Evidence-based Cognitive Rehabilitation

Chapter 1
Interventions for Attention and Working Memory
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The ability to pay attention and hold information in working memory (WM) has long been recognized as important for many cognitive tasks. Attempts to strengthen or remediate attention and WM through repetitive practice of select tasks are known by a variety of names, but they typically involve interventions designed to enhance targeted cognitive skills. This chapter will first briefly explore the conceptualization of attention and WM, discuss how deficits are affected by developmental age and severity of impairment, and describe general theoretical approaches to cognitive rehabilitation. Next, meta-analytic research will be reviewed. Several common standardized interventions will then be presented. Practical and clinical applications will be briefly discussed and the chapter will end with a case example. This chapter touches on research and/or treatment recommendations for children and adolescents with a history of brain injury, attention-deficit/hyperactivity disorder (ADHD), cancer, seizures, low birth weight, malaria, and human immunodeficiency virus (HIV).

Definitions of Attention and Working Memory

The conceptualization of attention and associated neurological mechanisms has evolved over the course of the last century. In 1958, Broadbent introduced the human information-processing approach and suggested that attention involves responding to select stimuli in the environment while inhibiting responses to competing stimuli. Subsequent information-processing models can be categorized into two broad classes: early-selection theories and late-selection theories. Early-selection theories posit perceptual suppression of non-target stimuli prior to attentional processing while late-selection theories suggest that non-target stimuli are perceived but not selected for further processing.

Attention can be subdivided into components such as attentional orientation (directing attention to a stimulus), selective attention (focusing attention on one stimulus while ignoring another), sustained attention (maintaining attention across time), and divided attention (dividing attention across multiple stimuli). Subcomponents of attention appear to involve distinct neural substrates, and it has been theorized that attention may be strengthened through cognitive training, which could lead to improvements in executive functioning and possibly behavioral control.

The construct of attention was later expanded to include WM (working memory), composed of four processes: (1) the central executive, which holds information in short-term storage while the attentional focus shifts to other stimuli, (2) the visual-spatial sketchpad, (3) the phonological loop, which briefly stores and allows manipulation of visual and phonological material, and (4) the episodic buffer, which binds information across visual, spatial,
and verbal domains, as well as across time so that it can be stored in memory.\(^7\) This theory of information processing is useful as it allows for multiple levels of attentional processing. Although there are a variety of WM models,\(^8,9\) there is evidence that both attention and WM are domain-specific and can be either verbally or visually mediated in the pediatric population.\(^10\)

For the purpose of this chapter, attention is considered to be the ability to maintain focus on a stimulus whereas WM is conceptualized as the ability to cognitively hold and manipulate information in mind.\(^3\) Although many of the theoretical models of attention do not offer clinical techniques to remediate deficits, they define the constructs of attention and WM and provide foundations on which rehabilitation intervention programs have been developed.

Deficits in attention and WM have a variety of congenital and acquired etiologies and occur across a spectrum of impairment. Poor attention and/or WM difficulties appear to play a significant role in ADHD,\(^11,12\) autism spectrum disorders,\(^13\) and language impairments.\(^14\) Although frontal lobes are widely considered important in attention and WM, damage to multiple brain regions such as the cerebellum, basal ganglia, or white matter pathways can also result in deficits.\(^15,16\) Disruption of attention and WM can range from mild to severe, and although functioning usually improves over time, difficulties may persist for months or years after an injury, and full recovery may never occur.\(^3,17\)

Attentional control has been hypothesized to act as a gating mechanism for the acquisition of other cognitive skills such as reading,\(^18\) language,\(^14\) and mathematical skills.\(^19\) In fact, because poor attention can impact later recall, attention deficits following brain injury are sometimes undiagnosed or miscategorized as memory deficits.\(^3\) It has been hypothesized that increased WM capacity will result in gains in skills dependent on WM.\(^20,21\) Research about the generalizability of WM interventions frequently refers to “near-transfer” and “far-transfer” effects.\(^20,22\) Essentially, near-transfer effects occur when WM performance gains generalize to tasks similar to the training task (e.g., digit span), and far-transfer effects occur when WM performance gains generalize to tasks dissimilar from training tasks (e.g., reading comprehension).\(^22\)

### Age and Development

Unlike in adults, in children insults to the pediatric brain occur in the context of rapid cognitive maturation, and it is important to consider a developmental perspective when evaluating attention and WM.\(^23\) There has been a considerable debate in the field regarding the impact of pediatric brain injury on the developing brain. Central to this debate are two theoretical perspectives: (1) “early plasticity,” which suggests that an immature brain has greater flexibility and potential for good recovery and (2) “early vulnerability,” which argues that a young brain is more susceptible to poor outcome.\(^24,25\) In their 2011 review, Anderson et al.\(^24\) argued that these competing theories represent extremes along a “recovery continuum,” with recovery dependent on injury-related factors (e.g., severity and timing of insult), individual factors (e.g., developmental stage, cognitive status, gender), and environmental factors (e.g., family interaction, access to treatment), which together contribute to the broad spectrum of outcomes.

In terms of early plasticity, evidence suggests that functional neural networks are not fully developed at younger ages, and WM and attentional control may have more potential to be remediated earlier in development.\(^26-28\) There is also indication that different brain structures are used to perform the same cognitive task at various ages. For example, in
laboratory studies, adolescents and adults have been found to use the dorsolateral prefrontal cortex and parietal regions during a visual-spatial WM task, whereas children utilize the caudate nucleus and anterior insula to complete the same task. With regard to early vulnerability, skills not yet developed at the time of neurological insult may be deficient later in development, and existing skills may lag as cognitive demands increase with age. For instance, deficits in auditory-phonological WM may not be immediately obvious in young children but may become more problematic later on, because auditory-phonological WM becomes more dominant than visual WM as children learn to read. Finally, children utilize different cognitive strategies at varying developmental stages, with early injuries possibly affecting the use of emerging strategies. In general, this evidence supports the use of a developmental framework when clinically assessing and facilitating interventions for attention and WM, and when evaluating research on interventions for attention and WM.

Wass et al. identified 37 studies that examined whether participant age was correlated with generalization of intervention-trained attentional and/or WM skills to other cognitive functions (i.e., degree to which skills transfer). Sixteen of the studies included pediatric samples, and the age range across studies was 11 months to 96 years. The authors grouped research studies into either mixed-attention studies (i.e., studies that targeted subcomponents of attention such as sustained attention and switching) or studies that explicitly trained WM. When all the studies were pooled together, a weak but significant correlation between the degree of transfer of training effects and age of participants was found, particularly when using the length of treatment as a covariate because different age groups tend to receive varying lengths of interventions. In addition, there was more transfer of training for the group of WM studies than there was for the mixed-attention studies, which could be explained by the heterogeneity of attentional subcomponents targeted in the mixed-attention group. Overall, younger individuals showed a larger degree of transfer of training. Taken together, the evidence suggests that cognitive development should be considered when planning attention and WM rehabilitation in the pediatric population.

**Theoretical Approaches to Attention and Working Memory Interventions**

Multiple theoretical approaches have been advocated over time to address attention and WM deficits. They can broadly be classified as (1) restorative interventions involving retraining, (2) functional adaptations involving compensatory techniques, and (3) holistic context-sensitive approaches that involve both environmental and behavioral modifications. In general, intervention approaches are influenced by the setting in which they are implemented. For example, patients in acute care settings often require interventions to facilitate skills related to basic functioning while patients in inpatient rehabilitation settings are more likely to require techniques focused on restoring previous skills or compensating for new impairments. Partial hospitalization allows practitioners to implement and reinforce compensatory strategies with patients while simultaneously providing them the opportunity for skill practice and implementation in the community. Outpatient interventions can involve ongoing therapy and support for independent functioning with developing skills. Holistic school-based interventions may also be appropriate for the pediatric population. Online and computerized programs allow for home practice and also may be particularly useful for individuals who have isolation precautions during treatment due to lowered immune functioning or high contagion.
Measurement of Attention and Working Memory
When interpreting research data on the effectiveness of attention and WM interventions, it is important to acknowledge that how attention and WM are measured can affect research outcomes and subsequent conclusions. For example, simple measures of attention such as recalling a span of digits may be inadequate for the measurement of WM. More complex measures, such as inhibiting an overlearned skill of reading while identifying ink color (i.e., the Stroop task), have also come under scrutiny because the task is sometimes used to measure selective attention and at other times used to assess WM. There are also concerns about the use of parent and teacher ratings because the subjective nature of rating scale and unblinded raters may result in apparent improvement due to the Hawthorne effect (i.e., alterations in behavior that occur when individuals are aware of being observed). However, rating scales, which may have better ecological validity than performance-based tests, can be useful measures of attention and WM training effects in daily life.

Formation of Practice Recommendations
About 20 years ago, investigators began examining the effectiveness of attention and WM interventions in the pediatric population, and in the last decade there has been an explosion of published studies on their efficacy. Despite increased interest and improved methodology, contrasting findings are not uncommon. Comparisons between research studies can be complex, as conclusions appear to be influenced by a number of factors, such as definition and measurement of attention and WM, type and length of interventions, variety of measures used to examine effectiveness, age of participants, type of control group, and population characteristics.

Several formal systems for reviewing the literature have been developed. The American Academy of Neurology (AAN) clinical practice guidelines are one example of how strength of studies can be classified. The AAN guidelines provide a basis for evidence-based practice recommendations, and classify studies based on the type of study and strength of evidence, ranging from less robust empirical evidence (i.e., Class IV) to randomized clinical trials with masked outcomes (Class I). See Table 1.1. Once available research is classified, the body of research can be examined to determine if evidence suggests treatment should be considered as a Practice Option, a Practice Guideline, or a Practice Standard (see Box 1.1). At present, there is no consensus in the literature about the efficacy of cognitive rehabilitation for attention and WM in the pediatric population; however, this chapter will identify when Practice Options, Guidelines, or Standards have been recommended in specific pediatric populations based on available research.

Meta-Analyses of Attention and Working Memory Training
A number of meta-analyses have been published in recent years on the available research. In 2013, Melby-Lervåg and Hulme conducted a meta-analytic review of 23 randomized controlled trials and quasi-experimental studies in typically developing children and adults to examine WM training efficacy in healthy individuals. The results suggested reliable short-term improvements in WM. The long-term effects appeared domain-dependent, with limited evidence for visual-spatial WM but not for verbal WM. The authors suggested variations in age and clinical trial differences impacted results, and concluded that findings do not
support using WM training programs to enhance cognitive functions in typically developing individuals.

That same year, Lauguenbahn et al. reviewed 34 cognitive rehabilitation studies including children and adults across 8 medical diagnostic categories affecting cognitive functions. This review supported a Practice Guideline for treating attention or memory deficits in children and adolescents who undergo treatment of brain tumors. In addition, a Practice Option for the treatment of seizure-related deficits in attention and memory was recommended.

In 2014, Robinson et al. conducted a systematic review and meta-analysis of cognitive interventions for children with neurological disorders, acquired brain injury (ABI), and neurodevelopmental disorders (i.e., ADHD). They included 13 randomized controlled trial studies and determined that there was a large effect size for attention and working memory treatments. However, there were concerns about heterogeneity of results and quality of evidence, so treatment recommendations were not proposed.

Most recently, a 2016 meta-analysis of 87 pediatric studies did not show reliable improvements in the generalization of WM skills after cognitive rehabilitation. The review examined whether WM training resulted in far-transfer generalization to intelligence and other cognitive domains (i.e., nonverbal ability, verbal ability, word decoding, reading comprehension, and arithmetic). All studies included control groups (either treated or

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**Box 1.1 Definition of Practice Recommendations**

| Practice Standard | Evidence from at least one well-designed Class I study and other Class II or Class III studies. Effectiveness of treatment for individuals with acquired neurocognitive impairment needs to be **substantially evident**. |
| Practice Guideline | Evidence from one or more Class I study with methodological limitations, or several well-designed Class II studies. Effectiveness of treatment for individuals with acquired neurocognitive impairment needs to be **probable**. |
| Practice Option | Evidence from Class II or Class III studies. Effectiveness of treatment for individuals with acquired neurocognitive impairment needs to be **possible**. |

From Cicerone et al. (2011)

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**Table 1.1 Classification of Intervention Studies**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Evidence in Representative Population</th>
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<tr>
<td>Class I</td>
<td>Prospective studies with randomized groups and blinded, well-defined outcome measure(s). Must include clearly delineated inclusion/exclusion criteria, independent groups, limited participant withdrawal, and balanced group characteristics.</td>
</tr>
<tr>
<td>Class II</td>
<td>Prospective, nonrandomized, matched cohort studies with blinded outcome measure, or randomized controlled studies with a substantial flaw.</td>
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<tr>
<td>Class III</td>
<td>Other controlled studies that include independent assessment of outcomes or outcomes are independently attained via objective measures.</td>
</tr>
<tr>
<td>Class IV</td>
<td>Research not meeting Class I to III guidelines, including uncontrolled studies, case reports, or expert opinions.</td>
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Source: Edlund et al. (2004).
untreated), as well as pre- and post-test measures. The authors concluded that WM training produces short-term specific training effects, but does not demonstrate generalization to real-world cognitive skills.

There is a growing body of research specifically examining cognitive interventions in the pediatric ADHD population. While some individual studies have concluded that deficits of attention and WM significantly improve following massed practice exercises of attention\(^{49,50}\) and WM,\(^{11,51,52}\) meta-analyses for this population suggest that cognitive training may improve immediate attention for near-transfer effects, but is either unsupported for long-term improvement in attention and far-transfer effects\(^{40}\) or has limited to no effects when using blinded raters or active control groups.\(^{53}\) WM training alone has been shown to be less effective than multi-process approaches for the reduction of ADHD symptoms.\(^{53}\)

As with ADHD, research on attention and WM training in children with brain injuries has expanded over time. However, the body of literature remains somewhat limited. In 2005, a review of available research by Limond and Leeke identified only 11 relevant studies with a total of 54 participants.\(^{54}\) Additionally, the authors were unable to draw conclusions about practice recommendations based on the available evidence. Later reviews in 2013 and 2014 also determined that there was not enough evidence to make definitive treatment recommendations.\(^{55,56}\) More recently, a 2016 meta-analysis focusing on WM interventions and brain injury included 103 adult and pediatric studies; in these studies, 1,585 of the 6,113 participants were children and adolescents with WM deficits.\(^{57}\) All groups in the meta-analysis, including pediatric populations, showed improvement in WM functioning, and participants (adult and pediatric) with ABI showed a trend for higher effect size. Although research in the adult literature suggests a Practice Standard for rehabilitation of attention during post-acute recovery following brain injury\(^{42}\) and a Practice Option to provide clinician-guided computer interventions,\(^{42}\) pediatric research only suggests a Practice Guideline for rehabilitation of attention to children and adolescents in recovery from acute brain injury.\(^{46}\) However, these practice recommendations are arguably based on dated reviews given the amount of research published in this area over the last decade.

Overall, meta-analytic results suggest the effectiveness of attention and WM rehabilitation in the pediatric population may be population- and domain-specific, which limits broad conclusions. Continued population-specific research, particularly Class I studies, will likely prove useful.

**Cognitive Rehabilitation Programs**

Although the structural and functional neuronal correlates are not yet fully understood, cognitive rehabilitation programs operate on the premise that training of attention and WM in the pediatric population may result in skill improvement.\(^{17,58}\) A variety of formal attention and WM training interventions have been developed, with many administered in the form of computer programs. Most of these interventions are adaptive, meaning the difficulty of tasks is adjusted to individual performance.\(^{20,59}\) By requiring an individual to perform repetitive tasks with WM demands somewhat higher than his or her current ability, the assumption is that practice will increase WM capacity.\(^{20,43,59}\) The level of support required by trained professionals and guardians varies by program. Several of the commercially available programs are described in this chapter, although the list is not comprehensive. See Table 1.2. There is a rapidly expanding literature base on cognitive rehabilitation programs, so only seminal or recent research will be included in this chapter.
<table>
<thead>
<tr>
<th>Program and Publisher</th>
<th>Core Components</th>
<th>Age Range</th>
<th>References</th>
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<tbody>
<tr>
<td><strong>Pay Attention</strong>&lt;sup&gt;62&lt;/sup&gt; Lash and Associates Publishing/Training, Inc., 2005</td>
<td>Computer-based attention exercises for children with history of brain injury or attention difficulties. Tasks use visual and auditory stimuli to target sustained, selective, divided, and alternating attention. Progress is measured by speed and accuracy with tasks increasing in difficulty. Clinicians provide immediate feedback about performance, communicate with caregivers, and emphasize home and school skill implementation.</td>
<td>4–10 years</td>
<td>ADHD: Tamm et al., 2013&lt;sup&gt;1&lt;/sup&gt;</td>
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<tr>
<td><strong>Cogmed Working Memory Training (CWMT)</strong>&lt;sup&gt;63&lt;/sup&gt; Pearson: cogmed.com</td>
<td>Computerized, massed-practice attention and working memory tasks designed to resemble a video game; facilitated by a certified coach. Includes initial interview, weekly phone coaching calls, access to the online coaching center, wrap-up session, and 6-month follow-up interview. JM – Five training sessions a week for 5 weeks; each session lasts about 25 min; seven total visual-spatial exercise, three per day; daily reward is new item in aquarium RM – (standard protocol) 50-min sessions; five a week for 5 weeks; 11 different visual spatial and phonological exercises; five to eight exercises per day; reward is racing game. QM – combination of 10 visual-spatial and verbal exercises conceptually similar to JM and RM, but are presented in more basic displays; variable protocols available depending on training time. Key feature of RM and QM: Complexity of exercises is dynamically adapted to participant performance.</td>
<td>Pre-school (Cogmed JM) Children (Cogmed RM) Adult (Cogmed QM)</td>
<td>TBI: Phillips et al., 2016&lt;sup&gt;27&lt;/sup&gt; Pediatric cancer: Conklin et al., 2015&lt;sup&gt;29&lt;/sup&gt; Low birth weight: Løhaugen et al., 2001&lt;sup&gt;17&lt;/sup&gt; Low IQ: Söderqvist et al., 2012&lt;sup&gt;28&lt;/sup&gt; ADHD: Klingberg et al., 2005&lt;sup&gt;15&lt;/sup&gt; Meta-Analysis: Spencer-Smith and Klingberg, 2015&lt;sup&gt;16&lt;/sup&gt; Research Disparity: Shinaver et al., 2014&lt;sup&gt;19&lt;/sup&gt;</td>
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*Table 1.2 Select Commercially Available Cognitive Rehabilitation Programs*
Table 1.2 (Cont.)

<table>
<thead>
<tr>
<th>Program and Publisher</th>
<th>Core Components</th>
<th>Age Range</th>
<th>References</th>
</tr>
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</table>
| **Captain’s Log**<sup>45</sup>  
MindPower Builder  
Brain Train; braintrain.com | Online “brain-training” exercises purported to help improve attention and other cognitive skills. Over 2,000 different exercises to keep training challenging; progress automatically logged. Encrypted performance data are accessible to clinicians over the internet and the company offers optional EEG biofeedback training to complement the program. Typical length of program includes 20–40 hours of cognitive training across 3–6 months supervised by a “brain coach.” | 5+ years | Malaria: Bangirana et al., 2009<sup>99</sup>  
HIV: Boivin et al., 2010<sup>102</sup> |
| **CogniFit**<sup>46</sup>  
CogniFit; cognifit.com | Computerized online training program claiming to target 23 cognitive skills, including attention and working memory; advertised as both a diagnostic and an intervention tool for neurodevelopmental disorders such as ADHD. Exercises and games for the pediatric ADHD component are completed in 20-min sessions, 2 to 3 days per week. Program creates an automatic progress report. | 6–13 years for ADHD | |
| **Jungle Memory**<sup>47</sup>  
Jungle Memory; junglememory.com | Self-directed online training program advertised to train students to use working memory. Suggested use is 15–30 min a day, four times per week; 8-week subscription; games are dynamically adaptive to skill level; online progress tracking system is provided. | 7–16 years | |
| **Lumosity**<sup>48</sup>  
Lumos Labs; lumosity.com | Online “training” games intended to target working memory, attention, and other cognitive skills; accessible using a variety of electronic devices; suggested frequency of daily; tasks adapt to skill level; program includes a baseline assessment score as well automatic training history score reports. Several condition-specific activities are available on an experimental basis. | “Any age” | Pediatric cancer: Kesler, et al., 2011<sup>117</sup> |

ABI = acquired brain injury; ADHD = attention-deficit/hyperactivity disorder; EEG = electroencephalogram; HIV = human immunodeficiency virus; TBI = traumatic brain injury.

Commercially Available Programs for the Pediatric Population

**Attention Process Training**

Sohlberg and Mateer’s Attention Process Training (APT) was originally designed as a multi-dimensional program incorporating hierarchically graded massed-practiced exercises...
designed to strengthen a variety of attention skills (e.g., focused attention, sustained attention, selective attention, alternating attention, and divided attention). Exercises include visual, auditory, and oral tasks. Criteria for advancement to more difficult tasks are dependent on individual performance. The most recent version, APT-3, is a computer-based program providing the clinician with streamlined data collection, analyses, and treatment planning. The training approach has also been expanded to include Pay Attention! Attention Training for Children (ages 4–10 years). Pay Attention! targets sustained, selective, divided, and alternative attention with both visual and auditory stimuli designed for children in a structured, but flexible system. Tasks increase in difficulty over time, and progress is measured in terms of both speed and accuracy. Children are provided immediate feedback about their performance as well as prompts on how to implement targeted skills in the home and school settings. Caregivers briefly meet with the Pay Attention! provider after each session to review skills being trained and how to support implementation outside of a clinical setting.

APT was initially created for rehabilitation of attention deficits in adolescents, adults, and veterans with a history of ABI, and Sohlberg and Mateer first trialed APT strategies on four adults with a variety of brain injuries and time since injury. The individuals were evaluated using a single subject, multiple baseline design, and results indicated all individuals showed significant gains in attention on a task requiring serial addition of aurally presented numbers. Improvements in attention remained at the final assessment 8 weeks post treatment cessation. The program showed domain specificity, as rehabilitation of visual processing did not result in improved attention. Later, a pilot study on the efficacy of Pay Attention! demonstrated that 54 children diagnosed with ADHD who completed the program for 12 weeks had significantly improved parent and clinician (but not teacher) ratings of executive functioning symptoms compared to a waitlist control group. Although there was improvement in strategic planning on post-testing, no improvements in attention and WM were shown on cognitive testing, suggesting that there can be functional symptom improvement in the absence of neuropsychological assessment findings.

CogMed Working Memory Training

One of the most widely researched and available programs is CogMed Working Memory Training, also known as Cogmed or CWMT. The official website claims the program is a solution for individuals who are held back by limited WM capacity, and by improving WM, individuals are better able to pay attention, resist distractions, self-manage behavior, and complete tasks independently. CWMT is a computerized training program with three versions for different age groups. An integral component of CWMT is intervention with a qualified coach who provides structure, encouragement, and feedback throughout the training. According to CWMT, this coaching model is largely responsible for a 90 percent training completion rate.

CWMT has been studied with a variety of populations, and independent research is encouraged by the publisher, with completed and ongoing studies available on the official CWMT website. CWMT reports that as of March 2016, there were 80 original studies examining the efficacy of CWMT published in peer-reviewed journals, approximately half of which address the pediatric population, and a fourth of which address pediatric populations with brain injuries or neurological disorders such as ADHD. The publisher suggests that the body of research demonstrates CWMT can lead to sustained improvements in WM for individuals starting as early as preschool, sustained improvements on subjective and objective measures of attention, changes in
neurochemistry and functional connectivity, improved attention for individuals diagnosed with ADHD on rating scales and objective measures, improved cognitive functioning during daily activities, and improved cognitive control. A comprehensive review of all individual research studies supporting claims that CWMT improves WM is beyond the scope of this chapter, but select studies of pediatric populations with neurologic involvement are presented below followed by a summary of recent meta-analyses.

In a 2016 study, 27 children with mild to moderate Traumatic Brain Injury (TBI) were assigned randomly to either adaptive WM training (CWMT) or non-adaptive WM training (i.e., modified CWMT that did not increase in difficulty), and then assessed by double-blind procedures. There were no significant gains on tests of attention, but participants in the adaptive intervention group showed significant gains on measures dependent on the visual-spatial sketchpad (i.e., visual WM capacity). The results for the adaptive training also showed far transfer to reading, but not math. These results suggest that in the TBI population, WM training is most effective when interventions are adapted to individual performance.

In a study examining the long-term efficacy of CWMT in pediatric cancer survivors, functional magnetic resonance imaging demonstrated that immediate improvements in attention and WM following CWMT corresponded with reduced activation in left lateral prefrontal and bilateral medial frontal areas. There were no group-level improvements in WM from midway through the intervention to post-intervention.

Children who are born at extremely low birth weight (ELBW) can be at risk for a variety of cognitive deficits, including impaired attention. Løhaugen and colleagues examined the effects of CWMT in a group of adolescents who were born at ELBW and compared them to full-term birth control participants who received the same training and full-term birth control participants who did not receive training. Participants in both the trained control and ELBW groups demonstrated an increase in performance on both trained and untrained WM tasks at 6 months post-intervention, which suggests that WM training has a lasting effect and generalizes beyond task-specific learning for this population. Pre- to post-assessment results were not significantly different for the non-intervention group. These results have since been replicated in the preschool-age population.

Soderqvist and colleagues examined WM interventions in 41 participants aged 6–12 who had an IQ of less than 70. Participants were randomized into either 5 weeks of adaptive CWMT training or into a non-adaptive version. Female participants with and without comorbid diagnoses, and those with higher baseline WM performance showed the most improvement. However, there were no significant effects after 1 year.

A growing number of reviews and meta-analyses examining CWMT are available, and the varying conclusions regarding efficacy have prompted considerable professional debate. For example, Shipstead et al. and Shinaver et al. argued in their respective reviews about the effects of CWMT. Of note, Shinaver et al., who provided much more favorable conclusions, were affiliated with Pearson, the commercial publisher of CWMT, at the time of their publication.

In 2013, Melby-Lervåg and Hulme conducted a meta-analysis of 23 studies with 30 group comparisons and concluded that CWMT may be more effective than other treatment programs. However, the studies included both children and adults and only eight of these studies utilized CWMT, so over-interpretation of results in a pediatric population is cautioned. This meta-analysis revealed that improvements in visual-spatial WM tasks across studies were highly significant. The type of training program was the only significant...
moderator for training effects of visual-spatial WM tasks, with the most improvement noted after training with CWMT. The meta-analysis also showed immediate, but not sustained improvements in verbal WM. Despite their conclusions that WM training programs produce reliable short-term WM skill improvement, the authors argued that there is not convincing evidence for generalization of skills. Melby-Lervåg and Hulme concluded that although the results suggested a significant sustained effect for visual-spatial WM, due to the limited immediate effects of training in the included studies, more research is needed to further understand the long-term effects of this training. However, Shinaver and colleagues argued WM training might be a catalyst for WM improvements, thus resulting in continued WM expansion over time. Melby-Lervåg and Hulme concluded that there is no evidence for generalization of these findings to other cognitive areas.

More recently, Spencer-Smith and Klingberg (one of the initial developers of CWMT) examined 12 randomized controlled trials evaluating CWMT with children and adults, and showed a moderate and significant training effect on inattention in daily functioning, as measured by parent, teacher, and self-ratings of inattention and ADHD symptoms on several widely used scales and questionnaires. This effect was observed for different groups (children, adolescents, and adults; individuals diagnosed with ADHD or at risk of impaired WM), and the effect did not change significantly depending on study methodology (type of control group or type of measure). Seven of the studies included in the meta-analysis reported persistent training effects for inattention in daily life (i.e., decrease in ADHD symptomology or improvement on behavior ratings) following a delay after completing CWMT. There was a small to moderate and significant effect for persisting benefits of CWMT after 2–8 months, and seven of the studies showed large and significant effect of CWMT on near-transfer measures of visual-spatial WM and verbal WM performance. The authors concluded that the CWMT program has clinical benefit for inattention in daily life for children, adults, and those with and without ADHD. However, Dovis et al. wrote letters to the editor detailing significant coding errors in the meta-analysis, as well as concerns regarding publication bias. After their corrections, they reported that the meta-analysis no longer indicated a significant overall effect of CWMT training on inattention. Additionally, statistical conclusions in the subgroup analyses differed; in particular, training effects were no longer significant for children and adolescents. Although Spencer-Smith and Klingberg published a formal correction, Dovis et al. later responded by pointing out that multiple concerning errors remained, and had not actually been corrected (e.g., post-test ratings were not compared to pre-test ratings).

Overall, CWMT is one of the most researched and publicly available training programs for the pediatric population. However, the body of research shows high levels of variability, and inconsistencies in conclusions have proved to be controversial. Continued research, particularly well-designed, large, multicenter studies of specific pediatric populations with neurologic involvement, is recommended in order to better inform rehabilitation guidelines. In addition, given concerns of researcher bias, further studies and meta-analyses conducted by non-CWMT affiliated researchers may provide additional clarity.

Additional “Brain Training” Programs

Other commercially available interventions include Captain’s Log MindPower Builder, a computerized cognitive rehabilitation therapy for attention and memory; Cognifit, an online training program that claims to target 23 cognitive skills; Jungle Memory, an online training program designed for youth between the ages of 7 and 16, and Lumosity, an online
training program that uses games designed to target a variety of cognitive skills, including attention. There are fewer studies on the efficacy of these programs in the pediatric population compared to the APT and CWMT programs. However, research may change as additional programs become commercially available.

In 2009, Bangirana studied the efficacy of Captain’s Log program with 62 children between the ages of 7 and 12 years who had a history of malaria and impaired attention. Compared to a control group, the treatment group showed improvement in WM. However, investigators were not blinded to group assignment, increasing the potential for bias in the results. In 2010, the effect of attention training using the Captain’s Log was investigated in a population of 60 children diagnosed with HIV. Participants were randomly assigned to the intervention group and subsequently completed 10 sessions, while the control group did not receive any intervention. Post-testing showed that participants in the intervention group had improved attention skills. In a study of 23 pediatric cancer survivors, intervention with Lumosity resulted in improvement for several cognitive domains, although not specifically for WM or attention.

Given the rapid pace of technological advances across the past several decades, the development of competing commercially available brain training programs is not unexpected. However, the strength of the literature for commercially available programs varies by program.

In general, programs tend to include clinician or trainer support. In addition, research appears to suggest that attention and WM training may be more effective in rehabilitation populations compared to healthy controls. Overall, more well-designed randomized controlled trials are needed to reach a consensus on the efficacy of these programs.

Non-Commercially Available Programs

Cognitive Remediation Program

Butler and Copeland developed the Cognitive Remediation Program (CRP) in an effort to remediate attention deficits in survivors of pediatric cancer by combining methods and techniques from three disciplines: (1) brain injury rehabilitation, (2) educational psychology, and (3) clinical psychology. From the brain injury rehabilitation field, the CRP utilizes Sohlberg and Mateer's APT program described earlier. From the educational field, a collection of approximately 15 metacognitive strategies designed to address preparedness, task approach, on-task behavior, and generalization are gradually introduced over the course of the program. These strategies are organized into three categories: (1) task preparation, (2) on task, and (3) post-task strategies. Examples of “task preparation” strategies include creating a magic/special word or term that serves as a cue, completing a brief breathing exercise, encouraging a game face (to use a sports analogy) and best performance by striving for a world record, and using an organized task approach (e.g., start at the top left and complete one row at a time). On-task strategies involve maintaining self-encouraging and self-alerting internal dialogue, and monitoring one’s own performance. For instance, children are taught to continually remind themselves what they are supposed to be doing, mark their place, look for shortcuts, take a break or start over if task is too difficult, monitor distractions by staring at a blank surface (look at the floor), and ask for help. Post-task strategies include checking work, asking for feedback, and rewarding effort. From the field of clinical psychology, cognitive behavioral interventions are employed with the goal of improving self-regulation of attention and behavior. These interventions include modeling positive self-talk, challenging negative beliefs, and overt practice of encouraging internal...
dialogue and acquired metacognitive strategies. Mnemonic strategies such as visual imagery and chunking are also taught to individuals.

In a 2002 pilot study, 21 off-therapy pediatric cancer survivors with documented attention deficits completed the CRP, which consisted of approximately 50 treatment hours over the course of 6 months. Treatment sessions were once weekly for a 2-hour period, with a 15-minute break between the two treatment hours. The length of the program (i.e., number of treatment sessions) was guided by the rehabilitation standard of care, with a goal of maximizing the effectiveness of treatment with a moderate treatment length. The comparison group was comprised of 10 children who were also off-treatment cancer survivors and were either on the waiting list to receive the CRP or unable to participate in the CRP. When tests scores of both groups were compared, the CRP group demonstrated statistically significant improvement on measures of attention, and there was no change for the comparison group. Neither group showed statistically significant changes for transfer skills on a math achievement test.

A subsequent multicenter, randomized clinical trial of the CRP in 2008 included 161 childhood cancer survivors ages 6–17 who were at least 1-year post-treatment and who exhibited attentional deficits. Two-thirds of the participants were randomly assigned to the CRP, and one-third to a wait-list control. All participants were assessed using a battery of academic achievement and neurocognitive tests and parent and teacher measures of attention. The CRP resulted in statistically significant improvement on parent measures of attention and academic achievement. Teacher ratings of attention showed positive trends for the CRP group, but were not significant. CRP group also acquired significantly more metacognitive strategies. The authors concluded the CRP had the most impact on measures of far-transfer generalization (e.g., tests of arithmetic and language-based functions), although treatment was not directed toward education. They noted the small to medium effect sizes were comparable to other clinical trials of brain injury rehabilitation. Finally, the authors concluded the CRP is a potentially beneficial treatment, and the development of a comprehensive and collaborative team (e.g., patient, parents, therapist, educational professionals) during rehabilitation is essential to promote generalization of skills. To that end, authors noted intentions to add proven caregiver interventions (i.e., problem-solving skills training) to increase the impact of the CRP.

Amsterdam Memory and Attention Training for Children

The Amsterdam Memory and Attention Training for Children (Amat-c) was developed by van’t Hooft and colleagues. Amat-c consists of a combination of daily practice and games, and specific attention and memory exercises. There are two versions: one for 9- to 12-year-olds and another for adolescents 13 years or older. Exercises are performed for 30 minutes 6 days per week for a period of 17 weeks. Exercises gradually become more difficult and are completed with a coach (e.g., parent or teacher). Additional components include behavioral modification approaches directed toward learning strategies in daily life and accomplishing school tasks, writing in a diary, and weekly therapeutic intervention sessions with the clinician. Amat-c was initially assessed in a randomized and controlled study of children with ABI. Pre- and post-testing showed improvement on tasks.

One small experimental study in 2007 of 38 children with ABI did include a randomly assigned control group, and the results showed significant improvement for attention 6 months post-intervention with the Amat-c. In addition, both selective attention and verbal WM showed continued improvement after completion of training. A later pilot study
by Sjo et al. assessed seven children diagnosed with ABI and revealed that although children demonstrated gains on a neuropsychological measure of attention, they did not show functional improvement on a standardized parent report. A 2015 pilot study of the Amat-c: English version assessed 10 children between the ages of 8 and 13 years at least 1 year post-ABI with documented evidence of attentional and/or memory difficulties and IQ above 70. Children completed 18 weeks of intervention by performing Amat-c tasks 30 minutes daily and meeting weekly with a therapist. Performance on attentional measures (including subtests of the Test of Everyday Attention for Children) post-intervention revealed improvement as compared to pre-intervention assessment both immediately and at 6 months post-treatment, with parent rating scales suggesting generalization to everyday tasks. Some participants demonstrated skill changes from pre- to immediately post-intervention, others showed no changes until 6 months post-intervention, and still others made gains both immediately after and 6 months post-intervention. The findings suggest that this intervention may not benefit all children equally and provides supporting evidence for individualized interventions by trained professionals in order to evaluate individual clinical needs. Taken together, Amat-c research suggests the program may be useful for strengthening attention in children with a history of ABI. However, it was only recently translated to English and the body of research remains limited at this time.

Computerized Progressive Attention Training

Shalev et al. developed the Computerized Progressive Attention Training (CPAT) program, a computer game–based intervention comprised of at least 18 one-hour sessions. The program includes four structured tasks designed to target orienting attention, sustained attention, selective attention, and executive attention. Each of the computer-based tasks is presented in a hierarchical fashion, with difficulty based on participant improvements in speed and accuracy. Participants receive auditory feedback about accuracy and positive visual feedback about response time. Training sessions are comprised of approximately eight blocks from different training tasks, with the total number of blocks varying depending on age and symptom severity. Blocks typically contain 40 trials, although one sustained attention task is longer and has either 60 or 80 trials. The efficacy of CPAT was examined with twenty 6- to 13-year-olds diagnosed with ADHD and performance was compared to 16 aged matched controls also diagnosed with ADHD. Participants received CPAT training twice weekly for 8 weeks, while controls played computer games. CPAT resulted in significant improvement in parental reports of attention, reading comprehension, and passage copying.

Kerns and colleagues examined the effects of attention training in 10 children aged 8–15 diagnosed with fetal alcohol spectrum disorder. Participants used the CPAT system and demonstrated significant improvement for both sustained and selective attention following training. In terms of far transfer, there were significant increases in spatial WM, math fluency, and reading fluency. The greatest improvements were for decreased distractibility, decreased reaction times, and increased auditory sustained attention. The research for CPAT is sparse, but positive.

Additional Programs

Galbiati et al. examined the efficacy of a specific rehabilitation program for attention in a study of 65 participants aged 6–18 with severe brain injuries and attention deficits. Forty participants received training four times per week for 6 months, with each session...
lasting 45 minutes. Training included 30 minutes of computerized tasks using the RehaCom program, the Attenzione and Concentrazione program, and 15 minutes of tabletop activities targeting components of attention (e.g., selective, focused, sustained, divided), as well as metacognitive strategy acquisition. Compared to the control group, the treatment group showed significant improvement on attention measures and adaptive functioning, and sustained decrease in impulsivity at 1 year post-training.

Sturm et al. developed a computerized training program called AixTent based on research that suggested different components of attention can be selectively impaired. AixTent was later used to examine the effectiveness of computerized attention training in 32 medicated pediatric ADHD participants. The results suggested significant post-treatment improvement in several components of attention, including vigilance, divided attention, and flexibility. However, not all components of attention were significantly improved and the authors suggest that training programs need to target the various components of attention rather than approaching attention as a singular construct.

In conclusion, non-commercial programs have solid theoretical grounding and treatment fidelity can be closely monitored in research trials. However, they can be difficult to obtain and justification for use of experimental programs in a clinical setting can be problematic without adequate research support for treatment efficacy.

### Practical and Clinical Applications

Clinical applications of cognitive training for attention and WM can be impeded by several practical concerns. First, the cost of obtaining and maintaining access to commercially available programs may be difficult for some providers, especially in settings where rehabilitation is not the primary focus. Additionally, given the variability of efficacy demonstrated in the available literature, it may be difficult to justify purchasing and implementing attention and WM training programs without further research providing justification for Practice Standards. Insurance companies may be unwilling to reimburse for intervention treatment given the paucity of evidence for long-standing treatment gains. Therefore, clinicians may need to allocate time to advocate for reimbursement and to explore billing practices for each insurer if utilizing attention and WM training programs for cognitive rehabilitation.

### Case Example

**Reason for Referral and Demographic Information**

Jane is an 8-year-old, right-handed female with a history of standard-risk acute lymphoblastic leukemia (ALL) diagnosed when she was 3 years old. She received chemotherapy with multiple medications including intrathecal methotrexate without significant complications. She completed treatment at 5 years of age, and at 8 years of age she was referred for the Cognitive Remediation Program (CRP) due to attention and concentration difficulties potentially related to her cancer treatment.

Other than ALL, Jane did not have a history of other serious medical illness or significant central nervous system involvement. Birth history was within normal limits; there were no complications with pregnancy or delivery. Early developmental milestones were acquired within age-level expectations. There was no history of
significant emotional or behavioral problems, although mild concerns regarding anxiety, irritability, and social withdrawal were noted.

Pre-Treatment Functioning

When Jane was 8 years, 6 months-old, she underwent a pre-treatment neuropsychological evaluation to establish baseline neurocognitive functioning. At that time, she was in the second grade in a private school. Formal special education services were not available (i.e., 504 Plan or Individualized Education Program), although she received classroom accommodations (e.g., preferential seating) and specially designed instruction for reading. Per parent report, attention and concentration difficulties were interfering with her academic performance. At school, she daydreamed and struggled to stay on task. Outside of school, she had difficulty focusing during piano lessons. At home, she frequently misplaced her belongings and often needed directions to be repeated. During the pre-treatment evaluation, she was cooperative and adequately motivated. Although she was alert and attentive, she displayed a mild degree of self-distractible behavior.

On neuropsychological testing, Jane’s presentation prior to treatment reflected intact functioning, with relative weaknesses (albeit in the low average range) in auditory attention, WM, and academic achievement. Some inconsistent attentional control or possible “late effects” of ALL treatment may have accounted for variable performance on measures of attention. Reading comprehension was the only domain well below age-level expectations. Parent ratings on standardized measures of behavioral/emotional functioning and parent stress indicated moderate concerns regarding Jane’s level of anxiety, depression, withdrawal, and somatization, as well as significant parental life stress. Jane’s self-report indicated moderate concerns about her tendency to externalize locus of control.

Cognitive Remediation Program

Jane completed 20 two-hour weekly CRP sessions over approximately eight months implemented by a clinical psychology graduate student under supervision of a clinical psychologist. The treatment plan was programmatic but individualized based on Jane’s baseline performance and progress. Components included hierarchically graded massed practice, strategy acquisition, cognitive-behavioral therapy (CBT) interventions, as well as games to encourage interest and participation, and activities to promote generalization (e.g., mental math, reading activities, homework, and parent and teacher contact). Given her weaknesses in auditory attention, auditory APT tasks (e.g., sounding a buzzer when a target sound is heard) were emphasized over visual APT tasks (e.g., shape or number cancellation tasks with and without distractor overlays).

Each CRP session started with a review of learned strategies and acquisition of one to two new strategies to help her prepare for tasks, maintain on-task behavior, and evaluate her own performance. Jane’s written list of strategies was updated on a weekly basis, and copies were provided to her mother and teacher in order to promote skill generalization outside of the treatment setting. In addition, Jane’s teacher was contacted three times during treatment (i.e., onset, mid-treatment, and conclusion) to ensure strategy use in the classroom environment. CBT interventions included positive
self-talk, modeling, and repeated review and practice of acquired metacognitive strategies. At the end of every session, Jane was given homework to practice her learned strategies while completing brief math worksheets.

In conjunction with the CRP, Jane's mother participated in a Caregiver Problem-Solving Skills Training Program (PSST) based on the Bright IDEAS: Problem Solving Skills Training intervention developed by Sahler et al. This additive intervention to the CRP consisted of eight weekly concurrent 60-minute caregiver sessions with the supervising psychologist focused on teaching Jane's mother how to positively and effectively manage problems, including how to navigate the educational system and advocate for Jane's special education needs. In addition, the PSST program was designed to help improve family communication and cohesion. Teaching strategies and training techniques used during this cognitive-behavioral approach included verbal instructions, live modeling, behavioral rehearsal, home practice, social reinforcement, and corrective feedback.

**Post-Treatment Functioning**

Approximately 1 month after completion of the CRP, Jane underwent a post-treatment assessment of cognitive and behavioral functioning. Compared to pre-treatment functioning, Jane's mother and teacher reported improved attention. For example, two of Jane's preferred pre-task strategies included sitting up straight and “getting her game-face on.” Both Jane and her teacher reported these pre-task strategies helped her focus when starting new classroom activities. Additionally, given her tendency to daydream, Jane reported it was useful to repeat the phrase “stop and refocus” when she caught herself being distracted. Her teacher also reported that Jane required fewer prompts to remain on-task after treatment. At home, Jane's mother did not need to repeat directions and Jane did not misplace personal belongings as often as prior to treatment. Clinically, Jane was attentive during the evaluation, although she continued to exhibit a mild degree of distractibility. Jane was observed utilizing learned metacognitive strategies effectively throughout the evaluation. For instance, prior to the start of a task, she often deliberately sat up straight, put her feet flat on the floor, and occasionally performed a breathing exercise. She also self-corrected her errors and checked her work independently. Although it is possible that Jane's utilization of metacognitive strategies during this evaluation was reflective of the Hawthorne effect (i.e., improved behavior while being observed), this is unlikely given parent and teacher report that she was demonstrating these strategies consistently at school, and also because these were new observations as compared to pre-treatment observations.

Jane's follow-up neuropsychological testing was broadly commensurate with pre-treatment testing, indicating that she continued to develop cognitive and adaptive skills at an age-appropriate rate. It is noteworthy that Jane, her mother, and her teacher reported perceived improvement in daily functioning, especially in reading. This is consistent with parent and self-ratings on standardized measures of behavioral and emotional functioning and parent stress, all of which improved to nonclinical levels post-treatment.

Overall, based on parent and teacher report, Jane demonstrated improvement in her ability to maintain attention and concentration, and ignore distraction when performing a given task. Throughout the CRP, she consistently identified and
demonstrated appropriate use of her learned metacognitive strategies to help improve her attention and concentration in the treatment setting, as well as in the classroom (per parent and teacher report). She also used her strategies to improve her self-efficacy and her ability to cope with stress. Throughout the post-treatment evaluation, she independently incorporated metacognitive strategies to improve her preparedness and task completion. Although these findings could be reflective of normal maturation or placebo, the generalization of rehabilitation training to daily functioning should not be entirely dismissed.

This case is a good example of cognitive rehabilitation in a clinical setting because it illustrates the difficulty of avoiding observer bias in parent rating scales, determining the effects of parent problem-solving skill improvements, eliminating confounding treatment effects of special education services, and interruptions in treatment compliance. Furthermore, as the girl in this case study was diagnosed with cancer prior to learning to read, the case demonstrates how gains in visual attention could account for reading improvements in youth who have not yet developed automatic visual letter and word recognition, raising the question of how much demand visual attention versus phonological attention and WM is needed for reading tasks.

Conclusions and Future Directions
Cognitive rehabilitation of attention and WM is an expanding field, which has become increasingly more technological over time. Earlier “paper and pencil” massed practiced training programs facilitated by trained professionals and available to only a narrow spectrum of individuals have been replaced by self-directed, adaptive web-based programs capable of performance tracking and analysis, and available to anyone with an Internet-accessible device. Subsequently, the body of literature on the efficacy of attention and WM training in the pediatric population has exploded over the last decade. However, this research is fraught with methodological challenges, including heterogeneous research populations, which have contributed to disparate and controversial findings. At present, there is no consensus in the literature about the efficacy of cognitive rehabilitation for attention and WM in the pediatric population.

Given methodological variability in available research, future studies aimed at addressing current limitations are needed. For instance, more well-controlled studies with randomized control groups, standardized interventions, and clear outcome measures (both neuropsychological and functional) are needed to inform practice recommendations. Replication studies with large representative populations would assist with conclusions about the clinical utility of attention and WM training programs. In addition, given that adaptive cognitive training appears to improve attention and WM for some populations, particularly when coaching is available (e.g., pediatric cancer survivors), but not for others, ongoing studies are warranted to investigate the degree to which specific components of intervention (i.e., massed practiced exercises, coaching support, metacognitive strategies) contribute to improvement attention and WM. Finally, given evidence that attention and WM deficits can be domain specific (i.e., verbal or visual-spatial), future research may be strengthened by assessing which domains are impaired in participants prior to beginning interventions in order to better target rehabilitation needs and refine study outcomes.
References


