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A Pilot Study of Working Memory and Academic Achievement in College Students With ADHD

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Objective: To investigate working memory (WM), academic achievement, and their relationship in university students with attention-deficit/hyperactivity disorder (ADHD). **Method:** Participants were university students with previously confirmed diagnoses of ADHD (n = 16) and normal control (NC) students (n = 30). Participants completed 3 auditory–verbal WM measures, 2 visual–spatial WM measures, and 1 control executive function task. Also, they self-reported grade point averages (GPAs) based on university courses. **Results:** The ADHD group displayed significant weaknesses on auditory–verbal WM tasks and 1 visual–spatial task. They also showed a nonsignificant trend for lower GPAs. Within the entire sample, there was a significant relationship between GPA and auditory–verbal WM. **Conclusion:** WM impairments are evident in a subgroup of the ADHD population attending university. WM abilities are linked with, and thus may compromise, academic attainment. Parents and physicians are advised to counsel university-bound students with ADHD to contact the university accessibility services to provide them with academic guidance. *(J. of Att. Dis. 2008; 12(6) 574-581)*

Keywords: *ADHD; college students; working memory; academic*

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neuropsychiatric disorders in childhood, with prevalence rates estimated at 4%–10% (see review by Skounti, Philalithis, & Galanakis, 2007). In many cases, ADHD symptoms persist into adolescence and adulthood, causing significant impairments in social, emotional, and cognitive domains. For years, research on ADHD has focused on attention problems as the core deficit, but more recently, ADHD has been linked to deficits in executive functions, a collection of interrelated processes that are responsible for purposeful, goal-directed, problem-solving behavior (Barkley, 1997). Five main categories of executive functions have been proposed: fluency, planning, working memory (WM), inhibition, and set shifting (Pennington & Ozonoff, 1996). Recent meta-analyses have shown that WM, which allows individuals to retain and manipulate information for a few seconds, is impaired in those who have been diagnosed with ADHD (Hervey, Epstein, & Curry, 2004; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Although WM impairments have been found in children, adolescents, and adults with ADHD, they are not manifest in all individuals with ADHD (Nigg et al., 2005).

WM has been found to predict academic achievement (Alloway, Gathercole, Adams, & Willis, 2005; Gathercole, Pickering, Knight, & Stegmann, 2004). For example, a prospective longitudinal study of a community sample of school-aged children revealed that WM performance is associated with achievement scores in English and math. In adolescents, strong links persist between WM and achievement in science and math but not in English (Gathercole et al., 2004).

Academic problems are well documented in individuals with ADHD. Despite average to above average intellectual functioning, school-aged children diagnosed with ADHD struggle academically (Currie & Stabile, 2006;

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Frazier, Youngstrom, Glutting & Watkins, 2007). These academic struggles persist well into adolescence and adulthood. Studies of adolescents with ADHD have found that they are less likely to complete high school and pursue postsecondary education. Those who do go on to college and university are more likely to have lower GPA scores, according to their retrospective self-reports (Barkley, Fischer, Smallish, & Fletcher, 2006; Biederman & Farone, 2006; Biederman et al., 2006). However, research on academic attainment in the subset of individuals with ADHD currently enrolled in college or university has yielded inconsistent findings. One study found that college students with ADHD had lower mean grade point averages (GPAs), were more likely to be put on academic probation, and reported significantly more academic problems than controls (Heiligenstein, Guenther, Levy, Savino, & Fulwiler, 1999). By contrast, another study found that college students with ADHD did not experience significant academic difficulties (Sparks, Javorsky, & Philips, 2004).

Students attending college and university constitute a newly emergent subgroup of individuals with ADHD that has been underinvestigated in the literature. Further research is needed to better understand the academic functioning of college and university students with ADHD, as well as the factors that may contribute to their academic success or failure (Weyandt & DuPaul, 2006).

The objectives of the present study were to (a) investigate WM in university students with ADHD and (b) determine whether WM was related to academic functioning at the university level.

On the one hand, we predicted that there would be no group differences on WM measures and GPA. WM deficits are not universal in ADHD and, as previously stated, WM is related to academic achievement. Presumably those with ADHD who succeeded in going to college had attained a reasonable level of academic achievement, which would predict no WM deficits in this group. On the other hand, we predicted that students with ADHD would perform significantly worse than control subjects on both auditory–verbal and visual–spatial WM tasks. We also predicted that students with ADHD would have significantly lower GPAs than controls. In addition, we hypothesized that there would be a positive relationship between auditory–verbal and visual–spatial WM and GPA in both groups.

Method

Participants

Participants were 46 university students (23 male, 23 female) aged 19–34 years (M = 22.18, SD = 2.67). A total of 16 students (10 male, 6 female; 35% of sample) aged 19–30 years had been previously diagnosed with ADHD (M = 21.34, SD = 2.59). A total of 30 students (13 male, 20 female; 65% of sample) aged 19–34 years (M = 22.48, SD = 2.68) comprised the control group.

Within the sample, 41 participants were enrolled in postsecondary programs at major Ontario urban schools, and 5 students were enrolled in programs in urban schools in Quebec. ADHD participants were recruited through fliers posted in the University Accessibilities Services offices at two major urban universities. Participants in the normal control (NC) group were recruited through announcements in undergraduate summer courses at a major urban university, as well as by a snowball technique (i.e. asking participants to inform their friends).

Inclusion criteria included current enrollment in an undergraduate program at the university level. Participants in the ADHD group were required to be registered with the university Accessibilities Services office. Registration required written documentation of the following: a professional evaluation completed in the past 3 years confirming a diagnosis of ADHD; evidence of current impairment; reports of previous psychoeducational assessment; specific diagnosis based on criteria of the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM–IV*; American Psychiatric Association, 1994) and recommended academic accommodations. Exclusion criteria included uncorrected sensory impairment; major neurological dysfunction and psychosis; and current use of sedating, mood-altering, or any other medication for ADHD other than stimulants. Those participants taking stimulant medication for ADHD (approximately 5%) were required to stop medication 24 hours before participation in this study. Participants in the control group were excluded if they reported a previous diagnosis of ADHD or had scores in the clinical range on the World Health Organization (WHO) Adult ADHD Self-Report Scale (ASRS-V1.1; Kessler, Adler, Ames, et al., 2005).

We used the ASRS-V1.1 to ascertain current ADHD symptomatology and to classify subtypes of ADHD. Seven participants met criteria for ADHD, predominantly inattentive type, and 9 participants met criteria for ADHD, combined type. Within the entire sample, 23 participants were male and 23 participants were female. Seventy-two percent of the sample was Caucasian, 20% were Asian, and 8% were East Indian.

Procedure

The study was approved by the Institutional Research Ethics Board in July 2006. Data collection began shortly thereafter. Informed written consent was obtained from

all participants before testing began. All participants were tested individually in a quiet room located at a university lab classroom, with all measures given during one session lasting approximately 2 hours.

Measures

Auditory–verbal WM. Three tasks were used to assess auditory–verbal WM. The first was the Digit Span subtest from the Wechsler Adult Intelligence Scale (3rd ed.; WAIS-III; Wechsler, 1997). Test–retest reliability scores for the WAIS-III ranged from 0.88 to 0.96. The Digit Span subtest requires the participant to listen to increasingly longer lists of digits that are read aloud by the examiner at a rate of one digit per second. On forward trials, the subject must repeat the numbers in the same order that the examiner read them. However, on the backward trials, the subject must repeat the numbers in the backward order. Testing commenced with a two-digit list and continued to a maximum of an eight-digit list or until the subject missed both trials of any list, whichever occurred first. The Digit Span raw score was converted to an age-adjusted scaled score, with a mean of 10 ($SD = 3$).

The second task was the Letter–Number Sequencing subtest from the WAIS-III. This subtest requires the participant to listen to groups of numbers and letters that are read aloud by the examiner at a rate of one letter/number per second. The participant must first repeat the numbers in numerical order, starting with the lowest number, after which they are to repeat the letters in alphabetical order. Testing commenced with a two-digit/letter list and continued to a maximum of an eight-digit/letter list or until the subject missed all three trials of an item, whichever occurred first. The Letter–Number Sequencing raw score was converted to an age-adjusted scaled score ($M = 10$, $SD = 3$).

The third task was the Paced Auditory Serial Addition Test, a well-validated test of WM (PASAT; Gronwall, 1977). The PASAT consists of sets of numbers presented auditorally on a computer in serial fashion at a predetermined rate. The participant is required to add each new successive number to the preceding number and report the sum verbally to the examiner. For example, when presented with the numbers 3 . . . 4 . . . 1 . . . 6, the correct responses would be 7 (i.e., 3 + 4), 5 (i.e., 4 + 1) and 7 (i.e., 1 + 6). Thus, the task requires continuous updating of WM, as well as inhibition and "forgetting" of the sum of the previous calculation. Two different sets were administered: Set A, in which numbers were presented at a rate of 2.4 seconds between each number, and Set B, in which numbers were presented at a rate of 1.6 seconds between each number. Traditionally, from a processing speed perspective, performance would be expected to deteriorate as the rate of presentation increases because of the increased demands on speed of calculation. In contrast, from a WM perspective, the longer the time interval between target stimuli, the greater the challenge for WM, as WM holds information for only 1–2 seconds. Therefore, we expected participants to have more difficulty with Set A. The total number of errors for each set constitutes the score for the test. Two different T scores are generated: a general T score based on a composite sample without demographic corrections and an age-adjusted T score. Higher T scores indicate better performance.

Spatial WM. Subjects were also administered two spatial WM tasks from the Cambridge Neuropsychological Testing Automated Battery (CANTAB; Fray, Robbins, & Sahakian, 1996): the Spatial Working Memory Task and the Spatial Span task. The CANTAB emphasizes the assessment of executive functioning, including measures of planning, set shifting, spatial WM, and nonverbal memory span (Luciana, 2003). Internal consistency coefficients for the CANTAB are high, ranging from .73 to .95. Stability coefficients range from .60 to .70. These tasks were administered on a computer equipped with a touch-sensitive monitor. Subjects first became acquainted with the CANTAB as they participated in a motor speed task, in which they were asked to touch the cross-point of 10 flashing crosses with their dominant hand. A one-way analysis of variance (ANOVA) indicated that motor speed did not differ significantly between groups, $F(1, 44) = 2.185$, $p > .05$.

The first task, the Spatial Working Memory Task, is a well-validated test of spatial WM (Luciana & Nelson, 1998). It is a self-ordered search task in which subjects are required to update information about spatial locations in WM. Subjects must search boxes to find the hidden token but must not return to the same box where a token had already been found. There are four trials in total, with four, six, and eight boxes. Performance is measured according to the number of errors made. There are two types of errors, a within-search error and a between-search error. At the end of the task, subjects receive a strategy score. A low score means efficient strategy use, whereas high scores represent poor strategy use.

During the Spatial Span task, subjects are presented with white squares on a screen that momentarily change color in a variable sequence. The subject must then touch the boxes in the same order that they changed color on the screen. Task demands intensify as the number of boxes is increased from two to nine. However, if the subject makes an error, the next trial remains at the same difficulty level. Spatial span scores range from 0 to 9, with

the score representing the highest level at which the subject reproduces at least one correct sequence.

Control executive function measure. In addition to the auditory–verbal and visual–spatial WM measures, we also administered a control executive function task, the Stockings of Cambridge task from the CANTAB. This task measures aspects of executive function other than WM, particularly planning. Inclusion of this task allows us to determine whether impairments are generalized across several executive functions, or whether they are specific to WM.

The Stockings of Cambridge task is based on the Tower of London. The subject is shown two displays, each containing three balls, with each set arranged in different "stockings" hanging in three pockets. The subject must move the balls in the lower display to copy the pattern in the upper display. This involves working out an optimal set of moves (the fewest moves possible) and then executing them by moving one ball at a time. Planning ability is calculated by computing the number of trials completed within minimum number of moves. Also, the planning efficiency is estimated from two latency variables: initial think time (before moving the first ball) and subsequent think time.

Self-reported GPA. Each participant was required to list his or her GPA based on all courses taken at the post-secondary level. Because the two universities have different grading systems, the Ontario Medical School Application Services grade conversion table was used to convert all GPAs to a number based on a standardized 4-point scale.

ADHD rating scales. Each subject was required to complete two ADHD questionnaires to assess current symptomatology and their impairment: The ASRS-V1.1 (Kessler, Adler, Ames, et al., 2005) Symptom Checklist and the Brown ADD Scale for Adults (Brown, 2001). The ASRS-V1.1 was developed by the WHO and the Workgroup on Adult ADHD. It is a reliable and valid scale for evaluating ADHD in adults and shows a high internal consistency and high concurrent validity with the rater-administered ASRS (Murphy & Adler, 2004). The ASRS-V1.1 is an instrument consisting of 18 questions based on the criteria used for diagnosing ADHD in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text revision; *DSM-IV-TR*; American Psychiatric Association, 2000) and addresses the manifestations of ADHD symptoms in adults. Questions focus on how often symptoms occur (0 = *never*, 1 = *rarely*, 2 = *sometimes*, 3 = *often*, 4 = *very often*). Scores for each item were added and divided by the total number of items (i.e., 18) to calculate a mean rating score.

The Brown ADD Scale for Adults (Brown, 2001) is a well-validated assessment tool designed to capture impairments that may not be reflected by the *DSM-IV-TR* criteria. It yields scores for five subscales of ADHD-related executive function impairments, including organization of work (Activation), sustaining attention and concentration (Attention), sustaining performance and effort (Effort), managing frustration (Affect), and WM functioning (Memory). All five subscales contribute to a total score. Raw scores for each subscale, as well as the overall score, were each converted to *T* scores and used in this study. A higher score indicates a greater level of impairment. This assessment tool has high internal consistency (Cronbach's coefficient $\alpha = .96$), and reliability is sound (4% false-negative rate and 6% false-positive rate in adult ADD; Weiss, Hechtman, & Weiss, 1999). For this study, we used total score as an index of overall impairment.

Statistical Analyses

To determine the effects of group and gender on ADHD questionnaire scores (ASRS mean rating and Brown *T* score total), highest year completed, and self-reported GPA scores, we conducted a 2 (Group: ADHD, NC) × 2 (Gender: male, female) ANOVA separately for each variable.

To determine the effects of group (ADHD, NC) and gender on WM, we conducted a two-way multivariate analysis of variance (MANOVA) separately for each variable. However, to determine the effect of group and gender on the PASAT (Set A, Set B), we computed a repeated measures MANOVA. In addition, an eta-squared value (η^2) was calculated to ascertain effect size. According to Grimm and Yarnold (2000), $\eta^2 = .01$ corresponds to a small effect, $\eta^2 = .09$ corresponds to a medium effect, and $\eta^2 = .25$ represents a large effect.

Correlational analysis was used to examine relationships between WM and GPA and between WM and severity of ADHD symptoms.

Results

Group Characteristics

Table 1 presents the overall means, standard deviations, critical values and effect sizes (partial η^2-squares) for each of the ADHD questionnaire variables. On the ASRS mean rating scores, as expected by the selection criteria, the ADHD group reported significantly higher levels of behavioral disturbance, compared with controls.

Table 1
Summary Data for ADHD Questionnaires and Education Variables for ADHD and Control Groups

	ADHD (n = 16)		NC (n = 30)				
Measure	*M*	*SD*	*M*	*SD*	$F(1, 42)$	*p*	ES
ASRS mean rating	2.37	0.664	1.33	0.354	42.24	.000	.501
ASRS mean inattention	6.75	2.21	2.00	1.44	77.89	.000	.639
ASRS mean hyperactive	3.88	2.68	1.37	1.45	17.12	.000	.280
Brown T score total	75.69	13.93	53.23	5.47	54.51	.000	.565
Education level	2.25	0.931	2.88	0.806	5.31	.02	.112
GPA	2.67	0.602	3.09	0.625	3.22	.08	.071

Note. ADHD = attention-deficit/hyperactivity disorder; NC = normal control; ES = effect size (partial eta squared); ASRS = World Health Organization Adult ADHD Self-Report Scale; GPA = grade point average.

The results indicated a significant main effect for group, of large effect size (partial η^2 = .501). There was no significant main effect for gender, $F(1, 42) = 2.67$, $p > .05$; and no Group × Gender interaction, $F(1, 42) = 1.51$, $p > .05$. On the Brown ADD Scale overall *T* score, the results indicated a significant main effect for group, as expected (see Table 1). There was no significant main effect for gender, $F(1, 42) = 3.95$, $p > .05$; and no Group × Gender interaction, $F(1, 42) = 0.652$, $p > .05$. Overall, the ADHD group had higher *T* scores, reflective of greater symptom impairment.

University-Level Academic Attainment

Analysis of the highest year completed of university education revealed a significant main effect of group; no significant main effect for gender, $F(1, 42) = 0.585$, $p > .05$; or Group × Gender interaction, $F(1, 42) = 1.6$, $p > .05$. The group main effect indicated that the NC group had completed significantly more years of postsecondary schooling than the ADHD group, despite the fact that the groups did not differ significantly in age, $F(1, 42) = 1.76$, $p > .05$.

As shown in Table 1, there was a trend for the ADHD group to have lower self-reported GPAs. However, neither the main effects for group and gender, $F(1, 42) = 2.681$, $p > .05$; nor the Group × Gender interaction, $F(1, 42) = .893$, $p > .05$, were statistically significant.

WM Measures

Table 2 contains the means, standard deviations, critical values, and effect sizes (partial η^2s) for both the auditory and visual–spatial WM measures.

Auditory–verbal WM. With respect to the Digit Span scaled score, there was a significant main effect for group, $p < .01$, of medium effect size (partial $\eta^2 = .154$), but not for gender, $F(1, 42) = 0.922$, $p > .05$. This finding indicated that the ADHD group scored significantly lower than the NC group. For the Letter–Number Sequencing scaled score, there was no main effect for group ($p > .05$) or gender, $F(1, 42) = 3.329$, $p > .05$. There was a trend for the ADHD group to perform more poorly, although the results were nonsignificant. In addition, the MANOVA indicated no significant interaction between group and gender on the Digit Span, $F(1, 42) = 0.390$, $p > .05$; or Letter–Number Sequencing scaled scores, $F(1, 42) = 0.798$, $p > .05$.

Analysis of the PASAT revealed significant main effects for group ($p < .001$) of large effect size (partial $\eta^2 = .25$) and gender ($p < .05$) of medium effect size (partial $\eta^2 = .09$). Moreover, none of the interaction effects (Group × Set, Gender × Set, Group × Gender × Set) were significant.

Visual–spatial WM. On the CANTAB Spatial Span Forward standard score, there was no significant main effect for group ($p > .05$), but there was a significant main effect for gender, $F(1, 42) = 8.233$, $p < .01$, indicating that females performed better than males. The interaction between group and gender was not significant, $F(1, 42) = 0.081$, $p > .05$. For the Spatial Span Backward score, there was a significant main effect of group ($p < .05$) but not gender, $F(1, 42) = 0.399$, $p > .05$. There was no significant Group × Gender interaction, $F(1, 42) = 0.399$, $p > .05$. The group main effect indicated that the ADHD group performed significantly worse than the NC group. On the Spatial Working Memory between-errors standard score, the group main effect was not significant, $F(1, 42) = 0.052$, $p > .05$. There was no main effect for gender, $F(1, 42) = 0.024$, $p > .05$; and there was no Group × Gender interaction, $F(1, 42) = 0.746$, $p > .05$.

Table 2
Summary Data for Working Memory Measures for ADHD and Control Groups

	ADHD (n = 16)		NC (n = 30)				
Measure	*M*	*SD*	*M*	*SD*	$F(1, 42)$	p	ES
WAIS-III Digit Span task	9.06	3.02	11.37	2.71	7.662	.008	.154
WAIS-III Letter–Number Sequencing task	9.94	2.27	11.07	2.46	3.652	.063	.080
PASAT Set A (*T* general)	48.7	11.57	57.57	6.82	12.62	.001	.231
PASAT Set B (*T* general)	56.06	9.90	62.7	8.22	7.89	.008	.158
CANTAB SWM, strategy score	–0.146	1.44	0.265	1.30	0.495	.485	.012
CANTAB SWM, between errors	–0.46	1.33	0.299	1.12	3.994	.052	.087
CANTAB SSP, forward	–0.341	0.951	0.151	1.14	1.058	.310	.025
CANTAB SSP, backward	–0.636	1.27	0.218	1.14	4.302	.044	.093
CANTAB SOC, initial think time	0.378	0.859	0.587	0.634	0.261	.612	.006
CANTAB SOC, subsequent think time	0.057	0.799	0.092	1.09	0.060	.808	.001
CANTAB SOC, problem solved in minimum no. of moves	–0.258	0.990	–0.249	1.12	0.004	.947	.000

Note. ADHD = attention-deficit/hyperactivity disorder; NC = normal control; ES = effect size (partial eta squared); WAIS-III = Wechsler Adult Intelligence Scales—Third Edition (Wechsler, 1997); PASAT = Paced Auditory Serial Addition Test (Gronwall, 1977); CANTAB = Cambridge Neuropsychological Testing Automated Battery (Fray, Robbins, & Sahakian, 1996); SWM = Spatial Working Memory task; SSP = Spatial Span task; SOC = Stockings of Cambridge.

Control Executive Function Measure

On the Stockings of Cambridge, there were no significant main effects for group or gender on any of the measures (mean initial thinking time standard score, mean subsequent thinking time standard score, and problems solved in minimum moves standard score; all ps > .05) and no significant interactions (ps > .05). This indicated that ADHD subjects did not display any significant impairment relative to controls in this type of executive function.

Relationship Between WM, Academic Achievement, and ADHD Symptoms

There was no relationship between visual–spatial WM and GPA ($p > .05$) in either the ADHD or control groups. Within the entire sample, GPA was significantly correlated with auditory–verbal WM ($r = .405$, $p < .01$). There was no significant correlation between GPA and visual–spatial WM ($r = .186$, $p > .05$) in either the whole sample or each group separately. There was also no relationship between severity of inattentive symptoms and performance on any of the WM measures when controlling for hyperactive symptoms ($p > .05$). Similarly, there was no relationship between severity of hyperactive symptoms and WM when controlling for inattentive symptoms ($p > .05$).

Discussion

This study, which is the first to examine WM, academic achievement, and their relationship in university students with ADHD, found that WM was impaired in the ADHD group, compared with WM in controls. Evidence was strongest for auditory–verbal WM. Although auditory–verbal WM was strongly related to students' academic achievement at university, as indexed by their self-reported GPA, we did not find robust group differences in GPA. Collectively, these findings suggest that university students with ADHD continue to show subtle impairments in WM, which pose a risk for academic achievement at the postsecondary level.

Evidence of WM impairment in university students with ADHD was strongest for auditory–verbal WM. Specifically, the ADHD group showed significant impairment on three out of the four measures of auditory–verbal WM (WAIS-III Digit Span subtest and both Set A and Set B of the PASAT, with a nonsignificant trend for worse performance on the Letter–Number Sequencing Test). By contrast, we found only limited evidence of impairment in visual–spatial WM. The findings indicated that the ADHD group performed more poorly than controls on the measure "Spatial Span, backward," and that they had a tendency for poorer performance on spatial WM, but did not differ on "Spatial Span, forward." Our findings are generally consistent with and extend previous research on WM impairments in ADHD (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Hervey et al., 2004; Martinussen et al., 2005) to a newly emergent subgroup: those who complete high school successfully and proceed to postsecondary education at university. However, our findings were somewhat contradictory to previous studies that have found

visual–spatial WM to be a much more robust deficit in children with ADHD, compared with auditory–verbal WM (Martinussen et al., 2005; Wilcutt et al., 2005). We speculate that the discordant findings are attributable in part to methodological differences and perhaps also to comorbidity with learning disabilities.

Academic Achievement and Its Relationship to WM

On the one hand, we did not find robust evidence of academic impairment in the ADHD group relative to controls, at least not by the measure of self-reported GPA. On the other hand, we found that the ADHD group had completed fewer years of university education, compared with their age-matched controls. Several explanations of this pattern of findings are possible. One possibility is that the ADHD group may have taken longer to complete the high school requirements or may have repeated a grade at some point during their school years, thus entering university at a somewhat older age than non-ADHD students. Thus by aiming to match the two groups for age, the ADHD group was more likely to have completed only 2 years of postsecondary education compared to 3 years completed by most of the controls. Another possibility is that methodological shortcomings might contribute to our failure to discern academic impairments in the ADHD group. For example, we relied on self-reported GPA rather than on official records: thus, it is possible that participants overestimated or underestimated their grades. Moreover, we did not examine whether subjects in the ADHD group were receiving special accommodations or whether they were taking fewer courses, both of which could influence their grades. Further research should attempt to examine the nature of accommodations that ADHD students receive, whether they take fewer courses, and/or how many courses they have failed or withdrawn from at university.

Our findings did, however, reveal the expected relationship between WM and academic attainment at the postsecondary levels, as indexed by self-reported GPA. That the relationship was restricted to auditory–verbal WM is not surprising, given that the majority of instruction at school involves reading and lectures, both of which rely on auditory–verbal WM. This study did not attempt to tease apart the relationship of each component of WM (auditory–verbal and visual–spatial) to various subject domains (English and math/science) in a college and university population. Future studies should attempt to delineate this relationship.

Our findings should be interpreted with caution because of study limitations, which might have had an impact on the results. For instance, we relied on self-reported GPA, rather than on official academic records to ascertain current academic levels of attainment at university. Thus, participants may have overestimated or underestimated their grades. However, a recent review of the literature on self-reported GPA concluded that the use of self-reported GPA is reliable insofar as findings are interpreted with caution (Cassady, 2001; Kuncel, Credé, & Thomas, 2005). Additionally, we used a small sample size, which limits the generalizability of the present findings and precluded an examination of subtype differences.

Notwithstanding the preceding limitations of this preliminary study, our results suggest that WM is impaired in university students with ADHD, even though these youngsters, by definition, had attained an academic standard commensurate with university academic entry requirements. Moreover, our findings reveal a significant relationship (of moderate effect size) between WM and academic achievement at university. Thus, ADHD and/or poor WM are risk factors for successful completion of university-level studies. Parents, physicians, and other health care professionals are advised to counsel university-bound youngsters with ADHD or WM deficits (or both) to contact accessibility services at their institutions to provide them with academic guidance and learning accommodations as needed.

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