Students with attention deficit hyperactivity disorder (ADHD) are at risk for academic underachievement. Children and youth with ADHD have been found to exhibit impairments on neuropsychological measures of executive functions, including working memory. Working memory is important to attentional control and learning. This article defines working memory, describes its importance to scholastic functioning, and highlights recent studies examining working memory functioning in students with ADHD. Finally, the authors discuss how educators can address working memory weaknesses in the classroom.

Attention deficit/hyperactivity disorder (ADHD) is a chronic neurobiological disorder that affects approximately 5% of children (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007). Students with ADHD exhibit developmentally inappropriate symptoms of inattention and/or hyperactivity-impulsivity that occur in more than one context (APA, 2000). Children and youth with ADHD often display lower levels of reading and math achievement than their typically developing peers (Frazier, Youngstrom, Glutting, & Watkins, 2007), particularly if they exhibit inattention symptoms (Todd et al., 2002). Written expression weaknesses are also common in children with ADHD (Mayes & Calhoun, 2006). Recent studies have shown that pharmacological treatment for ADHD symptoms does
not normalize the academic performance (e.g., GPA) of students with ADHD (Powers, Marks, Miller, Newcorn, & Halperin, 2008; Scheffler et al., 2009). Collectively, these findings suggest that many students with ADHD will require interventions that address their academic difficulties (DuPaul, 2007).

Executive function (EF) deficits are also implicated in ADHD (Barkley, 1997; Sonuga-Barke, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Although the term executive function has been defined in various ways, there is a general consensus that the term refers to a range of “complex cognitive processes that serve ongoing, goal-directed behaviors” (Meltzer, 2007, p. 1). Importantly, evidence suggest that students with ADHD with EF deficits display lower levels of academic functioning than their peers without ADHD, and students with ADHD without EF deficits (Biederman et al., 2004). EF weaknesses are also predictive of academic outcomes in girls with ADHD (Miller & Hinshaw, 2010). In this article, we focus on working memory, which is a core EF (Miyake et al., 2000); we will also define working memory, describe its association with academic achievement, and discuss how teachers can address working memory weaknesses in the classroom.

**Working Memory and Academic Achievement**

Although several theoretical models of working memory exist (Baddeley, 2000; Cowan, 2005; Engle, 2002), there is a general agreement that working memory involves executive or attentional control (Engle, 2002). Working memory has been defined as “a limited capacity system allowing the temporary storage and manipulation of information necessary for such complex cognitive tasks as comprehension, learning, and reasoning” (Baddeley, 2000, p. 418). For example, when composing a text, the author must keep in mind the overall goals for the text (e.g., the audience) while generating ideas, thinking of how to spell words, and monitoring the text for errors. Working memory is needed to engage in these various aspects of the writing process (McCutchen, 2000). It has been described as our “mental workspace” (Alloway, Gathercole, & Pickering, 2006, p. 1698).

Baddeley’s (2000) theoretical model of working memory also includes two limited-capacity short-term memory components: the phonological loop and visual–spatial sketchpad. The phonological loop stores verbal information for a limited time (e.g., brief retention of a series of words or digits). The visual–spatial sketchpad is responsible for the short-term storage of visual–spatial information (e.g., remembering a series of locations). Research with children supports the distinction between short-term memory tasks that involve storage of information and working memory tasks that involve attentional control (Alloway et al., 2006).

Working memory is associated with a wide range of academic skills including mathematical problem-solving, reading and language comprehension, and written expression (Alloway, Gathercole, Kirkwood, & Elliott, 2009; Montgomery, Polunenko, & Marinellie, 2009; Swanson & Berninger, 1996; Swanson, Howard, & Saez, 2007). It predicts learning outcomes in children with learning difficulties, even after controlling for previous levels of achievement and IQ (Alloway, 2009). It is also associated with children’s ability to complete common academic tasks such as following instructions (Gathercole, Durling, Evans, Jeffcock, & Stone, 2008). For example, Gathercole et al. (2008) reported a significant association between working memory and the accuracy with which children were able to carry out instructions (e.g., “Pick up the yellow ruler and put it in the black box”). Working memory, however, was not significantly associated with children’s ability to repeat the oral instructions. Working memory difficulties are also associated with weaknesses in planning, organizing information, and monitoring school work (as rated by teachers; Alloway, Gathercole, Kirkwood et al., 2009; Gathercole, Alloway et al. 2008). Thus, children with poor working memory may exhibit academic skill deficits as well as weaknesses in self-regulation skills (e.g., planning).
Working Memory Impairments in Students With ADHD

Several studies have reported that students with ADHD exhibit weaknesses in working memory (e.g., Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Martinussen & Tannock, 2006; Rapport et al., 2008; Willcutt et al., 2005). Although some studies have documented that students with ADHD exhibit greater impairments in visual-spatial working memory than verbal working memory (e.g., Martinussen et al., 2005), recent findings suggest that the extent to which the task places demands on working memory may be more important than the modality of the task (Brocki, Randall, Bohlin, & Kerns, 2008). Although working memory impairments do not characterize all children with ADHD (e.g., Alloway, Rajendran, & Archibald, 2009; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005), preliminary evidence suggests that students with ADHD and working memory deficits are at greater risk for academic underachievement than students with ADHD without working memory deficits (Alloway, Gathercole, & Elliott, 2010). Children with ADHD with comorbid anxiety disorder may also display greater working memory weaknesses than those without anxiety disorder (see review by Schatz & Rostain, 2006) because high levels of anxiety can have a negative effect on working memory capacity (Owens, Stevenson, Norgate, & Hadwin, 2008).

Working memory is also associated with inattentive behavior in children with ADHD (Kofler, Rapport, Bolden, Sarver, & Raiker, 2009). Kofler et al. reported that boys with ADHD exhibited higher levels of inattentive behavior when they completed experimental tasks that placed high demands on working memory, compared with tasks that placed minimal demands on working memory. Interestingly, Alloway and colleagues (Alloway, 2008; Alloway, Gathercole, Kirkwood et al., 2009; Gathercole, Alloway et al., 2008) have also found significant associations between working memory impairments and inattentive behavior in community samples of children. Overall, these findings suggest that students with a clinical diagnosis of ADHD, and students who exhibit marked attention problems in the classroom, but who may not meet the full criteria for ADHD, are at risk for working memory impairments (e.g., Alloway, 2008; Kofler et al., 2009).

Implications for Instruction

Because of the strong association between working memory and academic achievement, it is important for teachers to consider working memory load when designing instructional tasks (Alloway, 2006; Dehn, 2008). Dehn (2008) suggested that novel tasks (e.g., learning a new procedure), and tasks that are complex (e.g., solving a math problem), may be particularly challenging for students with poor working memory (see also Meltzer & Krishnan, 2007). To support students with working memory weaknesses, teachers can adjust the instructional context (i.e., adapt instruction), provide students with external supports to reduce working memory load, and teach students specific strategies to promote goal-oriented behavior (Dehn, 2008; Feeney & Ylvisaker, 2008; Meltzer & Krishnan, 2007).

Scaffolding Complex and/or Multistep Tasks

Teachers can use various approaches to reduce the working memory demands of complex academic tasks. First, teachers can break complex projects into several key steps or components (Dehn, 2008). For example, to enhance their students’ ability to follow multistep directions, teachers can deliver instructions in short chunks and pause between each chunk to give the students time to process the information (Rowe, Rowe, & Pollard, 2005). Second, teachers can provide their students with explicit instruction in learning strategies to help their students approach complex academic tasks (e.g., writing an essay) more systematically (Graham, Harris, & Olinghouse, 2007). Students who have poor working memory may also need external memory aids (e.g., cue cards, graphic organizers). These aids can help the students keep track of the steps
involved in the complex task (Roditi & Steinberg, 2007). Teachers can also provide their students with opportunities to practice memorizing the steps to a strategy to facilitate internalization of the key steps (Graham et al., 2007), and then remove the external supports once students have mastered each of the steps.

Students with ADHD with poor working memory may also exhibit weaknesses in oral or written text comprehension (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003; Sesma, Mahone, Levine, Eason, & Cutting, 2009). They may not be able to successfully monitor their comprehension of stories or expository text (see Lorch, Berthiaume, Milich, & van den Broek for a review; McInnes et al., 2003). To support text comprehension in students with poor working memory, teachers can provide instruction in comprehension monitoring strategies (e.g., asking questions while reading to check understanding; Dehn, 2008). Students may also benefit from instructional supports (e.g., a story grammar) that facilitate their ability to see the relations among the key ideas in the text (Berthiaume, 2006; Dehn, 2008). Teachers can also provide their students with guided practice in using the comprehension strategies and instructional supports (Rogevich & Perin, 2008).

**Scaffolds for Organization and Time Management**

Preliminary findings suggest that students with ADHD with poor working memory exhibit weaknesses in planning and organization (Alloway, Gathercole, Holmes et al., 2009; Toplak, Bucciarelli, Jain, & Tannock, 2009). To address these weaknesses, teachers can provide their students with explicit instruction in organizational strategies (e.g., how to organize materials such as books, binders; Langberg, Epstein, Urbanowicz, Simon, & Graham, 2008) and help their students use checklists to keep track of multicomponent assignments or tasks (Dawson & Guare, 2004; Dehn, 2008; Pfiffner et al., 2007). In addition, teachers can provide their students with instruction in goal-setting and planning (e.g., how to identify the key steps involved in a task; Dawson & Guare, 2004). Finally, recent findings suggest that it may be helpful to teach students to self-monitor their use of the organizational strategies (Gureasko-Moore, DuPaul, & White, 2006).

**Adapting Instruction: A Case Study**

This brief case study illustrates how teachers can use a range of supports and intervention approaches (e.g., instructional scaffolds, explicit instruction in cognitive and self-regulatory strategies, and behavior management strategies) to address the needs of students with ADHD with working memory weaknesses.

Mark is a student with ADHD who displays weaknesses in working memory. His fourth-grade teacher was concerned about his academic progress. She had noted that Mark often made careless errors in his assignments. His desk and materials were frequently disorganized. As a result, he was often not prepared for class. Mark also tended to perform poorly on assignments with multiple steps (e.g., long-term projects). He also displayed weaknesses in written expression. His stories were often short and poorly organized.

Mark’s teacher implemented a range of strategies to address Mark’s weaknesses in organization, assignment completion, and writing. First, she showed Mark how to organize his desk and materials. She also provided Mark with a written checklist that outlined the steps he needed to take to organize his materials. At first, she helped Mark use the checklist each day (guided practice) and then she gradually faded her support (Gureasko-Moore et al., 2006).

Mark’s teacher also helped Mark plan a long-term project. Together, they divided the long-term project into smaller and more manageable chunks and they set up a schedule for the completion of each component of the project (Dawson & Guare, 2004). Mark was asked to show his teacher each component once it was completed. Mark’s teacher found that this adaptation prevented Mark from getting overwhelmed by the project, and she was able to give Mark more frequent feedback on his progress.
Next, she provided Mark and the other students in her classroom with explicit instruction in writing strategies (using the Self-Regulated Strategy Development approach; Graham et al., 2007) to improve the quality of their narrative compositions (Reid & Lienemann, 2006). She also asked her students to self-monitor their writing productivity and the number of parts in their stories (Graham et al., 2007; Reid & Lienemann, 2006).

Mark’s teacher also implemented a daily report card with Mark. It targeted two key areas of difficulty: (a) his organization of materials and (b) the accuracy of his independent seatwork. She worked collaboratively with Mark’s parents to set up and implement the daily report card (DuPaul, 2007). Both Mark and his parents stated that they found the daily report card to be helpful.

**Conclusion**

Students with ADHD with working memory difficulties may struggle with academic tasks that place significant demands on working memory. Teachers can adjust their instructional practices to prevent working memory overload (Alloway, 2009; Gathercole, Lamont, & Alloway, 2006), and provide various instructional supports. These instructional supports, in conjunction with interventions targeting self-regulation skills (e.g., self-monitoring; see Johnson & Reid, this issue) and academic skills (e.g., written expression; Lienemann & Reid, 2008), can be used to promote academic success in students with ADHD.

**References**


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