INCOG Recommendations for Management of Cognition Following Traumatic Brain Injury, Part V: Memory

Diana Velikonja, PhD; Robyn Tate, PhD; Jennie Ponsford, PhD; Amanda McIntyre, MSc; Shannon Janzen, MSc; Mark Bayley, MD, FRCP, on behalf of the INCOG Expert Panel

Introduction: Traumatic brain injury results in complex cognitive sequelae. Impairments in memory are among the most common sequelae resulting in significant functional problems. An international team of researchers and clinicians (known as INCOG) was formed to develop recommendations for the management of impairments in memory. Methods: The experts met to select appropriate recommendations and then reviewed available literature to ensure recommendations were current. Decision algorithms incorporating the recommendations based on inclusion and exclusion criteria of published trials were developed. The team then prioritized recommendations for implementation and developed audit criteria to evaluate adherence to the best practice recommendations. Results: The recommendations for rehabilitation of memory impairments support the integration of internal and external compensatory strategies implemented using appropriate instructional techniques that consider functional relevance and important patient characteristics. Restorative strategies have regained significant popularity, given broader access to computer technology; however, evidence for efficacy of these techniques remains weak and the choice in using these should be guided by special considerations. Conclusion: There is good evidence for the integration of internal and external compensatory memory strategies that are implemented using instructional procedures for rehabilitation for memory impairments. The evidence for the efficacy of restorative strategies currently remains weak. Key words: cognitive rehabilitation, guidelines, knowledge translation, memory, neuropsychology, rehabilitation, therapeutic approaches for the treatment of central nervous system injury, traumatic brain injury.

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From an information-processing perspective, memory reflects processes of encoding, storing, and retrieving information from short- and long-term memory systems. Impairments in memory following traumatic brain injury (TBI) are among the most common cognitive deficits, typically manifested as problems learning new information. They can have debilitating functional consequences. The literature on rehabilitative approaches directed at managing memory impairments following TBI can be broadly divided into compensatory strategies and restorative techniques. Compensation approaches emphasize the use of the residual cognitive strengths of patients with brain injury to minimize the functional impact of their memory impairment in the course of performing daily tasks. Compensatory strategies are typically separated into internal and external strategies. With internal memory compensatory strategies, the performance of a task is modified to increase conscious effort during the encoding process, whereas with external strategies, the performance of a task is modified by the use of devices or strategies to counteract the thought processes that contribute to the memory impairment. Restorative strategies focus on the use of instructional techniques and environmental control to modify the thought processes and strategies of the person with brain injury. They can be considered minimally invasive or invasive, based on the extent of the attentional and motivational effort required. Minimally invasive strategies require the use of covert attentional resources, whereas invasive strategies require overt attentional resources. Both compensatory and restorative strategies should be considered in the management of memory impairments following TBI to maximize the functional and psychosocial outcomes of persons who have sustained brain injury.
phase of memory processing by increasing an individual’s ability to monitor his or her task performance. External memory strategies integrate a physical system of compensation.4 Restorative techniques aim to improve the specific impaired cognitive function through repeated exercises or massed training trials5 and derive evidence for their efficacy based upon the plasticity of cortical functions in the motor and sensory domains following such training.6

The INCOG guidelines include 7 recommendations for the best practice in the application of rehabilitation strategies for memory impairments following TBI. The recommendations are based on a review the evidence related to compensatory and restorative approaches to the rehabilitation of memory, as well as the instructional strategies that should be considered when attempting to teach new information or procedures to the patient with brain injury. There is considerable variability across the studies regarding reporting of severity of memory impairments, with varying descriptors used to define the level of memory impairment. Few studies have used standardized measures to define impairment ranges. Selection criteria often exclude comorbidities such as alcohol, neurodegenerative diseases, and neurodevelopmental conditions. Many patients have injury-related comorbidities such as problems with executive skills, attention, processing speed, and affect at varying levels of impairment. Most studies include patients with brain injury in the post–acute phase of recovery. The evidence should be viewed with these caveats in mind. The methodology of studies reviewed is broadly discussed with an accompanying reference table if further clarification is required.

METHODS

The Guidelines Adaptation and Development (ADAPTE) process was used to develop the INCOG guidelines.7,8 An international expert panel was formed through invitations of authors of previously published cognitive rehabilitation guidelines and contacts of the team. In preparation, a detailed Internet and MEDLINE search was conducted to identify published TBI and evidence-based cognitive rehabilitation guidelines.9 The quality of the development process for each eligible clinical practice guideline (CPG) was evaluated using the Appraisal of Guidelines for Research and Evaluation (AGREE II) instrument.10,11 The ADAPTE process involves extracting recommendations from these CPGs to allow easy comparison (eg, all recommendations about executive function were tabulated together). The Evidence-based Review of Acquired Brain Injury (ERABI: http://www.abiebr.com) synopses of evidence for each topic area were also distributed to the panel.12

The initial expert panel meeting was scheduled for convenience just prior to the World Congress of Neurorehabilitation in Melbourne, Australia, in May 2012. Some members attended via Web conferencing from the United States and Canada. This panel examined the recommendations matrix and selected suitable recommendations from existing guidelines or articulated novel recommendations based on the evidence available. This yielded an initial draft set of recommendations; however, to ensure the recommendations were updated according to the most current evidence, the research team prepared synopses of large systematic reviews, the GEM (Global Evidence Mapping) Initiative13 based in Australia (www.evidencemap.org), the Evidence-based Review of Acquired Brain Injury12 and PsychBITE (http://www.psycbite.com).14 Furthermore, the reference sections of all eligible cognitive rehabilitation CPGs were extracted. All relevant references were consolidated into a reference library that was made available to the author teams as they drafted the manuscripts and finalized the recommendations accordingly. By the end, the team completed the evidence review of more than 600 references found in this search process. This task has resulted in a comprehensive mapping of evidence to all previously and newly developed recommendations. The tables will be made available as online content on the Web site of the Journal of Head Trauma Rehabilitation. With the updated literature search in mind, the experts graded the evidence. As various systems for determining the level of evidence were used across the CPGs, the INCOG team standardized this by using the grading system outlined in Table 1, which was based upon that used in previous guideline development projects.15 These final recommendations were presented to the entire team for approval and then the expert panel used modified Delphi voting technique to prioritize the recommendations from the INCOG guideline for

| TABLE 1 | INCOG level of evidence grading system |
| A. Recommendation supported by at least 1 meta-analysis, systematic review, or randomized controlled trial of appropriate size with a relevant control group |
| B. Recommendation supported by cohort studies that at minimum have a comparison group, well-designed single-subject experimental designs, or small sample size randomized controlled trials |
| C. Recommendations supported primarily by expert opinion based on their experience through uncontrolled case series without comparison groups that support the recommendations are also classified here. |
Each of the experts was asked in this exercise to vote for his or her top 15 recommendations considering both the importance to practice and feasibility of auditing the recommendations.

For each cognitive rehabilitation domain of posttraumatic amnesia, attention, memory, executive function, and cognitive communication, a clinical algorithm was developed to help clinicians decide to whom the recommendations applied (see Figure 1). To finalize the algorithm, evidence tables were reviewed to find the inclusion and exclusion criteria for the study populations that were used. By understanding the subpopulations of TBI patients to whom the evidence applies, it is possible to understand what treatments are appropriate for each patient. In contrast to other guidelines, the INCOG team has identified recommendations that could be audited from clinical charts to determine adherence to the best practice guidelines in each section. This is known as the INCOG audit tool. More detailed version of the Methods is available in the third article of the series.

**LIMITATIONS OF USE AND DISCLAIMER**

These recommendations are informed by evidence for TBI cognitive rehabilitation interventions that was current at the time of publication. Relevant evidence published after the INCOG guideline could influence the recommendations contained herein. Clinicians must also consider their own clinical judgment, patient preferences, and contextual factors such as resource availability in their decision-making processes about implementation of these recommendations.

**RECOMMENDATIONS AND LITERATURE REVIEW**

The 7 INCOG guidelines for recommendations for best practices regarding the rehabilitation of memory impairments are accompanied by a review of the related current evidence (see Tables 2 and 3). There is a combination of grade A and B evidence to support the

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**Figure 1. Algorithm: Memory.**

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<table>
<thead>
<tr>
<th>Guideline recommendation</th>
<th>Grade</th>
<th>Reviews</th>
<th>RCTs</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory #1</td>
<td>Teaching internal compensatory strategies may be used for TBI patients who have memory impairments. These strategies include instructional and/or metacognitive strategies (e.g., visualization/visual imagery, repeated practice, retrieval practice, PQRST, self-cueing, self-generation, self-talk). Their use tends to be most effective with patients who have mild to moderate range impairments and/or some preserved executive cognitive skills. Using multiple strategies is considered effective, and strategies can be taught individually or in a group format.</td>
<td>A</td>
<td>Kaschel et al, Ryan et al, Shum et al, Twum and Parente</td>
<td>Dowds et al, Fleming et al, Freeman et al, Kuntz et al, Grilli and McFarland, Manasse et al, O’Neill-Pirozzi et al, Potvin et al, Raskin et al, Raskin and Sohlberg, Schefft et al, Thoene and Glisky</td>
</tr>
<tr>
<td>Memory #2</td>
<td>Environmental supports and reminders are recommended for TBI patients who have memory impairment, and most especially with those who have severe memory impairment (e.g., NeuroPage, mobile/smartphones, SIRI, PDA, notebooks, whiteboards). Patients with TBI and their caregivers must be trained in how to use these external supports.</td>
<td>A</td>
<td>Sohlberg et al</td>
<td>Fish et al, Lemoncello et al, McDonald et al, Ownsworth and McFarland, Wilson et al</td>
</tr>
<tr>
<td>Memory #3</td>
<td>The selection of external memory aids should take into account the following considerations regarding persons with TBI:</td>
<td>B</td>
<td>Lynch</td>
<td>Fish et al, McDonald et al, Schmitter-Edgecombe et al</td>
</tr>
</tbody>
</table>

(continues)
TABLE 2  INCOG guideline recommendations: Memory (Continued)

<table>
<thead>
<tr>
<th>Guideline recommendation</th>
<th>Grade</th>
<th>Reviews</th>
<th>RCTs</th>
<th>Other</th>
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<tbody>
<tr>
<td>Memory #4</td>
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<tr>
<td>There are a number of key instructional practices that can promote learning for individuals with memory impairments, which include:</td>
<td>A</td>
<td>Ehhardt et al&lt;sup&gt;60&lt;/sup&gt;</td>
<td></td>
<td>Baddeley and Wilson,&lt;sup&gt;70&lt;/sup&gt; Constantindou and Neils,&lt;sup&gt;69&lt;/sup&gt; Ehlhardt et al,&lt;sup&gt;65&lt;/sup&gt; Evans et al,&lt;sup&gt;87&lt;/sup&gt; Glasgow et al,&lt;sup&gt;22&lt;/sup&gt; Gisky et al,&lt;sup&gt;75&lt;/sup&gt;–&lt;sup&gt;77&lt;/sup&gt; Goldstein et al,&lt;sup&gt;67&lt;/sup&gt; Goldstein et al,&lt;sup&gt;67&lt;/sup&gt; Gordon Hayman et al,&lt;sup&gt;86&lt;/sup&gt; Goverover et al,&lt;sup&gt;82&lt;/sup&gt; Haslam et al,&lt;sup&gt;23&lt;/sup&gt; Hunkin and Parkin,&lt;sup&gt;71&lt;/sup&gt; Hux et al,&lt;sup&gt;96&lt;/sup&gt; Kalia et al,&lt;sup&gt;80&lt;/sup&gt; Melton and Bourgeois,&lt;sup&gt;89&lt;/sup&gt; Molloy et al,&lt;sup&gt;74&lt;/sup&gt; Quemada et al,&lt;sup&gt;82&lt;/sup&gt; Riley et al,&lt;sup&gt;72&lt;/sup&gt;,&lt;sup&gt;73&lt;/sup&gt; Sumowski et al,&lt;sup&gt;81&lt;/sup&gt; Svoboda et al,&lt;sup&gt;66&lt;/sup&gt; Tailby and Haslam&lt;sup&gt;85&lt;/sup&gt;</td>
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<tr>
<td>• Clearly define intervention goals;</td>
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<td>• Integrate methodologies that allow for breaking down tasks into smaller components such as task analysis when training multistep procedures;</td>
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<td>• Allow sufficient time and opportunity for practice;</td>
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<td>• Use principles of distributed practice;</td>
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<tr>
<td>• Teach strategies using variations in the stimuli/information being presented (eg, multiple exemplars, practical tasks);</td>
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<tr>
<td>• Promote strategies that allow for more effortful processing of information/stimuli (eg, verbal elaboration; visual imagery);</td>
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<tr>
<td>• Selection of and train to goals that are relevant to the patient (ie, ecologically valid); and</td>
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<tr>
<td>• Use teaching strategies that constrain errors (eg, errorless, spaced retrieval) when acquiring new or relearning information and procedures.</td>
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<tr>
<td>Ehlhardt et al&lt;sup&gt;60&lt;/sup&gt;</td>
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<td>Memory #5</td>
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<tr>
<td>Group-based interventions may be considered for remediation of mild to moderate memory deficits following TBI.</td>
<td>B</td>
<td>Jennett and Lincoln,&lt;sup&gt;98&lt;/sup&gt; Schmitter-Edgecombe et al,&lt;sup&gt;59&lt;/sup&gt; Thickpenny-Davis and Barker-Collo&lt;sup&gt;57&lt;/sup&gt;</td>
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<td>Giccone et al&lt;sup&gt;17&lt;/sup&gt;</td>
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<td>Memory #6</td>
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<tr>
<td>A trial of acetylcholinesterase inhibitors (eg, donepezil, rivastigmine) may be considered for adults with TBI who have deficits in memory. The effects of the medication should be assessed using objective and functional measures. NZGG 6.1.6, INCOG 16.</td>
<td>B</td>
<td>Kim et al,&lt;sup&gt;103&lt;/sup&gt; Tenovuo et al,&lt;sup&gt;102&lt;/sup&gt; Zhang et al&lt;sup&gt;104&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>NZGG 6.1.6, INCOG 16.</td>
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### TABLE 2

<table>
<thead>
<tr>
<th>Guideline recommendation</th>
<th>RCTs</th>
<th>Reviews</th>
<th>Other</th>
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<tbody>
<tr>
<td><strong>Memory #7</strong></td>
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<tr>
<td>Restorative techniques such as computer-based training show no evidence in enhancing sustained memory performance. Guidelines indicate that it should only be considered to develop adjunct memory rehabilitation strategies, and only if developed in conjunction with strategy development and transfer to functional tasks.</td>
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<tr>
<td><strong>Grade</strong></td>
<td>B-C</td>
<td></td>
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<tr>
<td><strong>Abbreviations</strong>: PDA, personal digital assistant; PQRST, Preview, Question, Read, Self-recitation, Test; RCT, randomized controlled trial; TBI, traumatic brain injury.</td>
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</table>

Recommendations related to the use of compensatory approaches. Weak, but consistent, evidence (grade B) was found supporting choice of various instructional strategies. The final recommendation addresses the efficacy of current computer-based restorative approaches in improving general memory processing, with primarily grade B and C evidence. The recommendations and a summary of the supporting evidence are presented in the following text:

Memory #1. Teaching internal compensatory strategies may be used for TBI patients who have memory impairments. These strategies include instructional and/or metacognitive strategies (eg, visualization/visual imagery, repeated practice, retrieval practice, PQRST, self-cueing, self-generation, self-talk, etc). Their use tends to be most effective with patients who have mild to moderate range impairments and/or some preserved executive cognitive skills. Utilizing multiple strategies is considered effective and strategies can be taught individually or in a group format. (Adapted from Cicerone et al,17(p523) INCOG16)

Historically, the use of internal compensatory memory strategies started with the teaching of techniques such as mnemonics,18 visual imagery,19 and self-instructional methods.20 In general, such techniques focus on directing attention to and elaborating in some meaningful way upon the information to be remembered, with the aim of facilitating subsequent retrieval.21 The studies have been largely conducted in experimental settings, with outcome assessed in terms of performance on standardized neuropsychological tests. For example, instruction in the PQRST (Preview, Question, Read, Self-recitation, Test) method has been associated with improvement in performance on standardized verbal memory measures.22 Similarly, patients instructed in techniques for creating visual imagery and verbal elaboration to assist them to remember new information generally performed better on standardized tests of verbal and visual memory than performed by untreated controls.23–26 The use of structured visual imagery has also been applied to learning of more practical information in a “real-world” setting with positive results.27

Studies integrating self-instructional methods have been more often applied to prospective memory tasks. Prospective memory represents the ability to remember future events and perform tasks that need to be completed.28 For example, training in visual imagery techniques to strengthen the association between prospective cues and intended actions has been associated with reduced forgetting of daily tasks.29 Self-awareness techniques that have focused upon improving the patient’s knowledge of the manifestations of memory impairments, combined with compensatory prospective cueing techniques, have also been associated with improved performance on prospective
### TABLE 3  Audit guidelines for priority recommendations: Memory

<table>
<thead>
<tr>
<th>Intervention (guideline recommendation)</th>
<th>Specific activities, devices, or tools</th>
<th>Assessment of need and effectiveness</th>
<th>Patient characteristics</th>
<th>Discipline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementing internal compensatory memory strategies: Teaching internal compensatory strategies may be used for TBI patients who have memory impairments. These strategies include instructional and/or metacognitive strategies (e.g., visualization/visual imagery, repeated practice, retrieval practice, PQRST, self-cueing, self-generation, self-talk). Their use tends to be most effective with patients who have mild to moderate range impairments and/or some preserved executive cognitive skills. Using multiple strategies is considered effective, and strategies can be taught individually or in a group format.</td>
<td>□ Pacing system □ Smartphone □ PDA □ Notebook □ SIRI □ Other applicable aids</td>
<td>□ Assessment of memory severity and executive cognitive skills □ Training provided □ Assess transfer of strategy to functional tasks □ Assess patients appropriateness for group intervention if this format is being considered</td>
<td>□ Mild to moderate memory impairment—psychometric or functional assessment □ Aspects of executive cognitive functioning that may be preserved</td>
<td>□ SLP □ Neuropsychology □ Rehabilitation psychology □ OT □ Other</td>
</tr>
<tr>
<td>External memory compensatory strategies: Environmental supports and reminders are recommended for TBI patients who have memory impairment, and most especially with those who have severe memory impairment—(e.g., NeuroPage, mobile/smartphones, SIRI, PDA, notebooks, whiteboards, etc). Patients with TBI and their caregivers/support staff must be trained in how to use these external supports.</td>
<td></td>
<td>□ Assessment to ensure appropriateness of device □ Training provided to caregivers/support staff</td>
<td>□ Amnesia and/or severe level of memory impairment—psychometric assessment</td>
<td>□ SLP □ Neuropsychology □ Rehabilitation psychology □ OT □ Other</td>
</tr>
<tr>
<td>Selection of external memory compensatory strategies: The selection of external memory aids should take into account the following considerations regarding the person with a TBI: • Age • Severity of impairment • Premorbid use of electronic and other memory devices • Cognitive strengths and weaknesses (e.g., executive cognitive skills) • Physical comorbidities</td>
<td>□ Pacing system □ Smartphone □ PDA □ Notebook □ SIRI □ Other applicable aids</td>
<td>□ Assess individual characteristics and needs of patient □ Training provided to caregivers/support staff □ Assess usability or functional uptake of the strategy for patient</td>
<td>□ Amnesia and/or severe memory impairment—psychometric assessment</td>
<td>□ SLP □ Neuropsychology □ Rehabilitation psychology □ OT □ Other</td>
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</tbody>
</table>

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### TABLE 3  Audit guidelines for priority recommendations: Memory\(^a\)(Continued)

<table>
<thead>
<tr>
<th>Intervention (guideline recommendation)</th>
<th>Specific activities, devices, or tools</th>
<th>Assessment of need and effectiveness</th>
<th>Patient characteristics</th>
<th>Discipline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group-based instructional formats:</td>
<td>☐ Appropriate group setting and materials</td>
<td>☐ Assess patients suitability for group-based intervention</td>
<td>☐ Mild to moderate memory impairment—psychometric or functional assessment</td>
<td>☐ SLP</td>
</tr>
<tr>
<td>Group-based interventions may be considered for remediation of mild to moderate memory deficits following TBI.</td>
<td></td>
<td></td>
<td></td>
<td>☐ Neuropsychology</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>☐ Rehabilitation psychology</td>
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<td>☐ OT</td>
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<td></td>
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<td>☐ Other</td>
</tr>
<tr>
<td>Instructional practices for memory-impaired patients:</td>
<td>☐ Materials for any structured programs being used (ie, I-MEMS, etc)</td>
<td>☐ Assessment of memory and other cognitive skills</td>
<td>☐ Mild to severe memory impairment—psychometric assessment</td>
<td>☐ SLP</td>
</tr>
<tr>
<td>There are a number of key instructional practices that can promote learning for individuals with memory impairments, which include:</td>
<td></td>
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<td>☐ Neuropsychology</td>
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<td>☐ Rehabilitation psychology</td>
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</tbody>
</table>
### TABLE 3  
Audit guidelines for priority recommendations: Memory<sup>a</sup>(Continued)

<table>
<thead>
<tr>
<th>Intervention (guideline recommendation)</th>
<th>Specific activities, devices, or tools</th>
<th>Assessment of need and effectiveness</th>
<th>Patient characteristics</th>
<th>Discipline</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Use teaching strategies that constrain errors (eg, errorless, spaced retrieval) when acquiring new or relearning information and procedures.</td>
<td>□ Therapist</td>
<td>□ Assess for key functional goals and generalization tasks</td>
<td>□ Mild to moderate memory severity—psychometric or functional assessment</td>
<td>□ SLP</td>
</tr>
<tr>
<td>□ Restorative memory strategies: Restorative techniques such as computer-based training show no evidence in enhancing sustained memory performance. Guidelines in using such techniques indicate that it should only be considered to develop adjunct memory rehabilitation strategies with evidence-based instructional and compensatory strategies, and only if developed in conjunction with a therapist with a focus on strategy development and transfer to functional tasks.</td>
<td></td>
<td>□ Evaluation of functional transfer</td>
<td></td>
<td>□ Neuropsychology</td>
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<td>□ □</td>
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<td>□ Rehabilitation psychology</td>
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### Pharmaceutical interventions: Memory

<table>
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<tr>
<th>Drug</th>
<th>Used</th>
<th>Indication</th>
<th>Patient characteristics</th>
<th>Found in</th>
</tr>
</thead>
<tbody>
<tr>
<td>AChE inhibitors</td>
<td></td>
<td>□ Memory impairment □ Other (please specify):</td>
<td>□ Evidence of deficits of memory □ Functional outcomes measures administered</td>
<td>□ Drug charts □ MD notes □ Other</td>
</tr>
<tr>
<td>• Donepezil</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>• Rivastigmine</td>
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</table>

A trial of AChE inhibitors may be considered for adults with TBI who have deficits in memory. The effects of the medication should be assessed using objective and functional measures.

Abbreviations: AChE, acetylcholinesterase; OT, occupational therapy; PDA, personal digital assistant; SLP, speech-language pathology; TBI, traumatic brain injury.

<sup>a</sup>The audit tool items for Memory are shown. These are the items that the panel voted as the most important for implementation.
memory tasks\textsuperscript{30} and found to be superior to rote rehearsal in facilitating the subsequent completion of tasks.\textsuperscript{31}

Implementation of structured training procedures in the use of multiple internal mnemonic strategies has been associated with improvements in recall of prospective tasks when delivered both in an individualized format\textsuperscript{12,33} and in group instruction. For example, the Internal Memory Strategies (I-MEMS)\textsuperscript{34} is a protocol involving a 12-week structured program in which multiple internal compensatory strategies (eg, visualization, associations) were delivered in a group format. Delivery of this protocol was associated with improvements on standardized verbal learning and behavioral memory tasks, including tests of prospective memory.\textsuperscript{34} Instruction in several concurrent strategies integrating self-awareness of memory deficits, customized cueing strategies, as well as organizational strategies also resulted in improved performance on prospective memory tasks.\textsuperscript{30,35,36}

Evidence suggests that combining compensatory memory techniques with self-instructional strategies that emphasize the use of executive skills to monitor their use enhances their efficacy.\textsuperscript{37} The need for use of executive cognitive skills in implementing these strategies may explain why individuals with less severe cognitive deficits have shown more benefit from internally based memory training than those with more severe deficits.\textsuperscript{38} Evidence of the generalizability of these techniques in reducing the daily functional problems experienced by patients with memory impairment has been equivocal, due to the inclusion of people with more severe memory impairment and additional executive cognitive deficits, which significantly limit their capacity to apply these techniques.\textsuperscript{4} Therefore, the application of such strategies must include assessment of the capacity of the person with brain injury to implement strategies taught in everyday contexts, including knowing when to use such strategies. Thus, combining the integration of internal and external compensatory strategies may enhance the effectiveness of remedial interventions for memory.\textsuperscript{39}

Memory #2. Environmental supports and reminders are recommended for TBI patients who have memory impairment and most especially with those who have severe memory impairment—(eg, NeuroPage, mobile/smartphones, SIRI, PDA, notebooks, whiteboards, etc). Patients with TBI and their caregivers/support staff must be trained in how to use these external supports. (Adapted from EFNS,\textsuperscript{40-42} INCOG\textsuperscript{16})

The evidence supporting the use of external compensatory strategies in reducing some of the daily problems associated with impaired memory has been extensively reviewed.\textsuperscript{4,39,41} The range of external aids includes diaries, notebooks, customized memory books, organizers, and planners.\textsuperscript{42-44} Difficulties with severe memory-impaired patients remembering to write down information and later checking what tasks they need to perform led to the introduction of paging systems.\textsuperscript{26,41,45} Greater long-term use of paging devices was associated with built-in prompting systems,\textsuperscript{26} as well as with patients who had better executive cognitive skills, regardless of the level of memory impairment.\textsuperscript{46}

Individuals with brain injury and good executive functioning scores have been shown to achieve a large percentage of attained target behaviors when trained to use a mobile phone with individualized prompts. In general, paging systems and personal voice organizers that provide a system of cues or prompts have been shown to improve the ability of individuals with brain injury to effectively achieve target behaviors, reduce the number of therapy sessions missed, and complete more personally meaningful tasks within the home and at work.\textsuperscript{47,48} The use of such devices has also resulted in improvement in the individual’s quality of life and sense of well-being.\textsuperscript{49,50} The use of PDAs programed to provide prompting has been associated with self-ratings of increased participation in daily activities and satisfaction in occupational performance.\textsuperscript{51} An assistive device that provided specific prospective memory prompts was associated with much greater task completion than that by assistive devices that did not incorporate such prompting.\textsuperscript{52} Programming a computer-based calendar system with prompts was shown to enhance prospective memory performance and reduce the need for monitoring when compared with the use of a standard diary.\textsuperscript{53}

The expense of electronic devices may be prohibitive for some people, and there may also be issues with learning how to use such technology, particularly for older people who have little experience with technology, or patients who do not have someone who can program the device for them. Hence, diary systems may be more helpful in certain cases. Studies have examined ways of increasing the use of diary systems. When training in diary use was combined with cueing, learning, and self-instructional techniques, greater improvements in performance on prospective memory tasks was found than those by instruction in diary use alone.\textsuperscript{35} Such training has also resulted in an increased use of compensatory strategies.\textsuperscript{54} Modifications to a standard diary that better suited the individual needs of patients and their functional application have also been associated with improved prospective memory performance.\textsuperscript{35,36}

Memory #3. The selection of external memory aids should take into account the following considerations regarding the person with a traumatic brain injury:

- Age
- Severity of impairment
- Premorbid use of electronic and other memory devices
- Cognitive strengths and weaknesses (eg, executive cognitive skills)
- Physical comorbidities. (Adapted from INCOG\textsuperscript{16})
Review of the literature has provided strong evidence that the use of external compensatory strategies is associated with reduced functional problems in daily living across individuals with variable memory severity. An important factor in the successful use of a mobile phone, which emerged from a series of case studies, was the individual’s ability to manage the sophistication of the device, which was strongly influenced by his or her age. One study using a randomized, controlled, crossover design with a large sample, more than half of whom had TBI, did demonstrate that better executive cognitive skills facilitated the integration of an external device. Data from a within-subject design demonstrated that provision of a conceptual understanding of how to use an external memory device as well as prior experience with technology were considered important in order for patients to gain any benefit from such devices. Moreover, using a within-subject design, electronic devices were more readily used if the individual with brain injury had prior experience with such devices, access to appropriate supportive technology, as well as a family member available to support and monitor the use of the device as a memory aid. In a small, randomized, controlled trial, group instruction and support were shown to be effective in increasing the use of a memory notebook at the end of the intervention; however, this effect was not sustained at 6-month follow up. Thus, there is emerging support that would indicate evaluation of these factors in considering the choice of technology or other memory support strategies.

Memory #4. There are a number of key instructional practices that can promote learning for individuals with memory impairments, which include:

- **Clearly define intervention goals**: This is the foundation for goal-directed learning and helps align the instructional approach with the individual’s needs.
- **Integrate methodologies that allow for breaking down tasks into smaller components such as task analysis when training multistep procedures**: This approach helps in breaking complex tasks into manageable parts.
- **Allow sufficient time and opportunity for practice**: Practice is crucial for skill acquisition and retention.
- **Use principles of distributed practice**: This involves spreading practice over time, which can enhance learning.
- **Teach strategies using variations in the stimuli/information being presented (eg, multiple exemplars, practical tasks)**: This approach increases the generalizability of learned strategies.
- **Promote strategies that allow for more effortful processing of information/stimuli (eg, verbal elaboration; visual imagery, etc)**: Using rich sensory information can enhance memory.
- **Selection of and train to goals that are relevant to the patient (ie, ecologically validity)**: Goals should be meaningful and relevant to the individual’s daily life.
- **Use teaching strategies that constrain errors (eg, errorless, spaced retrieval, etc) when acquiring new or relearning information and procedures**: This approach reduces barriers to learning.

Studies focusing on instructional practices generally support the use of structured methods to aid learning of skills or knowledge or to teach compensatory strategies. Wilson’s structured behavioral memory program, which emphasizes the need for a combination of environmental adaptations, external compensatory strategies, and various internal strategies individualized to the patient to maximize learning in individuals with brain injury, was evaluated using a combination of standardized and behavioral outcome measures. Results showed that using a combination of strategies was associated with functional improvements on tasks that were relevant to the daily life of patients. Assignment to a condition in which instructions were applied to “hands-on” tasks or tasks of practical significance to the individual resulted in significantly better recall of instructions than when verbal instruction was provided alone.

Training typically involves either teaching information (eg, names, word-lists, object names) or tasks such as data entry, programming, or learning to use an external memory aid or computer task. A number of review articles of approaches to training individuals with brain injury suggest that the goal of the training intervention must be relevant and clearly delineated to the individual with brain injury (eg, reduce missed appointments, increase daily tasks to be achieved, a computer program). These reviews also suggest that the use of instructional techniques that carefully structure the information or steps of the task is essential to ensure the success of training. Specific instructional packages have also been developed integrating task analysis, in which the steps of practical tasks are broken down into component steps, errorless learning, and an executive cognitive predictive strategy (TEACH-M; each letter represents 1 of the 7 steps of the procedure) to teach a complex e-mail task. In a pilot study using a multiple-baseline approach across 9 subjects, the TEACH-M package was shown to facilitate learning the sequences of steps in an e-mail task, with good maintenance of strategies learned and some generalization, but there was variability in the number of trials required to learn the steps. Use of “theory-driven” instructional strategies incorporating errorless learning and generalization to relevant tasks was shown to improve the use of a device in a single case, studied using an ABAB design.

Randomized controlled trials have shown that the use of internal strategies that increase the depth of semantic processing and embed visual imagery into verbal information is effective in enhancing recognition and cued recall of verbal information and for improving face-name recognition, with evidence of generalization. The use of internal strategies that integrate modalities, including auditory and visual techniques, has been shown to be effective in improving recall in individuals with moderate and severe memory impairments in a control group study. Strategies such as vanishing cues, a form of chaining with fading cues following an attempt at identifying the target, tend to show weaker effects in individuals with severe memory impairment, presumably.
due to the errors that are allowed in this more traditional process. However, even when the capacity to make errors was eliminated from the vanishing cue trials, no advantage was found over the more conventional methods in more severely memory-impaired individuals. Using a within-subject design, vanishing cues were confirmed to be associated with limited learning in severe memory-impaired patients but did demonstrate greater effects in semantic learning for individuals with milder memory impairments. Essentially cues could be reduced more rapidly in milder memory-impaired individuals, whereas those with more severe impairments required more gradual fading. A series of case studies showed that multiple internal compensatory strategies delivered in a structured instructional format resulted in improved recall for verbal and visual based structured information and was also effective in the context of more functional tasks.

The value of using training tasks of ecological relevance to the individual with brain injury was established in a landmark study that capitalized on the relatively intact implicit learning capacity of an amnesic woman, facilitating her procedural and semantic learning of a computer-based task through systematic instruction, which enabled her to be gainfully employed. On these tasks, there was clearer evidence that more severe memory impairments were associated with slower rates of learning. In a controlled trial study, errorless instruction was found to be more effective than traditional error-based learning to train the use of an external assistive compensatory device. Lynch noted that technology and compensatory devices were most effectively integrated when they were individualized to the practical daily life tasks needing to be performed by the individual with TBI.

Constraining errors can be achieved through a variety of techniques. It has been demonstrated that learning is facilitated by errorless strategies in populations with brain injuries because explicit memory, which is the memory system believed to systematically eliminate errors during learning, is most typically impaired, which leaves the consolidation phase of learning to be more reliant upon implicit memory that is highly susceptible to the interference caused by errors. One relatively well-controlled study found that combining errorless strategies with preexposure was particularly helpful in teaching target tasks such as name learning. Spaced retrieval/presentation is another training method that involves both reexposure and cued feedback at systematically increasing intervals during learning trials. This has been shown to be more effective than conventional strategies where there was more potential for errors, such as massed restudy and spaced restudy. In fact, compared with just massed learning, spaced retrieval was shown to be more consistently associated with better acquisition of functional tasks in the context of a within-subject design. Meta-analytic studies evaluating errorless strategies have demonstrated moderate effect sizes. The use of errorless strategies to improve verbal recall and functional task acquisition has resulted in gains with moderate effect sizes across the range of severity of memory impairment, but stronger effect sizes for use of errorless strategies have been found in individuals with more severe memory impairment. One study using a counterbalanced group design found that patients were able to have cues faded more rapidly during errorless learning conditions when memory impairments were less severe.

Distributed practice is a form of spaced retrieval in which training of recall strategies is provided over expanded intervals. Using a within-subject design, distributed practice was shown to be effective for teaching association strategies (names of known individuals) when training was delivered at no greater frequency than once a day. Positive results were found on prospective and episodic memory tasks when instructional practice was delivered during 30-minute daily phone sessions over 7 weeks. Both studies showed good acquisition across individuals with variable severity of memory impairment, but, again, the number of acquisition trials required varied across patients because of the differences in memory deficits.

Spaced retrieval and errorless strategies have been used with amnestic individuals, as the prevention of errors in such severe memory impairment is important for learning. Spaced retrieval involves the systematic increase in intertrial intervals during learning and is considered by some to be “effortless,” allowing for it to be a successful strategy with this severity of memory impairment. Some consider spaced retrieval to be an errorless procedure or strategy, whereas others consider it to be differences between the strategies and have argued that recall memory with spaced retrieval is superior to “errorless” strategies.

Using errorless approaches, amnestic individuals have been taught new factual information, novel associations and remotely linked information, as well as face-name associations. Use of spaced retrieval with generalization strategies has been shown to be effective in teaching specific goals and strategies, with evidence of maintenance for up to 1 month following training in mild to moderately impaired TBI patients. Spaced retrieval has also been shown to improve recall of words in TBI individuals with moderate to severe impairments when compared with massed practice. Use of errorless procedures for teaching semantic and procedural knowledge and cued conditions is particularly effective with those with better executive skills. Face-name associations were also more successfully taught using errorless strategies, particularly if preexposure conditions were
included. The benefits of errorless approaches have been shown to extend to route-finding tasks, suggesting that this strategy can facilitate perceptual learning. Spaced retrieval strategies have also been successfully delivered by telephone to patients and associated with positive mastery of treatment goals, which was maintained over time. There appears to be general support for constraining errors, especially with those patients who have more severe memory impairments.

Memory #5. Group-based interventions may be considered for remediation of mild to moderate memory deficits following traumatic brain injury. (Adapted from Cicerone)

Randomized controlled trial evidence has been provided supporting the efficacy of teaching combined internal and external compensatory memory strategies, using errorless learning, in a group format. This intervention was structured over 8 modules, presented in hour-long sessions twice a week for 4 weeks. Results immediately posttreatment and at 1-month follow-up showed that compared with wait-list controls, participants in the treatment group showed improvement in their knowledge of memory strategies, use of memory aids, and more effortful processing and problem-solving strategies, as well as improvements in performance on standardized and functional memory tasks.

A group format has also been used to teach a more structured experimental intervention using the I-MEMS, as referred to earlier in this article, in which multiple internal strategies (semantic association, elaboration, chaining, and imagery) are taught, along with “complementary” external strategies (memory book, PDA, etc) across 12 structured sessions. Training methods combined errorless learning and metacognitive strategies (self-generation and awareness). While gains were made across all levels of memory severity, better outcomes on both standardized and functional tasks were found for mild to moderately memory-impaired patients and for those with better executive cognitive skills. This supports the findings, stated earlier, that individuals with severe memory and/or executive impairments are less able to implement internal memory strategies.

Group instruction in the practical use of memory aids has also been found to increase the number of memory aids used by patients compared with wait-list controls. Group programs that have integrated external and internal strategies while also focusing on fostering social support among memory-impaired patients showed additional benefits in reducing symptoms of anxiety and depression. Preliminary evidence for the efficacy of group instruction in reducing “everyday memory failures” was provided in a 9-week memory notebook treatment program that incorporated both behavioral learning principles and educational strategies for individualizing instruction and provided over 4 stages, anticipation, acquisition, application, and adaptation, with didactic lessons and homework assignments presented by the therapists and regularly reviewed and modifications made as required. Generalization of skills to novel settings was also reviewed. Between-group comparison was conducted relative to a supportive group to examine the effects of a group intervention alone, which alone presented positive results. Memory #6. A trial of acetylcholinesterase inhibitors (eg, donepezil, rivastigmine, etc) may be considered for adults with traumatic brain injury who have deficits in memory. The effects of the medication should be assessed using objective and functional measures. (Adapted from New Zealand Guidelines Group, INCOG)

The cholinergic system has been associated with attention and memory processing and is also a system believed to be highly vulnerable to the damage associated with TBI, as the regulatory systems tend to be diffusely spread through the forebrain and brainstem. Acetylcholinesterase (AChE) inhibitors improve cholinergic transmission and have been associated with slowed decline in memory function in people with Alzheimer disease. In the TBI population, 3 randomized controlled trial studies have evaluated the efficacy of 2 separate AChE medications: rivastigmine and donepezil. Rivastigmine administered to patients with brain injury at a maximum dose of 12 mg daily over 2 titration periods as well as maintenance period was only associated with statistically significant improvements on self-report measures of general memory and attention functioning with no effect evident on standardized cognitive measures. Donepezil administered initially at a dose of 5 mg for 3 weeks and then increased to 10 mg for 3 weeks, the standard dosing for patients with Alzheimer disease, was associated with some improvement on a standardized test of mental control, naming and short-term recall, in a small randomized control trial study involving 26 patients with brain injury compared with matched controls. Increased cortical metabolism was also evident bilaterally across the mid frontal region, posterior parietal area, and temporal and occipital lobes on FDG-PET (fludeoxyglucose positron emission tomographic) scans. Zhang et al used similar dosing in a randomized, placebo-controlled, double-blind, crossover trial involving a relatively small sample of 18 individuals with TBI who were in the post–acute phase of recovery. Improvements were found during the period of medication administration on standardized measures of attention using the PASAT (Paced Auditory Serial Addition Test) and immediate auditory and visual recall, with sustained effects through the “washout” phase.

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techniques were developed following the concept of computer. Computer-based restorative rehabilitation donepezil and vitamin E combination with a therapist with a focus on strategy development and compensatory strategies, and only if developed in conjunction rehabilitation strategies with evidence-based instructional and that it should only be considered to develop adjunct memory performance. Guidelines in using such techniques indicate training show no evidence in enhancing sustained memory performance. Memory #7. Restorative techniques such as computer-based computer programs integrating hierarchically based training in which task difficulty is increased as more basic skills are demonstrated can be more effective. However, general outcome data showing gains are confined to psychometric and structured therapy tasks, although there is also some evidence for changes in neuroimaging. The functionality of such changes with respect to reduction in disability or generalization of skills into daily activities has not been demonstrated, especially for independently used programs. In a review article, it was suggested that computer-assisted memory training is most likely to be effective if sessions are therapist-driven, train basic memory skills, and integrate those skills into ecologically valid tasks, tailored to the patient with brain injury and generalized into practical tasks. In a prospective cohort study, computerized training (Cogmed QM), combined with coaching during the training sessions by therapists, education regarding the functional integration of strategies, as well as peer support (30 minutes to exchange experiences), was effective in improving functioning on daily tasks in a sample of participants with moderate to severe memory impairments. This demonstrated that computer training alone was not effective in improving performance on functional tasks but should be combined with instructional and compensatory strategies.

The remaining studies were typically open-label trials. They included 2 studies incorporating larger sample sizes, 5 with smaller numbers of participants, and single and case series designs. All involved donepezil titrated to 10 mg daily over 3 to 4 weeks. The exception to this was the Tenovuo study, which also included description of the effects of treatment with other central AChE inhibitors, rivastigmine and galantamine. Generally, very modest positive effects were evident on standardized measures of memory and/or self-report of cognitive symptoms and no significant difference was found between any of the 3 central AChE inhibitors used. In addition, improvements in executive functioning using fluency and trail making tests as well as affective symptoms were also associated with the use of donepezil. Using a block design matching procedure for control subjects compared with 36 patients with brain injury, donepezil treatment was associated with modest improvements only in cognition for the patients who were earlier in the acute rehabilitation process (about 1 month) relative to those closer to the 3-month stage. However, it was opined that the poorer results of this study may have been related to the use of FIM (Functional Independence Measure) change and efficiency scores to assess cognition, whereby ratings are provided by therapists, rather than performance-based measures of cognition. Improvement in general clinical abilities was also noted by therapist-raters for patients using a donepezil and vitamin E combination and when family members’ ratings of the patient were integrated. Currently, the evidence indicates very modest results using central AChE inhibitors to improve memory in patients with brain injury. Future studies should use more prospective, randomized, double-blind, placebo-controlled, clinical trials, with randomization stratified for age, injury severity, and time since injury.

Restorative techniques differ from compensatory techniques in that they focus directly on restoring impaired cognitive functioning through repetitive exercises performed in massed practice trials. These involved paper-and-pencil tasks prior to current technological advances and now are generally delivered via computer. Computer-based restorative rehabilitation techniques were developed following the concept of neural plasticity to remediate cognitive impairments associated with injury to the brain. Recently, these technologies have been advocated in nonclinical populations, with a substantially growing application of such techniques with older adults and with children, as well as with neurologically injured populations, with the goal of improving cognitive function or, in the case of older adults, slowing decline. There is, however, no substantive evidence to indicate improvement in memory functions beyond the trained tasks. This was demonstrated in a randomized controlled trial involving more than 11 000 viewers of a popular BBC show. Two experimental groups logged on and performed specific training tasks modeled after those commercially available, whereas the control group spent the same amount of time answering obscure questions from 6 categories. After 6 weeks, no improvement was found on standardized tests of cognitive skills, including memory. Computer-based brain training as a restorative technique has gained clinical popularity in the brain injury population, with weak and mixed outcomes from preliminary studies that are typically poorly controlled. One study using a within-subject pre-post design evaluated a remotely delivered series of structured exercises to patients in their homes. Variable results were found, with some positive association between subjective reports of improvement in cognitive ability and performance on the Automated Neuropsychological Assessment Metrics (ANAM4). A literature review has suggested that computer programs integrating hierarchically based training in which task difficulty is increased as more basic skills are demonstrated can be more effective. However, general outcome data showing gains are confined to psychometric and structured therapy tasks, although there is also some evidence for changes in neuroimaging. The functionality of such changes with respect to reduction in disability or generalization of skills into daily activities has not been demonstrated, especially for independently used programs. In a review article, it was suggested that computer-assisted memory training is most likely to be effective if sessions are therapist-driven, train basic memory skills, and integrate those skills into ecologically valid tasks, tailored to the patient with brain injury and generalized into practical tasks. In a prospective cohort study, computerized training (Cogmed QM), combined with coaching during the training sessions by therapists, education regarding the functional integration of strategies, as well as peer support (30 minutes to exchange experiences), was effective in improving functioning on daily tasks in a sample of participants with moderate to severe memory impairments. This demonstrated that computer training alone was not effective in improving performance on functional tasks but should be combined with instructional and compensatory strategies.
DISCUSSION

Overall, there is evidence that, while restorative memory training in itself is unlikely to be efficacious in restoring impaired memory, both internal and external memory strategies may be used successfully to alleviate memory difficulties in individuals with TBI. The extent to which these may be effective depends, however, on a number of factors. Internal strategies are only likely to be effective in individuals with sufficient motivation, self-awareness, and executive function to be able to identify the situations in which they are applicable and follow through with using them. Thus, the evidence would suggest that they are more appropriate for use in individuals with mild-moderate memory impairments. Those with more severe memory impairments are more likely to benefit from external strategies, which will also be of assistance to people with mild-moderate memory problems. The nature of the most appropriate external strategy will depend on the individual’s age and previous experience with technology, his or her literacy, preinjury use of memory aids, and the availability of a support person to facilitate the use of aids. Both errorless learning and spaced retrieval techniques are effective methods of learning in individuals with TBI. However, studies have consistently shown that all interventions are more likely to be effective if tailored to the individual and applied in the context of the individual’s daily life. More comprehensive, well-designed trials incorporating appropriate blinding and use of both objective and everyday functional measures of memory are needed to establish the efficacy of anticholinesterase inhibitors in alleviating memory impairments. Sufficient well-controlled studies do not exist supporting the independent use of restorative techniques such as computer-based programs as a strategy to restore impaired memory processes. Rather, the evidence to date suggests that such techniques may be considered if used in conjunction with compensatory techniques, occur with a therapist, are strategy-driven, and the skills learned are translated to functional tasks.

REFERENCES


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