Isolating Metamemory Deficits in the Self-Regulated Learning of Adults With ADHD

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Abstract:

ADHD in adulthood is associated with chronic academic impairments and problems with strategic memory encoding on standardized memory assessments, but little is known about self-regulated learning that might guide intervention. **Objective:** Examine the contribution of metamemory judgment accuracy and use of learning strategies to self-regulated learning in adults with ADHD, focusing on the use of self-testing. **Method:** A total of 34 adults with ADHD and 34 matched controls predicted their memory performance and regulated their learning of paired associates. **Results:** Adults with ADHD were as accurate as controls at predicting memory performance, despite remembering fewer words. By observation and self-report, they were less likely to use self-testing to learn the pairs. **Conclusion:** Across groups, self-testing was associated with significantly better recall and largely accounted for differences between diagnostic groups. Adults with ADHD often failed to employ a strategy that was associated with improved memory, identifying an intervention target that may improve self-regulated learning.

Keywords: self-regulated learning | memory | metamemory | metacognition | monitoring judgments | strategies | adult ADHD

Article:

ADHD is associated with chronic impairment in academic functioning (Frazier, Youngstrom, Glutting, & Watkins, 2007). A substantial proportion of people exhibiting ADHD symptoms in childhood continue to have symptoms and associated impairment into young adulthood (Barkley, Fischer, Smallish, & Fletcher, 2002). These adults are less likely to attempt and complete college (Barkley, Fischer, Smallish, & Fletcher, 2006; Weiss & Hechtman, 1993), and those who do report lower grade point average (GPA) and more pervasive academic difficulties (Barkley, Murphy, & Fischer, 2008). For adults with ADHD who attempt college, difficulties with self-regulated learning—that is, learning that takes place outside the classroom when students study on their own—are likely to play a role in academic impairments. Study skills and study habits are particularly predictive of academic success in a university setting where learning activities are often self-directed and large amounts of information must be encoded and synthesized (Crede & Kuncel, 2008). Adults and children with ADHD are most likely to demonstrate memory performance deficits when tasks require elaborative encoding strategies (Cornoldi, Barbieri, Gaiani, & Zocchi, 1999; Seidman, Biederman, Weber, Hatch, & Faraone, 1998). Thus, ADHD likely affects higher order strategic memory processes necessary for efficient self-regulated learning. However, few studies in adults with ADHD have gone beyond scores on memory tests to examine what these adults are actually doing (or not doing) when they attempt to guide their own learning.

Metacognitive Model of Self-Regulated Learning

A recent meta-analysis identified study skills, habits, and attitudes reported by college students as robust predictors of college success above and beyond the most frequently used predictors—high school grades, and standardized test scores (Crede & Kuncel, 2008). To study the self-regulation processes that are involved in college-level study skills and habits Nelson and Narens (1990) developed the metacognitive model of self-regulated learning. Successful self-regulated learning requires the learner to (a) allocate study based on awareness of what has been learned and (b) choose and execute effective strategies based on the to-belearned materials (Nelson & Narens, 1990). Nelson and Narens differentiated these processes of *monitoring* (evaluating the extent to which information has been learned) and *control* (selecting, initiating, and terminating study behavior).

Monitoring is a key process in the metacognitive framework as it is presumed to be necessary, but not sufficient, for effective control—that is, one must know something about what has been learned to decide how and what to study. In metacognitive studies, monitoring is often measured via Judgments of Learning (JOL). These judgments are made at some time interval after a participant has been given the opportunity to learn an item. For example, a participant is asked to study a set of paired associates (e.g., doctor–lobster, cat–fork). After studying each one, he or she predicts *the likelihood of recalling the response* (e.g., lobster) when later shown the cue (i.e., doctor–?) on a scale of 0 to 100. Actual memory performance can then be compared with these judgments to determine monitoring accuracy. JOL made immediately after an individual studies an item generally yields modest correlations with recall; however, when participants make JOL at a delay from when items are studied, they are highly accurate at predicting later recall (“delayed-JOL effect”; Nelson & Dunlosky, 1991) because the learner can rely on whether an answer can be retrieved and, if so, how quickly.

Yet accurate monitoring or awareness of what has been learned is not sufficient for effective self-regulated learning. Learners must engage control processes, determining *how* and *how much* they will study items and then carrying out those plans. A particularly important and effective learning strategy is self-testing during study because it functions as both a metamemory and a memory strategy (Roediger & Karpicke, 2006a). That is, attempting to remember previously studied items allows learners to monitor or evaluate their current learning and to boost their memory for the retrieved item. When used to monitor memory, self-testing allows learners to identify items requiring further study, but practicing retrieval of items can also have a direct influence on subsequent memory (Roediger & Karpicke, 2006b). Of course, self-testing can serve in both capacities simultaneously, and hence when it is used in self-regulated learning, it can have a powerful influence (Dunlosky, Kubat-Silman, & Hertzog, 2003; Karpicke, 2009).

Monitoring and Control in ADHD

From the perspective of self-regulated learning and current theories of ADHD, breakdowns could occur in monitoring processes, control processes, or both. If adults with ADHD are inaccurate at monitoring and thus less aware of what has been learned, this would limit their ability to change their behavior strategically (Thiede, 1996). Although children with ADHD have shown a “positive illusory bias” or tendency to overestimate with respect to their self-ratings of competence in broad domains of behavior (Owens, Goldfine, Evangelista, Hoza, & Kaiser, 2007), findings concerning this phenomenon in adults with the disorder have been less consistent (Golden, 2007; Knouse, Bagwell, Barkley, & Murphy, 2005). Most relevant to the current study, the few studies of *task specific* accuracy judgments in adults with ADHD have not demonstrated the bias. Knouse, Paradise, and Dunlosky (2006) did not find the immediate or delayed JOL of 28 adults with ADHD to be less accurate than those given by 28 controls in a paired-associates task. However, the groups also performed similarly on the memory task itself. More recently, Barrilleaux and Advokat (2009) found that adults with ADHD and a control group showed similar accuracy when rating their performance on a continuous performance task (CPT). The group with ADHD performed more poorly on the task but appeared to accurately perceive that poorer performance.

If adults with ADHD are indeed capable of accurate monitoring, they may still have difficulty controlling learning by appropriately changing, maintaining, or terminating strategies. Studies of children with ADHD support the idea that verbal learning deficits are most likely in situations that require higher level encoding strategies (August, 1987; Benezra & Douglas, 1988; Cornoldi et al., 1999; O’Neill & Douglas, 1991, 1996; Voelker, Carter, Sprague, Gdowski, & Lachar, 1989). Castel, Lee, Humphreys, and Moore (2011) recently found that although children with ADHD–Combined Type showed no deficits in memory capacity, they were less efficient at strategically deploying selective encoding toward high-value items. Studies of adults with ADHD have examined memory strategy use with the California Verbal Learning Task (CVLT; Delis, Kramer, Kaplan, Ober, & Fridlund, 1983), which requires participants to learn a 16-item list over five trials. Items fall into four categories of 4 items each, and scores indicating the use of semantic organization—an effective learning strategy for this task—can be derived. Holdnack, Moberg, Arnold, Gur, and Gur (1995) found that adults with ADHD had lower semantic clustering scores overall and recall deficits on the final learning trial. Seidman et al. (1998) also found significantly less clustering for adults with ADHD across all learning and recall trials. Roth et al. (2004) found less clustering and poorer recall for adults with the disorder, although they found some evidence that their results could be accounted for by state anxiety. Most recently, Young, Morris, Toone, and Tyson (2006) found that adults with ADHD were less likely to use a sequential search strategy during a working memory task. Together, these studies indicate less use of effective learning strategies during memory tasks for groups of adults with ADHD. It is reasonable, then, to hypothesize that deficits in strategic use of memory might contribute to metacognitive deficits and learning problems for adults with ADHD in academic settings.

Prominent theories of ADHD identify disorder-related deficits in higher order cognitive processes that could impact self-regulated learning. Barkley (1997b) posited behavioral inhibition deficits as the core feature of ADHD, resulting in downstream difficulties with verbal working memory, nonverbal working memory, emotion regulation, and abstract thinking. Deficient behavioral inhibition might translate into impulsive responding during a learning task, whereby the learner proceeds with simple learning strategies (e.g., rote repetition) without stopping to monitor the state of items in memory or to consider optimal strategies for a particular set of items. Rapport et al. (2008) have recently provided compelling evidence that locates the core deficit in ADHD in the central executive component of working memory. This theoretical formulation would also certainly have consequences for self-regulated learning, as adults with ADHD might have more difficulty holding learning goals “in mind” and coordinating monitoring and study across multiple items. Thus, both theoretical and empirical perspectives support the investigation of ADHD within the metamemory framework.

The Current Study

The current study was designed to answer the following questions: (a) Do adults with ADHD demonstrate deficits in monitoring or control (judgment accuracy or strategy use) during a self-regulated verbal learning task? and (b) What specific strategies are related to better memory performance for learners with and without ADHD? Importantly, the answers to these questions should suggest appropriate interventions for adults with ADHD to improve self-regulated learning. For example, inaccurate monitoring (when prompted to monitor) would support some kind of accuracy training with feedback to help learners better calibrate their predictions. With respect to control strategies, we were particularly interested in participants’ use of self-testing, given prior research on its effectiveness as both a memory and metamemory strategy (Roediger & Karpicke, 2006b).

The current study compared recall performance, monitoring accuracy, and strategy use between adult learners with and without ADHD on an experimental task designed to be representative of self-regulated learning situations encountered in a secondary or undergraduate academic setting (e.g., studying foreign language vocabulary). Participants learned pairs of unrelated nouns in the context of minimal experimental constraints. We collected JOL to measure monitoring accuracy and allowed participants to control study time and the strategies by which they learned the items. Based on the results of prior studies of monitoring and control in adults with ADHD, we predicted that, compared with adults without the disorder, adults with ADHD would be able to accurately monitor learned items but that they would be less likely to use strategic self-testing.

Method

Participants

A total of 34 adults (age 18-39) with ADHD meeting *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; American Psychiatric Association, 1994) criteria and 34 age and gender-matched controls participated. To be eligible for the group with ADHD, participants had to (a) report a current diagnosis from an outside provider or in the context of a large family-based research study, (b) endorse at least six of nine inattentive and four of nine hyperactive-impulsive symptoms[1] on diagnostic interview or self-report ratings scale (ADHD Rating Scale; DuPaul, Power, Anastopoulos, & Reid, 1998), (c) meet criteria for statistical deviance of ADHD symptoms in reference to population norms (93rd percentile/*T*-score of 65 or higher) on at least one *DSM-IV* derived subscale (inattentive or hyperactive-impulsive) on the Conners's Adult ADHD Rating Scale (CAARS; Conners, Erhardt, & Sparrow, 1999), (d) endorse symptom onset during childhood (prior to age 12), and (e) endorse functional impairment that could be reasonably related to symptoms in at least two domains of functioning (e.g., educational, occupational, home life, relationships, etc.) on the structured interview or self-report functioning scale. Participants in the control group had no reported, documented, or suspected history of ADHD. Participants were excluded from the study altogether if they reported a history of mental retardation, pervasive developmental disorder, psychosis, serious neurological conditions, closed head injury, or major sensory or motor impairment.

Materials

ADHD diagnostic interview. A version of the ADHD module from the National Institutes of Mental Health Computerized Diagnostic Interview Schedule for Children (4th ed.; C-DISC-IV; Shaffer, Fisher, & Lucas, 1997) and modified for adults was administered to participants. It assesses the presence of nine inattentive and nine hyperactive-impulsive symptoms and their onset, course, and impact on domains of functioning. Symptom counts, onset, and report of impairment from this measure were used in determining eligibility for the group with ADHD.

ADHD symptoms self-report. The ADHD Rating Scale (DuPaul et al., 1998) asks participants to rate the frequency of *DSM-IV* symptoms using a 4-point scale (0 = *never or rarely*, 1 = *sometimes*, 2 = *often*, 3 = *very often*). Total scores for inattentive and hyperactive-impulsive symptoms were used as a symptom severity index and items rated ≥ 2 for the past 6 months were used to index symptom counts. Participants also rated the extent to which symptoms interfere with functioning in several areas of life activities using the same 4-point scale (Barkley & Murphy, 2006). Number of areas rated ≥ 2 was an index of ADHD-related functional impairment.

The CAARS (Conners et al., 1999) is a normative self-report rating scale for current symptoms. For *DSM-IV* items, cutoff scores at the 93rd percentile were used in defining the group with ADHD.

Intellectual ability. Participants completed the Vocabulary and Matrix Reasoning subtests from the Wechsler Adult Intelligence Scale, Third Edition (Wechsler, 1997). Estimated Full Scale IQ scores were calculated according to tables published by Sattler (2001).

Task stimuli. The self-paced study task included 40 pairs of unrelated nouns each printed on one side of a laminated card. No stimulus in the entire set had forward or backward association strength greater than 0.15 to any other stimulus (Nelson, McEvoy, & Schreiber, 1999). Judgment and recall trials were programmed using E-Prime 1.2 (Psychology Software Tools, Pittsburgh, PA) and conducted on PC laptops.

Task interview. Between study and recall, participants were asked an open-ended question—what they had done to learn items—and their responses were coded from videotapes of the interviews. They were then specifically asked how frequently they had used self-testing on a 4-point scale and were asked to provide ratings of task difficulty and level of effort on a 5-point scale.

Interview coding scheme. A coding scheme of participant responses to the interview question "What were you doing to learn items?" was developed as follows. First, a set of 10 non–mutually exclusive codes was compiled based on face validity and experience with pilot participants. Next, two raters viewed a subset of video recordings and independently rated each memory strategy as present or absent. Kappa statistics were calculated for each code and codes with low values were modified or defined more stringently to improve reliability. Eleven codes comprised the final coding scheme, including *Rote Rehearsal*, *Repeat Aloud*, *Sort by Categories*, *Associate*, *Sentence*, *Story*, *Personal Reference*, *Visual Imagery*, *Self-Test*, *Chunking*, and *Monitoring Affects Control*.

Procedure

Recruitment. Participants with ADHD were recruited from several sources, including a tertiary care ADHD specialty clinic, a university office of disability services, and a large family-based ADHD research project. Controls were recruited via social nominations from ADHD participants, the family-based project, and from a psychology department subject pool.

Experimental session. Participants in the group with ADHD agreed to discontinue any stimulant medication the evening before the testing session. After completing clinical interview measures, participants completed the memory task. They were instructed to learn the word pairs for a later test and to study in any way they chose. They were told that during the test, they would be shown the cue word and have to type in the word that had been paired with it. Participants signaled to the experimenter that they were ready for the test by placing a red card on the stack of study cards—this also prevented further study of the items. Participants were not told how long they could study, but a 15-min limit was imposed; if the participant had not already given the signal, the experimenter terminated study and conducted the 5-min task interview. Study time was measured and the study period and interview were recorded with a video camera.

Following the task interview, JOL and recall trials were administered via computer. Participants were shown the first word of each pair and reported the likelihood that they would recall each item based on a scale from 0 (*definitely will not recall*) to 100 (*definitely will recall*). After making all JOL, participants completed cued recall, which was self-paced. Items were randomized during JOL and recall trials.

Observational coding. Videotapes of participant study behavior were coded dichotomously as to whether participants used self-testing while studying. This behavior was defined as the participant occluding the response word (second word) of the word pair with another card or his or her hand, looking at the cue word, and pausing briefly before revealing the response word. Each recording was coded by two raters, one blinded and one not blinded to group status. Kappa for this code across the entire sample was 0.91, indicating good interrater reliability. Disagreements in coding (3 videos) were resolved by raters viewing the video in question again and arriving at a consensus on the appropriate code.

Interview coding. Videotapes of participant responses to the interview question "What were you doing to learn items?" were coded by two raters using the refined interview coding scheme. Kappa statistics for each code ranged from 0.83 to 1.0, indicating good interrater reliability. Disagreements were resolved by the coders viewing the disputed videos together and deciding on the appropriate code. In a few cases, the in-session experimenter had directly prompted participants with coding scheme items after asking the initial open-ended question. In these cases, participants' responses were only coded prior to the inappropriate prompt.

Results

Group Characteristics

The mean participant age was 26.85 years (59% female), and both groups had a similar number of years of education (Table 1). In all, 84% self-identified as White, 18% African American, 3% Hispanic or Latino, and 3% Native American, $\chi 2(1, N = 68) = 3.86$, $p = .43$. Self-reported job status did not differ between groups, with 37% of the sample indicating "student" as their primary occupation. Participants had mean estimated WAIS-III Full Scale IQ in the above average range with no differences between groups.

Table 1. Group Characteristics

	Controls		ADHD		*t*	*p*	*d*
Variable	*M*	*SD*	*M*	*SD*			
Education	15.53	2.21	14.76	2.18	1.44	.16	

(years)							
WAIS-III Est. Full Scale IQ	116	13.07	115	11.63	0.36	.72	
ADHD-RS–inattentive	3.24	2.97	18.38	4.85	15.54	<.001	3.76
ADHD-RS–hyp/impulsive	3.18	2.84	16.71	5.13	13.45	<.001	3.26

Note: WAIS-III = Wechsler Adult Intelligence Scale, Third Edition; Est. = estimated; ADHD-RS = Adult ADHD Rating Scale total scores; Hyp = Hyperactive

Table 2. Study Task Measures

	Control	ADHD	*Test*[a]			*p*	*d*
	M	*SD*	*M*	*SD*			
Words correct at test	29.94	10.89	22.48	13.06	2.54	.01	0.62
Judgment of Learning magnitude	73.58	22.33	56.09	27.02	2.91	.01	0.71
Difficulty	3.35	0.77	3.74	0.96	1.80	.08	0.44
Absolute accuracy	−0.01	0.14	0.00	0.16	0.22	.83	
Relative accuracy[b]	.61	0.67	0.92	0.13	267.00b	.09	
Study time (s)	753.94	155.65	700.15	237.86	1.10	.27	
Effort	4.15	0.78	4.25	0.70	0.57	.57	
Number of strategies	2.94	1.01	2.94	1.32	0.00	1.00	
Self-reported self-testing	2.50	0.90	1.76	1.30	2.71	.01	0.66

[a]All other test statistics are independent samples *t* statistics. [b]Variable significantly skewed. Test statistic reported is Mann–Whitney *U*.

The group with ADHD reported significantly more severe inattentive and hyperactive-impulsive symptoms on the Adult ADHD Rating Scale (Table 1). On the CAARS, inattentive scores for controls fell at about the 23rd percentile compared with the 99.9th percentile for the group with ADHD. *DSM-IV* hyperactive-impulsive symptoms for controls fell at about the 12th percentile, whereas these symptoms for the participants with ADHD fell at the 96.8th percentile. A total of 44% of the ADHD group reported taking medications specifically prescribed for ADHD at the time of the study and a majority of those participants (73%) reported taking a stimulant. (As mentioned above, these participants agreed to discontinue any stimulant medication the evening before the testing session.) In addition to participants taking ADHD medications, an additional 15% of the ADHD group reported taking psychotropic medication for conditions other than ADHD, mostly antidepressants. Medication status was not associated with significant differences in current inattentive or hyperactive-impulsive symptom severity.

Consistent with prior research (Kessler et al., 2006; Miller, Nigg, & Faraone, 2007), the group with ADHD self-reported higher rates of psychiatric diagnoses other than ADHD, including current depression (12 ADHD vs. 1 control), $\chi 2$ (1, N = 68) = 11.51, p = .001; current anxiety disorders (9 ADHD vs. 2 control), $\chi 2(1, N = 68) = 5.31$, $p = .02$; and history of reading disorder[2] (RD; 6 vs. 0), $\chi 2(1, N = 68) = 6.58$, $p = .01$. However, about half of the participants with ADHD (52.9%) did not self-report any current or past psychiatric diagnoses other than ADHD. Adults with ADHD also reported higher levels of depression and anxiety symptoms using dimensional measures. The group with ADHD reported significantly greater severity of depressive symptoms on the Beck Depression Inventory–II (BDI-II; Beck & Steer, 1993), $t(67) = 5.10$, $p < .001$ (ADHD: $M = 12.47$, $SD = 9.47$; Control: $M = 4.26$, $SD = 4.85$) and anxiety symptoms on the Beck Anxiety Inventory (BAI; Beck, Steer, & Brown, 1996), $t(67) = 5.32$, $p < .001$ (ADHD: M = 12.94, $SD = 9.36$; Control: $M = 4.26$, $SD = 6.85$), with mean symptoms scores for the ADHD group in the mild range.

Memory Performance and Monitoring Accuracy

Adults with ADHD were impaired in their recall of word pairs compared with controls by more than seven words with a medium effect size (Table 2). Controls remembered approximately 75% of the words whereas adults with ADHD remembered about 57%. A categorical analysis yielded similar results. When participants were categorized as to whether their word recall was below (13 words or less), above (39 or more), or within one standard deviation of the overall mean recall (14-38), 27% of the group with ADHD scored below the mean compared with 6% of the non-ADHD group and only 15% of the group with ADHD scored above the mean compared with 29% of the non-ADHD group, $\chi 2(1, N = 67) = 6.33$, $p = .04$. Accordingly, adults with ADHD gave significantly lower mean JOL and rated the task, at a trend level, as more difficult.

Absolute JOL accuracy was measured by subtracting each participant's recall performance from the mean of his or her JOL. Positive values indicate overconfidence and negative values indicate underconfidence. To estimate relative accuracy, Goodman–Kruskall gamma coefficients were calculated for each participant between JOL and recall accuracy (yes/no; Nelson, 1996). For a few participants, a gamma correlation could not be computed because either JOL or recall was invariant. As a result, final sample sizes for relative accuracy data were 29 for adults with ADHD and 25 for healthy controls.

Neither absolute nor relative accuracy differed significantly between groups (Table 2). Across groups, participants showed good absolute accuracy with means near zero, and group differences for relative accuracy actually favored adults with ADHD. However, it is important to note that the median values were high for both the ADHD group (.97) and the healthy controls (.93). Most important, adults with ADHD did not demonstrate poorer accuracy than the healthy controls.

Self-Regulated Study Behavior

Both groups used similar amounts of study time, studying for, on average, about 12 min (Table 2). No significant differences were found in self-reported effort or in the total number of strategies spontaneously reported in response to the open-ended interview prompt. Likewise, no significant between group differences were obtained in frequency of reporting any specific strategy in response to the open-ended interview prompt using chi-square analyses. However, results for two strategies approached statistical significance and deserve mention. The Sort by Categories strategy (sorting pairs into groups based on either word of the pair) was reported by a small number of participants: one in the comparison group and five in the group with ADHD, $\chi 2(1, N = 68) = 2.96$, $p = .09$. Fewer participants with ADHD (62%) than controls (79%) spontaneously reported the Associate strategy (associating words within pairs semantically with method not further specified), $\chi 2(1, N = 68) = 2.56$, $p = .11$.

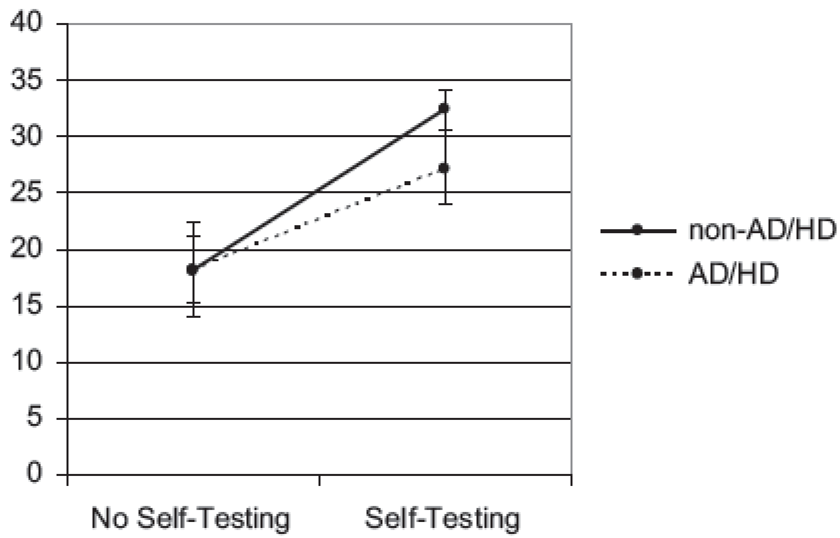

Figure 1. Mean words recalled by group and whether the participant was observed to self-test Note: Error bars represent the standard error of the mean for each cell. Note that cell sizes are unequal because fewer adults with ADHD (17 of 33)[3] than controls (28 of 34) were observed to self-test.

Although no between-group differences in spontaneously reported self-testing were observed, when specifically asked the extent to which they had used this strategy, adults with ADHD reported significantly less frequent use compared with controls with a medium effect size[2] (Table 2). Corroborating participants' self-reports, significantly fewer participants in the group with ADHD were observed to use self-testing even once during the study period—82% (28 of 34) of the healthy controls versus 52% (17 of 33)3 of the group with ADHD, $\chi 2(1, N = 67) = 7.22$, $p = .01$.

Effect of Self-Testing Across Groups

As illustrated in Figure 1, a 2 × 2 (Self-Testing × Diagnostic Group) ANOVA yielded a significant main effect for self-testing, such that participants observed to self-test ($M = 30.55$, $SD = 11.12$) remembered more words than those who did not ($M = 18.18$, $SD = 11.19$) with a large effect size ($d = 1.11$), $F(1, 62) = 13.39$, $p < .001$. In this analysis, the main effect of ADHD status on words recalled was not significant, $F(1, 62) = 0.68$, $p = 0.41$. The interaction effect of ADHD status and self-testing was not significant, indicating that self-testing was similarly associated with better recall for participants with and without ADHD, $F(1, 62) = 0.69$, $p = .41$. Taken together, these results indicate that adults with ADHD were less likely to use self-testing even though it was just as effective as for adults without ADHD.

Discussion

During a self-regulated learning task, a relatively high functioning group of adults with ADHD remembered fewer words than their matched counterparts, despite similar amounts of study time, perceived effort, and self-reported use of a range of other strategies. Self-reported and observed use of self-testing during this paired-associate task differentiated the study behavior of the groups, largely accounting for differences in recall. As predicted, adults with ADHD were less likely to use the powerful strategy of self-testing, and, across the sample, self-testing was associated with better recall. Thus, a substantial proportion of learners with ADHD did not employ a strategy that might have normalized their memory performance.

People with ADHD, when prompted to do so, were able to accurately assess which responses they would later recall, replicating earlier work on item-specific metamemory monitoring (Knouse et al., 2006). What is evident from self-testing behavior (which is a strategy that yields data for learners' monitoring) is that individuals with ADHD were less likely to spontaneously monitor their memory in the absence of overt prompts. This distinction is critical from both a theoretical and applied perspective because it demonstrates that adults with ADHD may not suffer from an inability to monitor or a problem of miscalibration but from a performance deficit. They often fail to perform the adaptive behavior in the situation and at the time that it would be most effective (i.e., at the "point of performance"; Ingersoll & Goldstein, 1993), a concept also emphasized in Barkley's (1997a, 1997b) theory of ADHD and self-control. The ability to make accurate monitoring judgments provides a basis for interventions predicated on teaching adults to make and use these judgments rather than a focus on "accuracy training." Such interventions have been shown to improve the self-directed learning of older adults (Bailey, Dunlosky, & Hertzog, 2010; Dunlosky et al., 2003).

Based on these findings, the question for future studies should not be, “Can adults with ADHD monitor accurately?” but rather should be, “Under what circumstances do adults with ADHD monitor accurately?” (Indeed, Moulin, James, Perfect, & Jones, 2003, found that under the right circumstances, even adults with Alzheimer’s disease can monitor memory accurately!) Future studies must identify the types of judgments and contexts that are most susceptible to ADHD-related monitoring problems and those conducive to better accuracy. This is exemplified by research on the positive illusory bias in children, as more recent studies have focused on identifying the individuals and types of judgments that are most susceptible to these overestimations (Evangelista, Owens, Golden, & Pelham, 2008; Owens & Hoza, 2003). Two arguments support this shift in focus. First, identification of circumstances in which accurate monitoring judgments can be made will point more directly to appropriate intervention strategies. Second, failure to attend to the level of structure and ecological validity of the task being studied may “wash out” important findings with respect to executive functions (Burgess, 1997). For example, few memory tasks given in the laboratory allow participants to control presentation rate or to choose the strategies that they will use to learn items. Constraints such as these may mask processes that are critical to understanding the verbal learning difficulties adults with ADHD experience when trying to study outside the laboratory.[4]

The results of this study support the efficacy of self-testing as a cognitive and metacognitive strategy (Roediger & Karpicke, 2006a). Importantly, the positive impact of testing and retrieval practice on learning has been shown to generalize to improvements in final exam performance in real-world undergraduate classroom settings (McDaniel, Roediger, & McDermott, 2007). However, research with university students indicates that they generally underutilize self-testing when studying on their own in the laboratory and in “real-life” settings (Karpicke, 2009; Karpicke, Butler, & Roediger, 2009). This may be due, in part, to students’ lack of awareness of the benefits of retrieval practice and self-testing (Karpicke et al., 2009). There is some evidence of this lack of awareness for participants in our study. Across both groups, few participants spontaneously reported self-testing in response to the open-ended prompt, “What were you doing to learn items?” although they endorsed the strategy when specifically asked about it and were often observed to use self-testing. Failure to recognize that self-testing

has a direct effect on recall in addition to its function

as a memory monitoring strategy may explain this discrepancy.

Corroborating this interpretation, Kornell and Son

(2009) found that students reported that their motivation for

using self-testing was to find out how well they had learned items rather than to improve learning directly. Thus, participants may not perceive self-testing to be an encoding strategy, per se, despite evidence of powerful direct effects on memory. Thus, increasing students' awareness of the positive effects of self-testing may lead to more frequent use of this strategy (Karpicke, 2009).

Why might adults with ADHD have been less likely to use self-testing? It is tempting to hypothesize a knowledge deficit—that is, most adults with ADHD simply did not know that self-testing was a helpful memory strategy whereas most adults without ADHD did. However, this explanation seems unlikely to completely account for the between-group differences observed in our study, especially given the above studies demonstrating that few students *in general* are fully aware of the benefits of self-testing. This is an empirical question for future studies, and theories of ADHD provide some additional testable explanations, most of which better fit the interpretation of a performance deficit rather than a knowledge deficit. First, because of deficits in behavioral inhibition associated with the disorder, participants with ADHD may be more likely to respond directly to the environment, employing simple stimulus-driven strategies. This might explain why groups were comparable in their self-reported use of visual imagery on the task in the current study—reading pairs of unrelated nouns such as "potato–frog" may immediately bring to mind memorable and unusual images. Second, deficits in central executive working memory functioning (Rapport et al., 2008) may reduce the likelihood that an adult with ADHD will be able to keep key task parameters in mind when forming a study plan that includes appropriate strategies (Dunlosky & Kane, 2007). In this study, adults with ADHD may have been less likely to use the information provided to them about the final test to choose their strategies. The few participants who reported trying to put pairs into category groups based on associations *across* pairs (rather than within pairs) may exemplify this particular difficulty because, in this paired-associates task, forming associations between words in different pairs is likely to impede rather than enhance performance. Future studies employing clever experimental designs or latent variable approaches should examine which of these cognitive processes underlie difficulties in strategy use.

Teaching adults with ADHD how and when to use self-testing and other normatively effective strategies seems an obvious direction for intervention. Because of the likelihood that ADHD-related study strategy deficits reflect a performance deficit rather than merely a knowledge deficit, interventions must include training in how to appropriately apply strategies based on to-be-learned material and the nature of the later test and how to maintain motivation to use the strategy. Adults with ADHD may need to actively practice monitoring and self-testing during study until these techniques become less effortful and until they directly experience positive outcomes from the strategies that will motivate continued use. Interventions that impose an external structure on the process—such as computer programs that prompt JOL and administer tests of to-be-learned material—may be even more powerful tools. Importantly, interventions must be selected and applied based on a thorough assessment of each individual student's needs as not all students with ADHD will exhibit the same areas of difficulty. Skills-based cognitive-behavioral intervention programs that teach organization and distractibility reduction strategies are receiving increasing empirical support for adults with ADHD (Safren et al., 2010; Solanto et al., 2010). Specific interventions tailored to improve the self-regulated learning of students with ADHD could be a useful add-on to such programs in a clinical or university disability services setting.

Several issues should be considered when interpreting the present results and considering future directions. The adults with ADHD in the current study were intellectually high functioning and relatively well educated and thus may not be representative of all adults with ADHD. However, the sample was quite representative of adult students seeking services in the clinic and academic services office where recruitment took place. Future studies should also include a non-ADHD clinical comparison group to determine the specificity of these effects to ADHD and not just adults with psychopathology in general. In particular, more detailed examination of the impact of RD on metamemory processes alone and in combination with ADHD is warranted, given than these disorders are often comorbid and that this comorbidity may present more difficult learning challenges for college students than either disorder alone. We did not collect detailed data on the academic functioning of participants in our study, and future work must more critically examine the link between strategic difficulties observed in laboratory memory tasks and the learning problems that students with ADHD exhibit when learning in vivo. In future studies, additional information on participants' GPAs and academic impairment should be systematically collected via open-ended interview methods and standardized measures, such as the Learning and Study Strategies Inventory–2nd Edition (Weinstein & Palmer, 2002). Information on participants' knowledge of normatively effective study strategies should also be collected to test whether knowledge deficits can account for differential use of study strategies. Other relevant academic constructs that could influence the self-regulated learning of adults with ADHD should be measured, including learning self-efficacy and test anxiety.

Learning on different types of tasks must be investigated to identify those parameters that are most predictive of learning difficulties for students with ADHD. Our study only measured retention at a relatively short interval and over the course of only one study period. Much more sophisticated task models now exist to generate detailed data on self-regulated learning and metacognitive monitoring and their effects on longer term retention over repeated trials (e.g., Karpicke, 2009), and these methods could be applied to adults with ADHD. Finally, participants' use of strategies other than self-testing was only assessed using coded responses to an open-ended prompt. Future studies should collect data on these other strategies using prompted verbal reports and, to the extent possible, behavioral observation and coding.

The current study identified features of self-regulated learning associated with ADHD and poorer memory performance—specifically, less frequent use of self-testing strategies—that await integration into academic interventions for adult learners. Observations of self-regulated learning behavior as well as carefully gathered verbal report data can be used to investigate and improve students' learning in an effort to increase the likelihood of academic success.

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Notes

1. The *DSM-IV* hyperactive-impulsive symptom list may contain less appropriate indicators of hyperactivity-impulsivity for adults (McGough & McCracken, 2006). Four of nine hyperactivity impulsivity symptoms were found to represent the same degree of statistical deviance in adults as six of nine symptoms in the *DSM-IV* field trials with children (Murphy & Barkley, 1996). Some individuals with only inattentive symptoms may represent a meaningfully different subgroup with different cognitive and behavioral correlates (Milich, Balentine, & Lynam, 2001). Thus, the four of nine thresholds were used to identify adults with clinically significant hyperactive-impulsive symptomatology and to guard against identification of adults with purely inattentive ADHD.

2. For all main analyses, we evaluated the possibility that the six participants with ADHD reporting a past reading disorder (RD) diagnosis accounted for ADHD versus non-ADHD effects. We conducted a series of 2 × 2 (ADHD Status × Past RD Status) ANOVAs for each of the major continuous dependent variables and next computed effect sizes for each of these variables with participants reporting past RD excluded. For most measures, the effect of past RD was not significant and the pattern of effect sizes with past RD participants excluded was similar. However, past RD + ADHD was associated with significantly lower frequency of self-reported

self-testing (*M* = 0.83, *SD* = 1.17) than ADHD alone (*M* = 1.96, *SD* = 1.26, *p* = .02), but the ADHD versus non-ADHD effect size for this variable with those with past RD excluded was still 0.49 and the results of the chi-square analysis of number of participants in each group observed to self-test was unchanged (non-ADHD = 82%, ADHD = 54%). Our results, then, do not appear to be driven by the presence of individuals with past RD in our group of participants with ADHD, although they suggest that individuals with this comorbidity may be even less likely to use the important self-testing strategy.

3. Due to experimenter error, recall data from one participant with ADHD and observed self-testing data from another participant with ADHD were lost.

4. For example, a subset of participants in the current study also completed a more highly structured computer-administered version of the task reported here where to-be-learned items were presented on a computer, one at a time, with a fixed presentation rate (Knouse, 2008). Between-group differences in recall at final test were smaller (*d* = 0.36) in this more highly structured task than in the task described in the current study, where a medium effect size for recall was observed.

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