer et al., 1998; Fox et al., 1989; Levine et al., 2000; Marshall et al., 2004).

Neuropsychological test results

With the exception of the study by Webb and Gluecauf (1994), standard neuropsychological tests were reported although the number and type of tests varied across studies (14 or 93.3%).

Motor function and language spoken

Three studies (20%) reported on the motor function of participants (Cicerone & Wood, 1987; Fox et al., 1989; Stablum et al., 2000). Three studies (20%) reported on the language participants spoke (Delazer et al., 1998; Manly et al., 2001; Rath et al., 2003).

Summary of population sample characteristics

The average number of characteristics used to describe participants across studies was 11.8 ($SD = 2.18$, range $= 7-15$). Characteristics that were initially coded but documented by two or fewer studies (and therefore not on the Table of Evidence) included: premorbid occupations, IQ, and living situation; family status; socioeconomic status; race; vision; hearing status; medications; and occupations of control participants.

Study design and intervention

All 15 studies provided a rationale for employing the intervention. However, studies varied in the precise aspect of executive function that was targeted; some targeted making realistic predictions or self-monitoring of performance in problem-solving tasks (e.g., Cicerone & Giacino, 1992), whereas others emphasised setting and managing goals (e.g., Levine et al., 2000), managing time (Fasotti et al., 2000), or initiating and sustaining steps in an organised sequence to carry out a functionally complex activity (e.g., Manly et al., 2001, Turkstra & Flora, 2002). In an RCT, Rath et al. (2003) sought to improve individuals' ability to self-regulate their emotions during problem-based activities that also required strategic thinking. Still others trained strategic problem solving through verbal reasoning activities (e.g., Marshall et al., 2004).

Individual or group treatment

In the majority of studies treatment was provided individually (86.67%). Two studies provided group treatment only (Fox et al., 1989; von Cramon et al., 1991), whereas Rath et al. (2003) provided a combination of group and individual treatment.

Treatment dosage

Duration of treatment refers to the length of time within treatment sessions and the total amount of time participants' received treatment. Frequency of treatment refers to how often participants received treatment. With the exception of Fox et al. (1989) and Marshall et al. (2004), all studies documented duration and/or frequency of treatment (86.6%). The average amount of time spent in treatment was approximately 12 hours. However the range was large; from two 15-minute sessions in the Manly et al. (2001) study to 48 hours of group or group and individual treatment in the Rath et al. (2003) study. Six of the 11 studies (54.5%) that reported frequency of treatment provided 1–3 sessions weekly.

Treatment delivery and setting

Four of the 15 studies (26.6%) explicitly described the relationship that the person who delivered the treatment had with the study. von Cramon et al. (1991) and Webb and Gluecauf (1994) indicated that these individuals did not know the intent or goals of the study, whereas experienced clinicians delivered the treatment in the Rath et al. (2003) study, and the second author – a student clinician – delivered the treatment in the Turkstra and Flora (2002) study.

The setting or environment where treatment was delivered was reported in eight of the 15 studies (46.6%). The setting varied from universities, to outpatient clinics (e.g., Cicerone & Wood, 1987; Rath et al., 2003; Turkstra and Flora, 2002) and schools (e.g., Suzman et al., 1997).

Study design and intervention

Eleven of the 15 studies (73.33%) either provided references for readers interested in replicating the treatment techniques, or provided such explicit and detailed descriptions of the treatment, that the first and second authors of this report determined that the treatment could be replicated.

Different aspects of problem solving, planning, organisation and multitasking were emphasised across studies although there was much less variability in the type of intervention. Three kinds of intervention emerged: training multiple steps, which included metacognitive strategy instruction (MSI); training strategic thinking; and training multitasking. Some studies used a combination of the former two kinds of intervention.

Metacognitive strategy instruction (MSI) approaches were used in 10 studies. Participants were trained to solve problems, to plan or to be better organised by training step-by-step procedures that included MSI (Burke et al., 1991; Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Fasotti et al., 2000; Levine et al., 2000; Rath et al., 2003; Turkstra & Flora, 2002; Suzman et al., 1997; von Cramon et al., 1991; Webb & Gluecauf, 1994). This approach uses direct instruction to teach individuals to regulate their own behaviour by breaking complex tasks into steps while thinking strategically (Sohlberg, Ehlardt, & Kennedy, 2005). To self-regulate, individuals need to identify an appropriate goal and predict their performance in advance of the activity, identify possible solutions based on their general predictions (one of which will work based on past experience), self-monitor or assess their performance during an activity, and change behaviour by choosing a strategy (i.e., use self-control) if, through self-assessment, the goal has not been met.

All five RCT studies used an MSI approach. In an early study, von Cramon et al. (1991) compared the effects of teaching internal memory strategies to problem-solving therapy (PST). In PST, participants identified problems and solutions, weighed the pros and cons of solutions, and monitored their performance after solutions were implemented. Those who received PST improved on a planning task and on standardised tests more than those who received memory strategy therapy (whose recall improved).

Webb and Gluecauf (1994) randomly assigned adults with brain injury to receive intervention in which their involvement in goal setting was "high" or "low". Individuals in the "high" involvement condition described the importance of setting goals, learned the goal attainment scaling (GAS) technique that involved several steps using worksheets, and were taught to monitor their progress towards goals and adjust goals accordingly. By contrast, individuals in the "low" involvement condition only monitored their progress towards goals. Both groups demonstrated improvements in setting goals after intervention, whereas at a 2-month follow-up, those from the "high" involvement condition were better at setting goals than those from the "low" involvement condition. The authors proposed that the active self-monitoring and self-control aspect of GAS promoted maintenance.

In a third RCT, Fasotti and colleagues (2000) randomly assigned adults with chronic impairment from TBI to receive time pressure management training (TPM) or concentration therapy (CT). The goal of the study was to determine TPM's effectiveness. In TPM, participants' awareness and acceptance of their disability was addressed first. They were then taught a step-by-step approach to use in problem situations that was rehearsed with increasing distractions. In CT, participants were taught to stay focused and avoid distracting thoughts. After therapy, participants watched videos that increased in abstraction. Both groups were more accurate in identifying solutions, although those who had received TPM used more steps to identify solutions and improved more on standard tests of attention and memory; this was maintained after 6 months with no treatment.

Levine et al. (2000) investigated the effects of goal management training (GMT) on disorganised approaches to novel paper and pencil tasks. Adults with brain injury were identified as having "strategy application disorder" and randomly assigned to receive GMT or motor skills training (MST), although those assigned to GMT were slower than those assigned to MST. GMT consisted of five steps that included making predictions, self-monitoring performance during activities, evaluating the usefulness of solutions and strategies, and generating alternative solutions. MST consisted of reading and tracing mirror-reversed text and designs. On the proofreading task, participants who received GMT were more accurate but slower than those who received MST.

Rath et al. (2003) investigated the effects of group therapy aimed at improving emotional self-regulation and reasoning in everyday problem situations. In this group therapy, participants completed two modules. During "problem-orientation", the emphasis was on having participants identify problem situations, document their impulsive over-reactions using worksheets, and reframe the situation to identify how strategies could be used so as to avoid reactions. During "problem solving", participants role-played the use of personal strategies that had been identified during problem orientation and received feedback from group members; this allowed them to get practice accepting feedback as well. When compared to TBI participants who had received "conventional cognitive rehabilitation", individuals who received problem modules demonstrated greater gains on several standardised measures of problem-solving, in everyday problem situations, and in their self-assessment of their problem-solving skills.

Three Class III studies used MSI to address aspects of poor problem solving (Burke et al., 1991; Cicerone & Giacino, 1992; Suzman et al., 1997). Burke et al. (1991) investigated the effects of multi-step intervention that targeted the specific executive function impairments individual participants experienced. Using single-subject designs, six individuals with brain injury received individualised treatment using shaping and fading of individualised cues as well as instruction to inhibit and self-monitor unwanted behaviour. All behaviours improved during therapy and were maintained when therapy was withdrawn. Cicerone and Giacino (1992) demonstrated the effects of making predictions and getting feedback, the effects of self-instruction with feedback (talk aloud during moves, whisper, and talk to self), and the effects of self-monitoring therapy for those who did not improve during self-instruction. With self-monitoring therapy, five of six participants had fewer errors and less off-task behaviour after therapy. During self-monitoring therapy, performance improved with feedback, but decreased again when feedback was withdrawn. Suzman et al. (1997) used several components in cognitive-behavioural therapy to improve problem-solving skills in children with TBI: self-instruction and regulation; metacognitive strategies; attribution training; and feedback as reinforcement. Children produced fewer errors while solving problems during a computerised game, although the researchers did not distinguish between therapy components or phases.

Two Class III studies employed MSI to improve problem solving, planning or organisation in single case examples (Cicerone & Wood, 1987; Turkstra & Flora (2002). Cicerone and Wood (1987) examined the effects of verbal self-instruction on planning and off-task behaviour during completion of the Tower of London task. Turkstra and Flora (2002) examined the use of step-by-step organisational strategies and role playing with an adult who had sustained multiple TBIs and was attempting to return to work. Outcomes in each of these studies were positive and changes were maintained several months after therapy.

Three studies taught strategic thinking through *explicit verbal reasoning*. Fox et al. (1989) (Class II), Delazer et al. (1998) (Class III), and Marshall et al. (2004) (Class III) trained adults with brain injury to strategise when solving problems that involved verbal reasoning. Fox et al. compared problem-solving therapy to no therapy. Group problem-solving therapy (PST) consisted of problem situations that were presented in turns, with "wh" questions provided as cues for solutions. Participants provided solutions and the group provided feedback and alternative solutions, followed by therapist feedback. After the criterion was met, "wh" cues to solutions were withdrawn. Those who received PST generated more accurate solutions that were maintained after the withdrawal of "wh" cues for up to 6 months after therapy, than those who did not receive therapy. Delazer et al. used explicit cues to facilitate verbal reasoning where figuring the steps to solving mathematical word problems, finding that correct operational steps were present after training, although the number of solutions did not improve. Marshall et al. assessed problem solving of their chronic TBI participants before, immediately after, and one-month after training. During training, the examiner alternated roles of problem solver and examiner, modelled exemplary strategies, explained reasons for using certain strategies, and asked the participant to explain reasons for use of particular strategies. After training, participants asked fewer, more constrained, and more efficient questions on the RAPS and these findings were maintained one month after training.

Two Class II studies focused on *multitasking* (Manly et al., 2001) or doing two things at once (Stablum et al., 2000). Manly et al. (2001) presented some participants with brain injury with audible tones to cue them to do the next task in a series of six "hotel" tasks that were multifaceted and complex. The auditory tone condition was compared to a condition without tones. Without tones, participants were slower, attempted fewer activities, were less accurate and did not distribute time across tasks efficiently when compared to healthy controls and when compared to the condition with audible tones. Stablum et al. (2000) trained adults with TBI, adults with anterior communicating artery stroke, and neurologically normal adults to respond quickly and accurately in computer tasks that were "single", i.e., responding to letters presented in the right or left field, and "dual", i.e., responding to letters presented in the right or left field *and* stating whether letters were the same or different.

Treatment aimed at generalisation or maintenance

Two of the 15 studies (13.3%) provided treatment with the specific intent of generalising techniques or strategies to untrained situations or problems. Cicerone and Wood (1987) included the application of verbal self-instruction to everyday activities, whereas the note-taking format used by Turkstra and Flora (2002) mimicked what the participant would use at work.

It could be argued that the intent of any treatment that includes shaping and fading of cues in various conditions is to promote generalisation and maintenance of skills. Eight of 15 studies (53.3%) shaped behaviour and/or faded cues (Burke et al., 1991; Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Delazer et al., 1998; Fox et al., 1989; Fasotti et al., 2000; Turkstra & Flora, 2002; Rath et al., 2003). Of these studies, all reported at least partial maintenance and/or generalisation of treatment effects.

Experimental control and use of statistics

All 15 studies demonstrated some evidence of experimental control in a variety of ways: chronicity of disability (e.g., Cicerone & Wood, 1987; Manly et al., 2001; Marshall et al., 2004; Rath et al., 2003; Stablum et al., 2000; Turkstra & Flora, 2002); the use of naïve trainers (e.g., Cicerone & Wood, 1987; Fox et al., 1989); stability of baselines and/or rate of change during intervention in single-subject designs (Cicerone & Giacino, 1992; Delazer et al., 1998); and the use of a "control" intervention or group (e.g., Levine et al., 2000; Rath et al., 2003; von Cramon et al., 1991). Unfortunately there are also examples of reduced experimental control: the raters in the Suzman et al. (1997) study were not naïve, no control participants or control intervention was provided by Delazer et al. (1998), and a few participants in the acute phase of recovery were included in three studies (Fasotti et al., 2000; Suzman et al., 1997; von Cramon et al., 1991).

Parametric statistics were not appropriate in all studies, in part because of the studies' design; that is, single-subject design studies may have used a visual display of the data to determine the effects of an intervention. Eight of the nine studies in which direct quantitative comparisons (88.8%) could be made reported the level of statistical significance. Finally, given the recent trend in the research literature to report effect sizes, it is not surprising that only one study reported effect sizes (Rath et al., 2003).

Treatment outcomes

Treatment outcomes were identified as impairments or activities and participation in accordance with the ICF classification (World Health Organization, 2001), and maintenance and generalisation treatment effects were documented when they were provided (see Table of Evidence for details). In this section we first describe the immediate treatment outcomes of all studies, i.e., estimated ESs of impairment and activities/participation outcomes (and other comparisons when ESs could not be estimated) for randomised and non-randomised group studies, single-subject multiple-baseline designs and single case studies. This is followed by the results of a meta-analysis of treatment effects from a subgroup of studies. Lastly, we describe maintained and generalised treatment outcomes from studies that included them.

Immediate treatment outcomes

All nine studies that involved groups of participants and most of the single-subject design and single case studies, reported positive outcomes immediately following the experimental intervention, when compared to a control intervention or a control group. Nine of the 15 (60%) studies used impairment-level outcomes to document change (Table 1) (Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Delazer et al., 1998; Fasotti et al., 2000; Rath et al., 2003; Stablum et al., 2000; Suzman et al., 1997; Turkstra & Flora, 2002; von Cramon et al., 1991). With the exception of three studies (Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Stablum et al., 2000), all others used activity or participation outcomes to document treatment effects (12 of 15, 80%). Notably, six studies (30%) reported both impairment *and* activity/participation outcomes (Delazer et al., 1998;

Fasotti et al., 2000; Rath et al., 2003; Suzman et al., 1997; Turkstra & Flora, 2002; von Cramon et al., 1991).

With the exception of the study by Rath et al. (2003) which provided ESs, Cohen's *d* and Hedge's *g* ES were estimated from means and standard deviations when available, or from the statistics for between or within group comparisons from seven other group studies (Fasotti et al., 2000; Levine et al., 2000; Manly et al., 2001; Marshall et al., 2004; Stablum et al., 2000; von Cramon et al., 1991; Webb & Gluecauf, 1994). Effect sizes could not be estimated from the Fox et al. (1989) study. In total, 66 immediate treatment ESs (Table 2), nine maintenance ESs (Table 3) and two generalisation ESs were documented. Studies varied in the types of comparisons they made (e.g., pre/post comparisons within groups, or between-group differences in the amount of change from pre- to post-treatment). They also varied in the type of data provided. For example, Rath et al. (2003) was the only study that provided ESs, but only for comparisons that were statistically significant; they did not report data from non-significant findings making it impossible to calculate ES for those comparisons.

Overall, the immediate ESs of all experimental treatments (MSI, alert-prompting systems, or strategic, verbal reasoning) across both types of outcomes were large but variable ($M\,d = 0.90$, $SD = 1.01$, range $= 0.04–4.47$; $Mg = 0.83$, $SD = 0.88$, range $= 0.04–4.47$) (Table 2). These ESs included within-group pre- and post-treatment comparisons or between-groups comparisons post-treatment, depending on the data available. Overall, immediate ESs of control treatment (e.g., motor treatment, memory therapy) across both types of outcomes were medium but variable ($Md = 0.58$, $SD = 0.70$, range $= 0.04–2.92$; $Mg = 0.46$, $SD = 0.40$, range $= 0.04–1.50$). Marshall et al. (2004) reported the largest ES; TBI participants were more efficient asking strategic questions following verbal, dynamic interaction therapy, although there was no control group or treatment condition in this Class III study. The smallest immediate treatment ES was reported by Levine et al. (2000) in a Class I study; TBI participants who received goal management training made small gains in proofreading accuracy after treatment, although other gains were made with large ESs in activity and participation outcomes.

Immediate impairment outcomes. With the exception of studies by Delazer et al. (1998) and Turkstra and Flora (2002), the other seven studies that used impairment outcomes documented positive improvement after therapy, although there was some inconsistency within a given study. For example, using a single-subject design Cicerone and Wood (1987) found that the number of incorrect moves on the Tower of London task diminished at the beginning of self-instruction therapy. Using a modified version of the same task, Cicerone and Giacino (1992) found that five of six participants became error-free during self-prediction and self-instruction therapy,

TABLE 2
Cohen's *d* and Hedges' *g* effect sizes (ESs) reported for immediate treatment for group intervention studies aimed at improving problem solving, planning and reasoning in chronological order

			Effect size			
			Impairment-level outcome		*Activity or Participation outcome*	
Study	*Task–outcome measure*	*Comparison*	*d*	*g*	*d*	*g*
von Cramon et al. (1991)*	Problem solving, planning	Pre-post			0.63	0.62
	Inductive reasoning subtest	Pre-post	0.46	0.46		
	Tower of Hanoi – Problem solving	Pre-post	0.47	0.47		
Webb & Gluecauf (1994)*	Goal attainment scaling score	High and low involvement Ss combined; pre-post			2.15	2.01
	Goal attainment scaling score	High involvement; pre-post			2.71	2.54
	Goal attainment scaling score	Low involvement; pre-post			1.61	1.50
Fasotti et al. (2000)*	Harvard Graphics task – Number of managing steps	Time pressure management group; pre-post			1.00	0.95
	Water bed task – Number of managing steps	Time pressure management group; pre-post			0.78	0.74
	Harvard Graphics task – Accuracy	Time pressure management group; pre-post			0.85	0.81
	Water bed task – Accuracy	Time pressure management group; pre-post			1.61	1.53
	Cognitive functioning and psychosocial well-being – Memory summary score	Time pressure management group; pre-post	1.40	1.40		
	Cognitive functioning and psychosocial well being – attention summary score	Time pressure management group; pre-post	0.94	0.94		

(*Table continued*)

TABLE 2 Continued

			Effect size			
			Impairment-level outcome		*Activity or Participation outcome*	
Study	*Task–outcome measure*	*Comparison*	*d*	*g*	*d*	*g*
	Dutch version of Rey's 15 words test – Acquisition score	Time pressure management group; pre-post	0.16	0.16		
	Dutch version of Rey's 15 words test – Relayed recall score	Time pressure management group; pre-post	0.22	0.22		
	Rivermead Behavioural Memory Test – Profile score	Time pressure management group; pre-post	0.08	0.08		
	Auditory Concentration Test – Detection score	Time pressure management group; pre-post	0.11	0.11		
	Auditory Concentration Test – Detection score in function of Rate of Presentation	Time pressure management group; pre-post	0.19	0.19		
	Paced Auditory Serial Addition Task – Total score	Time pressure management group; pre-post	0.25	0.25		
	Visual simple reaction time	Time pressure management group; pre-post	0.05	0.05		
	Visual choice reaction time	Time pressure management group; pre-post	0.12	0.12		
	Dutch version of Rey's 15 words test – Acquisition score	Concentration training group; pre-post	0.40	0.38		
	Dutch version of Rey's 15 words test – Relayed recall score	Concentration training group; pre-post	0.13	0.13		
	Rivermead Behavioural Memory Test – Profile score	Concentration training group; pre-post	0.06	0.06		

Fasotti et al. (2000)*	Auditory Concentration Test – Detection score	Concentration training group; pre-post	0.04	0.04		
	Auditory Concentration Test – Detection score in function of Rate of Presentation	Concentration training group; pre-post	0.04	0.04		
	Paced Auditory Serial Addition Task – Total score	Concentration training group; pre-post	0.23	0.22		
	Visual simple reaction time	Concentration training group; pre-post	0.21	0.20		
	Visual choice reaction time	Concentration training group; pre-post	0.22	0.20		
Levine et al. (2000)*	Proofreading – Accuracy	Goal management training group; pre-post			0.04	0.04
	Grouping	Goal management training group; pre-post			0.82	0.79
	Proofreading – Speed	Goal management training group; pre-post			1.00	0.97
	Room layout	Goal management training group; pre-post			0.25	0.25
	Proofreading – Accuracy	Motor skills training group; pre-post			1.03	1.00
	Grouping	Motor skills training group; pre-post			0.22	0.21
	Proofreading – Speed	Motor skills training group; pre-post			0.30	0.29
	Room layout	Motor skills training group; pre-post			0.56	0.54
Manly et al. (2001)	Alerting tones vs no tones; number of tasks started	Patient group; tones/no tones			0.55	0.74
	Total time that deviated from optimal time – Task components	Patient group; tones/no tones			0.92	1.23
	Total time in activity	Patient group; tones/no tones			0.17	0.23
	Number of responses corresponding with the nominated times	Patient group; tones/no tones			0.24	0.32
	Clock use – Number of times looking at clock	Patient group; tones/no tones			1.44	1.94
	Switching following a tone – Interval between tone and switch	Patient group; tones/no tones			0.16	0.22

(*Table continued*)

TABLE 2 Continued

Study	Task–outcome measure	Comparison	Effect size: Impairment-level outcome *d*	*g*	Activity or Participation outcome *d*	*g*
Stablum et al. (2000)	Dual task cost	CHI; pre-post	3.24	1.54		
	Dual task cost	Uninjured controls; pre-post test	2.92	1.38		
	Dual task condition – Reaction time	CHI; session1/session 5	3.17	1.50		
	Dual task condition – Reaction time	Uninjured controls; session 1/session 5	2.04	0.97		
Rath et al. (2003)*	Rosenberg Self-Esteem Scale	Innovative group; pre-post			0.22	0.22
	Problem-solving inventory – Self-appraised critical thinking	Innovative group; pre-post			0.69	0.68
	Problem-solving questionnaire – Clear thinking score	Innovative group; pre-post			0.58	0.58
Rath et al. (2003)*	Problem solving questionnaire – Self-regulation scale	Innovative group; pre-post			0.44	0.44
	Problem Solving Role Play Test – PSRPT score by other rater	Innovative group; pre-post			0.62	0.61
	Problem checklist (PCL) – Physical severity; self-rated	Conventional group; pre-post			0.34	0.34
	PCL – Cognitive severity; symptoms rated by significant other	Conventional group; pre-post			0.24	0.24
	PCL – Physical severity; symptoms rated by significant other	Conventional group; pre-post			0.52	0.52
	PSQ – Self-regulation; symptoms rated by significant other	Conventional group; pre-post			0.37	0.37

	Logical memory (WMS) – Immediate	Innovative group; pre-post	0.42	0.42		
	Logical memory (WMS) – Delayed	Innovative group; pre-post	0.39	0.39		
	Visual memory (WMS) – Immediate	Innovative group; pre-post	0.64	0.64		
	Visual memory (WMS) – Delayed	Innovative group; pre-post	0.45	0.45		
	Logical memory (WMS) – Immediate	Conventional group; pre-post	0.69	0.69		
	Logical memory (WMS) – Delayed	Conventional group; pre-post	0.41	0.41		
	Visual memory (WMS) – Delayed	Conventional group; pre-post	0.40	0.40		
	Watson-Glaser Critical Thinking – Academic logic score	Conventional group; pre-post	0.38	0.38		
Marshall et al. (2004)	Verbal reasoning; number of questions	TBI; pre-post			2.56	2.56
	Verbal reasoning; percent of constrained strategy questions	TBI; pre-post			2.56	2.56
	Verbal reasoning; question asking efficiency	TBI; pre-post			4.47	4.47

*Studies that used a metacognitive strategy instruction approach intervention. Effect size from these studies were used in the meta-analysis.
WMS = Wechsler Memory Scales.

whereas the participant who did not improve went on to receive self-monitoring therapy. Self-monitoring therapy was unsuccessful in eliminating errors when external feedback was removed for the participant who had not improved in the earlier phases of therapy.

From four group studies (Fasotti et al., 2000; Rath et al., 2003; Stablum et al., 2000; von Cramon et al., 1991), 32 immediate ESs from impairment outcomes were generated, averaging 0.65 (*M d, SD* $=$ 0.90) and 0.47 (*Mg, SD* $=$ 0.45), i.e., medium effects (Table 2). Variability across outcomes is exemplified in three group studies. In the Fasotti et al. (2000) study, the group that received time pressure management improved on two out of three of the standardised memory tests and all three attention measures (ESs, *M* $=$ 0.35, *SD* $=$ 0.45) with medium ES, as compared to the control group who received concentration training (ES, *M* $=$ 0.17, *SD* $=$ 0.12) with small ESs. Rath et al. (2003) found that participants who received the problem-orientation and problem-solving therapy (the "innovative" treatment condition) demonstrated less perseveration on the Wisconsin Card Sorting Test and improved visual memory on the Wechsler Memory Scales (WMS), whereas participants who received "conventional" treatment improved in visual memory and narrative memory on the WMS with medium ES. von Cramon et al. (1991) found that participants who received problem-solving therapy improved on three of five intelligence subtests and the Tower of Hanoi, whereas only one participant who received memory therapy improved on these tests after therapy. However, participants who received memory therapy improved in their memory for word pairs and names–faces, whereas those who received problem-solving therapy did not. The effects of these changes were medium. Thus, in these latter two studies, as well as in a case study by Turkstra and Flora (2002) and study by Delazer et al. (1998), impairment-level outcomes were also used to demonstrate experimental control.

Immediate activity and participation outcomes. A number of activity and participation outcome measures were used to document change after intervention, including the number of errors, on-task behaviour, accurate solutions to problems, and number of steps when managing complex tasks. From group studies, 34 immediate activities/participation ESs were generated, averaging 0.96 (*Md*, *SD* $=$ 0.96) and 0.97 (*M*g, *SD* $=$ 0.95), i.e., large effects (Table 2). Levine et al. (2000) found that those who had participated in goal management training (GMT) were more accurate at everyday paper-and-pencil tasks, proofreading and grouping when accuracy was stressed, than those who received motor skills training (MST), even though the GMT group was slower than the MST group. Fasotti et al. (2000) found that those who received time pressure management training used more steps to identify solutions to problems than those who received concentration training, although both groups became more accurate in identifying solutions. Rath et al. (2003) found that TBI participants in the innovative treatment condition, which focused on self-regulation and strategic thinking for individualised problem situations, demonstrated greater gains in problem solving than participants in the conventional treatment condition.

Positive activity/participation treatment effects were reported as well in studies for which ESs could not be generated. Burke et al. (1991) used faded cues (e.g., checklists, cue cards, notebooks, verbal feedback) to shape various problem-solving skills and specific self-regulation behaviours across participants, depending on the needs of the participant. Problem solving, self-initiation, continuation and self-regulation all improved during therapy and were maintained at various time increments across participants. Group treatment provided by Fox et al. (1989) involved four types of problem situations presented in turns with "wh" questions on cards as cues to solutions. Participants provided their solutions and others listened and gave alternative solutions, with trainer feedback if necessary. During the treatment phase, participants provided more correct solutions than at baseline, with continued gains when "wh" question cues were withdrawn. Post-treatment, the experimental group provided more correct solutions than controls who had not received treatment.

Turkstra and Flora (2002) targeted the organisational and planning skills of a TBI participant who had failed at obtaining and holding a job as a chemical dependency counsellor. They trained him to take notes in "subjective objective, assessment and plan" (SOAP) format while role-playing an interview with an individual with chemical dependency. After therapy, the number of accurate facts increased and the number of factual errors decreased, whereas spelling and cohesive discourse (not targeted in therapy) did not change. The participant reported less anxiety and stress when writing reports, and ultimately acquired and maintained a job as a chemical dependency counsellor, demonstrative of an outcome at the participation level.

Delazer et al. (1998) targeted solving mathematical word problems by three adults with chronic TBI. Training was aimed at the encoding stage of solving problems, in which participants were provided with cues about the operational steps. Participants identified correct operational steps more frequently after training. Training did not target the execution stage of word problems and indeed the number of correct solutions did not increase.

Meta-analysis of immediate MSI intervention. The effects of five of the group studies (Fasotti et al., 2000; Levine et al., 2000; Rath et al., 2003; Webb & Gluecauf, 1994; von Cramon et al., 1991) that had used step-by-step MSI were synthesised in a fixed effects model. Three group studies were not included in the meta-analysis because the intervention differed greatly from the step-by-step MSI used in the five studies and because their ESs did not meet the test of homogeneity (Manly et al., 2001; Marshall et al., 2004; Stablum et al., 2000).

Because the studies were unequal in methodological strength and rigor, each study was rated by the first investigator using criteria identified as pertinent to group studies by the AAN's 2004 classification system (see Appendix). A study could receive the highest score of 8 if it was an RCT and met all of the following criteria: outcomes were clearly defined and reliable; scorers were masked from knowing the condition in which participants were placed; inclusion and exclusion criteria were provided and representative of the population; and baseline measures were similar or adjustments were made in the statistical analysis to handle dissimilarity. For each missing criterion, 0.5 was subtracted from 8.

No study received the highest possible score of 8. Rath et al. (2003) and Fasotti et al. (2000) both received 7.5 because one criterion was missing from each. Levine et al. (2000) and von Cramon et al. (1991) received 7.0 because two criteria were missing. Webb and Gluecauf (1994) received 6.0 because four criteria were missing. These values were used as "research quality index" for the unbiased Hedges' g effect sizes ($T = g^U$):

$$\bar{T}_\bullet = \frac{\sum_{i=1}^{k} q_i w_i T_i}{\sum_{i=1}^{k} q_i w_i}$$

where q_i is the study's score on the index, and w_i is the reciprocal of the variance. This adjustment or weighting transformed the ESs from methodologically strong studies into relatively higher values and ESs from less rigorous studies into relatively lower values (Becker, 1994). These weighted ESs were used in the meta-analysis.

Based on the ESs available, we attempted to answer two questions related to immediate outcomes: (1) Is MSI efficacious for immediately improving impairments as well as activity and participation outcomes? and (2) Is MSI more efficacious than "control treatment" for improving immediate impairments as well as activities and participation outcomes?

When impairment-level outcomes were used as indicators of change, there was little difference between adjusted ESs from MSI ($M = 0.41$, $SE = 0.002$) and the control treatment ($M = 0.37$, $SE = 0.003$) (see Table 4). The between groups effect did not reach a significant level ($Q_{bet} = 0.16$) indicating the MSI and control treatment effects were not significantly different. Importantly, the ES within each treatment group met the assumption of homogeneity, i.e., 0.06 and 0.01 were below the critical value needed to reject the homogeneity hypothesis. However, each type of treatment resulted in immediate effects that were significantly different from chance ($p < .05$), indicated by $Z = 8.73$ for MSI and $Z = 6.43$ for control treatment, for which the critical value was 1.96.

When activities and participation outcomes were the indicators of change, the ES from MSI ($M = 0.57$; $SE = 0.002$) was significantly larger than the ES from the control treatment ($M = 0.38$; $SE = 0.004$), indicated by $Q_{bet} = 5.67$. Additionally, the ES within each treatment group met the assumption of homogeneity, i.e., 2.29 and 3.38 were below the critical value needed to reject the homogeneity hypothesis. Finally, each treatment resulted in effects that were significantly different from chance, indicated by $Z = 11.69$ for MSI and $Z = 6.42$ for control treatment, for which the critical value was 1.96.

Based on this meta-analysis of these ESs, both treatment conditions resulted in significant immediate improvement for both types of outcomes (compared to chance), although MSI was more efficacious than the control treatment when activity and participation outcomes served as the measures of change. When impairment-level outcomes were the measures of change, ESs from each treatment group did not differ from the other. When activity and participation outcomes were the measures of change, ESs from MSI were larger than ESs from control treatment.[2] However, these findings do not include studies for which ESs were not generated, such as single-subject designs across participants and single case reports.

The maintenance and generalisation of outcomes

Of particular clinical importance is whether or not treatment effects were maintained over time, and whether treatment effects or the strategies employed during treatment generalise to untrained tasks and contexts. Nine studies (60%) reported positive maintenance effects (Burke et al., 1991; Cicerone & Wood, 1987; Delazer et al., 1998; Fasotti et al., 2000; Fox et al., 1989; Marshall et al., 2004; Rath et al., 2003; Stablum et al., 2000; Webb & Gluecauf, 1994), nine studies reported generalisation effects (53.33%) (Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Delazer et al., 1998; Fasotti et al., 2000; Fox et al., 1989; Stablum et al., 2000; Suzman et al., 1997; Turkstra & Flora, 2002; von Cramon et al., 1991) and

[2]If there was bias in this meta-analysis, it was a conservative bias. Many studies did not provide raw data or the statistical information to be able to estimate ES when the comparison did not yield statistically significant results. If the control treatment did not result in significant pre- and post-treatment differences, ES could not be estimated because of missing data. For example, Rath et al. (2003) reported greater gains in problem solving by the innovative treatment group compared to the conventional group, whereas the conventional treatment group reported greater gains in memory and attention. We could not estimate these ESs from results that were not-significant, namely the effect of problem solving from participants in the conventional treatment condition. So, the between-group difference (in ES) would have been even larger, if studies had reported the data for all comparisons whether statistically significant or not.

five studies reported maintenance *and* generalisation effects (26.67%) (Cicerone & Wood, 1987; Delazer et al., 1998; Fasotti et al., 2000; Fox et al., 1989; Stablum et al., 2000). Three studies provided sufficient data to estimate nine maintenance ESs (Marshall et al., 2004; Fasotti et al., 2000; Stablum et al., 2000). All ESs were large, ranging from 0.82 (Fasotti et al., 2000) to 4.30 (Marshall et al., 2004) (Table 3).

Maintenance and generalisation of impairment outcomes. Of the nine studies that used impairment outcome measures, two (25%) reported positive maintenance of impairment-level changes. Cicerone and Wood (1987) found that the number of incorrect moves remained low during the Tower of Hanoi task and participants were slower as well, suggesting that they continued to use self-instruction techniques. Stablum et al. (2000) found that reaction times during dual tasks remained faster than prior to treatment, at 3 months after ending treatment for both TBI participants and healthy controls, with large ESs (Table 3).

Three studies reported that intervention generalised to impairment outcomes. Participants from the time-pressure management group improved on several cognitive and attention tests in the study by Fasotti et al. (2000). Stablum et al. (2000) who trained participants in computerised dual-tasks, found that following dual-task treatment, TBI participants got faster on the PASAT (Paced Auditory Serial Addition Task) (in addition to the computerised task), with large ESs ($d = 2.05$, $g = 0.97$). Healthy controls performed similarly. In the Class III study by Cicerone and Giacino (1992), generalisation depended on the treatment: those who were trained to self-monitor by identifying errors used this strategy in other tasks, whereas those who needed additional instruction to use overt-covert self-talk, did not generalise this skill to other problem tasks.

Maintenance and generalisation of activity or participation outcomes. More studies used activity or participation than impairment outcomes to measure the maintenance of treatment effects (Burke et al., 1991; Delazer et al., 1998; Fasotti et al., 2000; Fox et al., 1989; Marshall et al., 2004; Rath et al., 2003; Webb & Gluecauf, 1994). Although the length of time since treatment termination varied across studies (2 weeks to 6 months), all seven studies reported at least partial maintenance of the treated behaviour. For example, at 1, 3 and 6 months post-treatment, Fox et al. (1989) found that those who had received problem-solving treatment provided more correct solutions to problem situations than controls, who had not received treatment. For some, the maintenance effects were more impressive than the immediate treatment effects. Webb and Gluecauf (1994) found that those who had high involvement in goal attainment scaling (GAS) were more likely to accomplish goals at 2

TABLE 3

Cohen's *d* and Hedge's *g* effect sizes (ESs) reported for mainenance of treatment for group intervention studies in chronological order

			Effect size			
			Impairment-level outcome (standardised test or task)		*Activity or Participation outcome*	
Study	*Task – Outcome measure*	*Comparison*	*d*	*g*	*d*	*g*
Fasotti et al. (2000)*	Harvard Graphics task – Number of managing steps	Time pressure management group; pre-tx to follow-up			0.94	0.90
	Water bed task – Number of managing steps	Time pressure management group; pre-tx to follow-up			0.94	0.50
	Harvard Graphics task – Accuracy	Time pressure management group; pre-tx to follow-up			0.86	0.82
	Water bed task – Accuracy	Time pressure management group; pre-tx to follow-up			1.31	1.25
Stablum et al. (2000)	Dual task cost	CHI; pre-tx to follow-up	3.11	1.47		
	Dual task cost	Uninjured controls; pre-tx to follow-up	3.20	1.52		
Marshall et al. (2004)	Verbal reasoning; number of questions	TBI; pre-tx to follow-up			2.68	2.68
	Verbal reasoning; percent of constrained strategy questions	TBI; pre-tx to follow-up			3.10	3.10
	Verbal reasoning; question asking efficiency	TBI; pre-tx to follow-up			4.30	4.30

Tx: treatment.

months than were participants in the low-involvement GAS group, both treatment groups had improved in setting and reaching goals immediately after treatment with large ESs.

Fasotti et al. (2000) found that at 6 months post-treatment the group who had received time-pressure management instruction continued to use more steps to manage a computer task (learning Harvard Graphics) than the group who had received concentration therapy, but not to manage a second task; whereas both treatment groups maintained their gains in accuracy for both tasks. ESs were all large. Marshall et al. (2004) used dynamic interaction to teach TBI participants to ask strategic questions during a 20-questions game. They found that at 1 month after treatment, TBI participants maintained their improvement over pre-treatment by asking fewer questions that were more strategic, demonstrating maintenance in both quality and efficiency of asking questions with large ESs (Table 4).

Seven studies reported that activity or participation outcomes generalised to untrained tasks (Burke et al., 1991; Fasotti et al., 2000; Fox et al., 1989; Rath et al., 2003; Suzman et al., 1997; Turkstra & Flora, 2002; von Cramon et al., 1991). Fox et al. (1989) found that participants who had received problem-solving treatment provided correct solutions for new problems during interviews more often than participants who had not received treatment, even at follow-up. Naïve rehabilitation staff reported improved everyday problem-solving abilities from participants in the problem-solving treatment condition in the study by von Cramon et al. (1991). Suzman

TABLE 4
Meta-analysis of immediate treatment ESs by outcome type (impairment, activities and participation) for studies that used step-by-step metacognitive strategy instruction (MSI)

	Between groups effect (Q_{bet})	*N*	*Means weighted Hedges' g*	*Standard error*	*Z*	*95% Confidence Interval for g*		*Homogeneity within Each Treatment Group (Q_{wi})[a]*
						CI upper	*CI lower*	
Impairment outcomes	0.16							
Step-by-step MSI		18	0.41	0.002	8.73*	0.50	0.31	0.06
Control treatment		12	0.37	0.003	6.43*	0.49	0.26	0.10
Activity and participation outcomes	5.67*							
Step-by-step MSI		16	0.57	0.002	11.69*	0.67	0.48	2.29
Control treatment		9	0.38	0.004	6.42*	0.50	0.27	3.38

*statistically significant at $p < .05$.
[a]Significance indicates rejection for the hypothesis of homogeneity; none were significant.

et al. (1997) anecdotally reported that multi-component cognitive and behavioural intervention improved children's organisation skills when approaching new tasks.

DISCUSSION AND CLINICAL RECOMMENDATIONS

First, we summarise and discuss the methodology and outcomes reported in these studies. Second, we provide clinical recommendations for intervention aimed at improving problem solving, planning and multi-tasking, guided by instructions outlined by the American Academy of Neurology (2004). Finally, we conclude with a summary of areas in need of additional research.

Methodology across studies

One way of thinking about the strength of the evidence is by examining the methodology across studies, asking the question "Can these outcomes be attributed to the intervention, rather than other confounding factors?" This discussion is organised in the same way the results section was organised; by examining population sample characteristics and the design and intervention used.

Population sample characteristics

Compared to the descriptions of TBI participants from the systematic review of direct attention training (Sohlberg et al., 2003) and the use of external memory aids with TBI survivors (Sohlberg et al., 2007), the studies reviewed here provided more detailed descriptions of the participants. The majority of the participants were chronically disabled young to middle-aged adults, although a few participants were in the acute recovery phase (Fasotti et al., 2000; Suzman et al., 1997; von Cramon et al., 1991), and one study was aimed at children (Suzman et al., 1997). No studies included older adults. With the exception of von Cramon et al. (1991), the RCTs and group studies provided inclusion and exclusion information, whereas studies that employed single-subject, multiple baseline designs or single case reports provided even more details about the participants. Although the severity of the injury was not always made explicit, most studies included evidence of injury severity ranging from mild to very severe such as GCS scores. However, rather than rely on injury severity to describe the sample, we have argued that it is more important to document participants' type and severity of cognitive disability, particularly for the cognitive function being addressed by the intervention (Kennedy & Turkstra, 2006). In general, the studies reviewed here provided adequate information on the population sample characteristics to allow for replication. Still, some features were not reported consistently but should be. These included participants' level of education, prior treatment history, vision and hearing status, co-morbid diagnoses, and current medications.

Study designs and intervention

The strength of research evidence is in part based on the design of the studies and whether or not they "controlled" for outside factors that could explain the outcomes. Five of the 15 studies in this review were RCTs, Class I evidence (American Academy of Neurology, 1999). These varied in the extent to which they contained all characteristics necessary to be considered Class I RCTs "with masked outcome assessment in a representative population with qualifiers" when more recent classification systems are used (e.g., American Academy of Neurology, 2004). Applying the latter 2004 classification system, two studies met all the criteria for well-conducted RCTs (Fasotti et al., 2000; Rath et al., 2003). Neither provided evidence that those administering the intervention did not know the intent of the study, although this is not a requirement of an RCT. While it is a hallmark of other kinds of RCTs such as clinical drug trials, some have criticised behavioural studies for lacking this kind of control. Others have argued that this particular feature of RCTs is impractical in intervention studies where shaping of behaviour is the goal (Kennedy & Turkstra, 2006).

Rath et al. (2003) and Fasotti et al. (2000) provided detailed descriptions of the participants along with inclusion and exclusion selection criteria and fully randomised participants across groups. Groups were equivalent on critical features, such as impairment of social-vocational skills (Rath et al., 2003) or IQ and a sample of neuropsychological tests (Fasotti et al., 2000) and dropout rate was lower than the recommended 25% cutoff.[3] In both studies, there was no indication that those reporting or assessing outcomes were masked to the treatment condition as recommended at by the AAN (2004). However, this may also be impractical for studies that use activities or participation outcomes, which frequently require self-other reports from participants, employers, and family (Kennedy & Turkstra, 2006). The other three RCTs were partially degraded because they were missing other characteristic features of Class I RCTs beyond the failure to mask those who scored outcomes to the treatment condition.

Not surprisingly, the goals of intervention delivered in the reviewed studies varied depending on the aspect of executive functions targeted. Fifteen studies that met selection criteria focused on some aspect of problem solving, planning, organisation and multi-tasking, including: social

[3]The American Academy of Neurology (2004) degrades RCTs from Class I to Class II if the dropout rate is higher than 25%.

(Rath et al., 2003) or behavioural (Burke et al., 1991) problem solving; time management (Fasotti et al., 2000); goal management (Levine et al., 2000; Webb & Gluecauf, 1994); generating solutions and decision making (von Cramon et al., 1991); planning using self-regulation during complex problem activities (Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Suzman et al., 1997); verbal reasoning (Delazer et al., 1994; Fox et al., 1989; Marshall et al., 2004); continuing complex activities with cues (Manly et al., 2001); using organisation strategies during functional activities (Turkstra & Flora, 2002); and dual-task training (Stablum et al., 2000).

An unexpected finding was the similarity of intervention approaches across studies, despite variability in specific treatment targets. The intervention from 10 studies contained several features of metacognitive strategy instruction (MSI) (Burke et al., 1991; Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Fasotti et al., 2000; Levine et al., 2000; Rath et al., 2003; Suzman et al., 1997; Turkstra & Flora, 2002; von Cramon et al., 1991; Webb & Gluecauf, 1994). Although different aspects of problem solving, etc. were trained, these approaches were similar in their use of steps that included self-monitoring, self-recording of performance, making strategy decisions based on goals and adjusting or modifying the plan based on the self-assessment and/or external feedback.

Could clinicians or researchers replicate the intervention that was delivered? With the exception of four studies (Burke et al., 1991; Fox et al., 1989; Marshall et al., 2004; Rath et al., 2003) all others provided a reference or a therapy manual that could be referred to as a guide. With the exception of two studies (Fox et al., 1989; Marshall et al., 2004), all provided sufficient information to estimate the average amount of intervention – 12 hours of either individual, group, or combined therapy, although the amount of therapy varied considerably (from two 15-minute sessions to 48 hours total). Of the six studies that reported frequency of intervention, sessions of one to three times weekly were provided. So, although there remain unanswered questions about the specific dosage of intervention, there is sufficiently detailed information here to guide clinicians as they decide how to approach treating a TBI survivor with deficits that include the skill sets for problem solving, planning, and organisation.

Treatment outcomes

All studies reported positive immediate treatment outcomes based on our qualitative and quantitative analyses. Of the group studies for which ESs were estimated, both impairment outcomes and activities/participation outcomes were significantly different from chance. When both types of immediate outcomes were combined, ESs of outcomes from experimental treatment were large, whereas ESs of outcomes from control treatment (or control groups) were medium. When types of outcomes were quantitatively analysed in a meta-analysis from studies that used MSI, the immediate ESs of activity and participation outcomes were significantly larger than the immediate ESs of impairment outcomes. When outcomes from non-group studies are considered (Burke et al., 1991; Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Suzman et al., 1997; Turkstra & Flora, 2002), the positive immediate treatment outcomes are strengthened for this intervention approach.

The majority of studies reported maintenance or generalisation of treatment outcomes and in general these outcomes were positive. However, ESs could be estimated from only three studies and these were from studies that differed substantially in the way in which intervention was conducted: Fasotti et al. (2000) compared time pressure management to concentration treatment in an RCT using aspects of MSI; Marshall et al. (2004) trained verbal reasoning using dynamic interactive treatment; and Stablum et al. (2000) trained individuals on a computerised dual-processing task. When maintenance outcomes from other studies (for which ES could not be estimated) are included, the trend is generally positive (Cicerone & Wood, 1987; Burke et al., 1991; Delazer et al., 1998; Fox et al., 1989; Rath et al., 2003; von Cramon et al., 1991).

Unfortunately, the same cannot be said for the use of trained approaches that generalised or transferred to untrained activities or contexts. While participants, family, clinicians or others reported some kind of generalisation, this information was often subjective or qualitative, lacking reliability and, therefore, experimental control. The reasons for generalisation effects remain unclear. Some authors speculated that generalisation occurred because of the self-regulatory techniques embedded in the intervention protocol; that is generalisation to other problem situations occurred when treatment included explicit self-monitoring or self-assessment training with strategic decisions, although there is little objective evidence to support this speculation.

Treatment recommendations for problem solving, planning, organisation and multi-tasking

What recommendations can be made as to the kind of intervention that is efficacious or effective, and for whom? What kinds of outcomes can be expected from this intervention? There is a substantial amount of compelling research evidence from 10 intervention studies that training individuals with TBI using step-by-step MSI will improve problem solving, etc. for personally relevant activities or problem situations. Although various sets of skills were emphasised across studies, immediate positive changes in functional activities, and to a lesser extent in impairment outcomes, were observed after intervention from five RCTs or Class I studies (Fasotti et al., 2000; Levine et al., 2000; Rath et al., 2003; von Cramon et al., 1991; Webb & Gluecauf, 1994) and four Class III studies (Burke et al., 1991; Cicerone & Giacino, 1992; Suzman et al., 1997; Turkstra & Flora, 2002). With the exception of the Suzman et al. (1997) study that focused on children with TBI, participants were young and middle-aged adults in chronic stages of disability as a result of TBI, indicating that these individuals should be good candidates who would benefit from this kind of intervention.

The amount and strength of the evidence leads to the recommendation of a *Practice standard* for this age group, meaning that metacognitive strategy instruction (MSI) should be used with young to middle aged adults with TBI for difficulty with problem solving, planning and organisation. The evidence here exceeds the minimum requirements set forth by the AAN for this level of recommendation. Although the dosage averaged about 12 hours, there was tremendous variability across studies. There was also variability in the types and number of steps included in MSI, but with some consensus across studies that step-by-step procedures should include acknowledging and/or generating goals, self-monitoring and self-recording of performance, strategy decisions based on the performance–goal comparison in which individuals adjust the plan based on self-feedback or external feedback.

Although there is less evidence to support the maintenance of activity outcomes after the withdrawal of MSI treatment, there is sufficient positive evidence from three RCTs or Class I studies (Fasotti et al., 2000; Rath et al., 2003; Webb & Gluecauf, 1994) and one Class III study (Burke et al., 1991) for it to be considered likely. Two RCTs or Class I studies (Fasotti et al., 2000; von Cramon et al., 1991) and three Class III studies (Cicerone & Giacino, 1992; Cicerone & Wood, 1987; Turkstra & Flora, 2002) reported generalisation of MSI effects to untrained contexts or problem situations, although the reasons for generalisation were unclear.

Positive treatment effects from a single Class III study (Suzman et al., 1997) provides limited evidence in favour of intervention for problem solving with children and adolescents with TBI. Although step-by-step, MSI appears to provide favourable outcomes, there is insufficient evidence to make a clinical recommendation for this age group of TBI survivors. It should be noted that this kind of strategy instruction has been used for many years with children with learning disabilities (Swanson, 1999) and with children with attention deficit/hyperactivity disorder with great success (Reid, Trout, & Schartz, 2005). Unfortunately, there was no research evidence published through 2004 for treating these executive functions in older adults either. However, there is no evidence to suggest that this type of intervention would *not* be effective with individuals from either age group.

For young and middle age adults with chronic disability, evidence supporting intervention involving strategic thinking using verbal reasoning was provided by a Class II study (Fox et al., 1989) and a Class III study (Marshall et al., 2004). Delazer et al. (1998) provided promising results with positive immediate improvement in the steps needed to figure out mathematical word problems after cueing procedures were trained to adults with TBI. Research evidence from a single study (Manly et al., 2001) supports the use of an alerting device to prompt young and middle age adults with chronic disability to continue with the next "step" while multi-tasking a complex activity, although additional evidence for alerting systems is provided in a prior review (see Sohlberg et al., 2007).

Areas for future research

Although the results of this evidence review were generally supportive of intervention for executive dysfunction, it revealed several key areas in which further study is needed. There are no data for adults over age 75, who currently have the highest rate of hospitalisation and death from TBI of any age group (Langlois, Rutland-Brown, & Thomas, 2006). There are few sources of data for children, in whom the estimated annual incidence of TBI is nearly 500,000 (Langlois et al., 2006). Children might appear to have few problems initially but are likely to manifest executive dysfunction as expectations for self-regulation and problem solving increase with age. There is a particular need for school-based intervention studies in this group, as intervention is likely to be delivered by a combination of healthcare professionals and teachers. This is true for college-aged students as well, as there are, to our knowledge, no studies of intervention that specifically address executive function in this age group, despite the high incidence of TBI in older adolescents and young adults.

Individuals from racial minorities are over-represented in the TBI population relative to the percent of individuals from minority groups in the general population, and African Americans and Alaskan Natives have the highest TBI hospitalisation rates of any racial group (Langlois et al., 2006). This statistic is confounded with income, as individuals from racial minorities are disproportionately poor and at risk for TBI. There is a critical need for data on intervention in minority and impoverished groups, beyond including one or two individuals in a treatment study. This is particularly true given the evidence in this report that intervention conditions should be matched as closely as possible to contexts in which skills will be used (i.e., participation-level outcomes must be considered). There is no evidence that the general principles identified here would fail to apply to individuals from these populations, but it is nevertheless important to collect data to address these specific contexts.

There were few studies of intervention in the acute and sub-acute stage after injury, although this is the only time at which many individuals with TBI have reimbursement for cognitive rehabilitation. The results of previous reports by this committee (e.g., Sohlberg et al., 2003) suggest that acute intervention aimed at component process remediation might not yield benefits beyond spontaneous recovery, but the extent to which this idea is true of executive dysfunction is unknown.

A final group missing from the studies reviewed here is combat veterans. As of March 2007, more than 1100 active duty veterans have sustained brain injuries in the Global War on Terror (Operation Iraqi Freedom, Operation Enduring Freedom, and other conflicts) (Fischer, 2006). The majority of these veterans have been injured by improvised explosive devices (IED). These injuries differ in important ways from civilian TBI (Cernak, Savic, Ignjatovic, & Jevtic, 1999), and the best practices in intervention for those with blast injuries are currently unknown.

Although the data strongly support the general practice of intervention for executive dysfunction after TBI, much remains to be learned about specific intervention techniques. Although most studies provided sufficiently detailed methodology to permit replication, it would be helpful to have further details regarding factors such as participant co-morbid characteristics, training requirements for individuals delivering the intervention, and how goals should be selected for individuals.

A noteworthy outcome from this review was that changes were more likely to be observed at the level of activities and participation in daily living than on standardised tests (i.e., impairment outcomes). This is expected in studies of executive dysfunction, which often is not apparent in structured testing environments. Researchers are encouraged to continue to consider outcomes beyond standardised tests, and to establish that participation-level outcomes are enduring over time. We also encourage clinical researchers who are considering treatment studies to think "meta-analytically" – that is, to provide sufficient detailed information so that in the future, others can estimate effect sizes and generate meta-analyses as the cognitive rehabilitation literature continues to evolve and as additional high-quality evidence is produced.

Finally, evidence from cognitive neuroscience supports theoretical models of executive functions that indicate the absence of a central executive homunculus; rather several cognitive subsystems act together to comprise the central executive system (e.g., for overview see Miller & Cohen, 2001). One subsystem keeps information active so that comparisons can be made about tasks and contexts, and so that goal-directed behaviour can be carried out. Another subsystem deals with competition; one that engages in top-down biasing of information, and suppresses some information over other information. A third subsystem monitors, detects and compares conflicting information and makes judgements about performance. Yet, there remains a gap between theories about subsystems and intervention practice. Theoretically driven intervention studies would advance our understanding of executive functions, but may also advance our understanding of generalisation or transfer of skill sets to untrained tasks and contexts.

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Manuscript received June 2007
Revised manuscript received September 2007
First published online Month year

APPENDIX

Quality Standards Subcommittee of the American Academy of Neurology (Miller et al., 1999)	*Quality Standards Subcommittee of the American Academy of Neurology (Miller et al., 1999)*	*American Academy of Neurology Classifications (American Academy of Neurology, 2004)*	*American Academy of Neurology Clinical Recommendations (American Academy of Neurology, 2004)*
Class I: Prospective, well-designed randomised controlled clinical trial (RCT)	*Practice standards* are based on Class I studies, RCTs, or very strong Class II studies	*Class I:* Prospective, randomised controlled clinical trial with masked outcome assessment in a representative population with qualifiers	*Level A:* Intervention should be done; intervention is established by two consistent Class I studies for specific condition in the specified population resulting in a *Practice Standard*
Class II: Well-designed, observational clinical studies with concurrent controls (such as with single case control or cohort control studies); single-subject multiple baselines across subjects	*Practice guidelines* are based on a moderate degree of clinical certainty, usually based on Class II or a strong consensus from Class III	*Class II:* Prospective matched group cohort study in a representative population with masked outcome assessment that meets Class I criteria or a randomised controlled trial that lacks one criteria for Class I	*Level B:* Intervention should be considered; intervention is probably effective by at least one Class I study or two consistent Class II studies for a specific condition in the specified population resulting in a *Practice Guideline*
Class III: Case series, case reports or studies with historical controls. Expert opinion is also included here (Golper et al., 2001; Yorkston et al., 2001)	*Practice options* occur when the evidence is inconclusive or there is conflicting evidence	*Class III:* All other controlled trials (including well-defined natural history control subjects or patients serving as own control subjects) in a representative population where outcome assessment is independent of patient treatment	*Level C:* Intervention may be considered; intervention is possibly effective by at least one Class II study or two consistent Class III studies for a specific condition in the specified population resulting in a *Practice Option*
		Class IV: Evidence from uncontrolled studies, case series, case reports, or expert opinion	*Level U:* Data are inadequate or conflicting; current knowledge, treatment is unproven resulting in no specific recommendation