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ORIGINAL ARTICLE

Executive functioning in high-IQ adults with ADHD

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Background. To examine the association between psychological tests of executive functioning and functional outcomes among high-IQ adults with attention deficit hyperactivity disorder (ADHD).

Method. Subjects were high-IQ adults with ($n=64$) and without ADHD ($n=53$). Subjects were administered a battery of neuropsychological tests assessing executive functioning.

Results. High-IQ adults with ADHD performed less well than those without ADHD on several psychological tests of executive functioning, including the Wisconsin Card Sorting Test (WCST), Stroop Color and Word Test, Rey–Osterrieth Complex Figure Test (ROCF), California Verbal Learning Test (CVLT) and an auditory continuous performance test (CPT). Test performance in the high-IQ adult ADHD group, however, was average. In the entire sample, performance on several tests of executive functioning including the ROCF and the CVLT were significant predictors of real-world functioning.

Conclusions. High-IQ adults with ADHD perform less well on tests of executive functioning relative to high-IQ control participants. Performance on several tests of executive functioning was a significant predictor of functioning.

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Key words: Adult ADHD, executive functioning, IQ.

Introduction

Executive functioning deficits are common in both pediatric and adult attention deficit hyperactivity disorder (ADHD) (Frazier *et al*. 2004; Hervey *et al*. 2004) and show substantial stability in longitudinal studies (Biederman *et al*. 2007, 2008*a*). Although insufficient to make a diagnosis of ADHD, psychological tests assessing these executive functions are often used to clarify the impairments of ADHD patients (Barkley & Murphy, 2006).

Executive dysfunction negatively affects functioning, particularly in academics. The academic domain is often the most functionally impaired domain in adult ADHD (Wender, 1995; Weiss & Weiss, 2004; Barkley *et al*. 2006, 2007). For example, adults with ADHD completed fewer years of education, with nearly one-third failing to complete high school (Barkley *et al*. 2006). Others have similarly reported that relatively few young adults with ADHD attempt college (20%) and even fewer graduate (5%) from college (Weiss & Hechtman, 1993; Biederman *et al*. 2006*a*).

Compared to children with ADHD who are followed into adulthood, clinically diagnosed adults with ADHD are found to have higher intellectual levels, have graduated from high school and have at least attempted college (Barkley *et al*. 2007). Although there is evidence in the pediatric literature that ADHD can exist in the context of a high IQ (Antshel *et al*. 2007, 2008), the validity of ADHD in adults with a high IQ has not been addressed systematically.

In our initial attempt to address this issue (Antshel *et al*. 2009), we operationalized high IQ as having a full-scale IQ $\geqslant 120$. We identified 53 adults with a high IQ who did not have ADHD and 64 adults with a high IQ who met diagnostic criteria for ADHD. High-IQ adults with ADHD reported lower quality of life, had poorer familial and occupational functioning, and had more functional impairments. Co-morbid psychiatric disorders were more frequent in high-IQ adults with ADHD. In this report from the same sample, we sought to determine whether high-IQ adults with ADHD showed deficits in executive functions.

The relationship between executive functions and intelligence is complex and depends on which executive function is being assessed. For example, in a typically developing adult population, Friedman *et al*. (2006) reported that performance on working memory tasks was strongly associated with intelligence yet inhibition and set shifting task performance was not associated with intelligence. Others have reported that intelligence and executive function abilities are related

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positively (Jung *et al*. 2000). For example, Jung *et al*. (2000) found a linear relationship between IQ and psychological test scores on the Rey–Osterrieth Complex Figure Test (ROCF) and the California Verbal Learning Test (CVLT); adults with a superior IQ outperformed high-average-IQ adults, who in turn outperformed average-IQ adults.

Mahone *et al*. (2002) investigated the relationship between ADHD and executive functions in 92 children (51 with ADHD, 41 controls). Participants were separated into three groups based on their IQ: average (85–109), high average (110–119) and superior ($\geqslant$120). Among the average-IQ children, significant differences were apparent between the ADHD group and controls on three out of the five executive function measures, with average effect sizes in the medium range (Cohen's $d=0.57$). By contrast, the high-average- and superior-IQ children with ADHD performed comparably with the IQ-matched control group on all of the executive function measures, with mean effect sizes in the small range (Cohen's $d=0.41$ for high-average and 0.33 for superior-IQ groups). These data suggest that IQ mediates poor performance on tests of executive functioning in ADHD. Indeed, the authors note in their discussion that IQ scores accounted for more variance in the executive function measures than did having ADHD (Mahone *et al*. 2002). This implies that the pediatric high-IQ ADHD population mimics the pediatric high-IQ non-ADHD population in executive function performance, although we know of no empirical investigation addressing this question in adults with ADHD.

From a clinical perspective, investigating the executive functioning skills of high-IQ adults with ADHD has several implications. First, executive function deficits make substantial contributions to real-world functional impairments in ADHD (Biederman *et al*. 2004, 2006*b*, 2007). Adults with ADHD and high levels of self-reported executive dysfunction had significantly more social functioning impairments, more current ADHD symptoms, more co-morbid disorders, and lower socio-economic status (SES) compared to adults with ADHD who had lower levels of self-reported executive dysfunction (Biederman *et al*. 2006*b*). If having a high IQ mediates executive dysfunction, this may have implications for treatment. Second, given that many adults without a history of an ADHD diagnosis are presenting to adult ADHD clinics for diagnostic evaluations, it may be helpful for clinicians to know the extent to which executive functioning psychological tests can be useful in the diagnosis of ADHD (Barkley & Murphy, 2006).

We hypothesized that performance on psychological tests of executive function would not differ between high-IQ adults with ADHD and high-IQ control adults. In addition, and going beyond the Mahone *et al*. (2002) study, we were interested in assessing the relationship between executive dysfunction and real-world functioning, both self-reported and objectively defined. Based upon our previous work in the average-IQ ADHD population (Biederman *et al*. 2006*b*), we hypothesized that executive dysfunction would be associated with functional deficits in both high-IQ samples.

Method

Subjects

Detailed methods have been published elsewhere (Faraone *et al*. 2006*a*, *b*, 2007). In brief, subjects between the ages of 18 and 55 years were eligible. We recruited ADHD subjects from referrals to Psychiatric Clinics at the Massachusetts General Hospital (MGH) and advertisements. We recruited potential non-ADHD subjects through advertisements. The institutional review board approved the study and informed consent was obtained from all participants. Using the approach adopted by Lovecky & Silverman (1998), we categorized high IQ as $\geqslant$120.

Assessment measures

We interviewed all subjects with the Structured Clinical Interview for DSM-IV (SCID; First *et al*. 1997) supplemented with modules from the Schedule for Affective Disorders and Schizophrenia for School-Age Children Epidemiologic Version adapted for DSM-IV (K-SADS-E; Orvaschel, 1994) to cover ADHD. Initial diagnoses were prepared by the study interviewers and were then reviewed by a Diagnostic Committee of board-certified psychiatrists or licensed psychologists. Diagnoses were made for two points in time: lifetime and current (past month). ADHD status (Yes/No) was based upon a current diagnosis. Control participants did not meet criteria for either a current or a past diagnosis.

Two subtests from the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1993), Vocabulary and Block Design, were used to estimate general cognitive abilities. Validity coefficients for the Vocabulary and Block Design scores relative to the full form are 0.88 for Verbal IQ and 0.83 for Performance IQ (Sattler, 2001). WAIS-III Digit Symbol Coding, Symbol Search, Arithmetic and Digit Span subtests were also assessed.

The executive functioning battery included the Wisconsin Card Sorting Test (WCST; Heaton *et al*. 1993), the Stroop Color and Word Test (Golden, 1978), the CVLT (Delis *et al*. 1987) and the ROCF (Rey, 1941).

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Table 1. *Participant characteristics*

Variable	High-IQ ADHD ($n = 64$)	High-IQ Control ($n = 53$)
Age (years)	33.4 (10.4)*	27.9 (7.6)
Gender (% females)	44	49
Number of ADHD symptoms	13.5 (2.7)**	0.8 (0.9)
Estimated WAIS-III full-scale IQ	127.9 (7.5)	127.9 (6.2)
WAIS-III Block Design Scaled Score	14.2 (2.2)	14.4 (1.7)
WAIS-III Vocabulary Scaled Score	15.7 (1.6)	15.6 (1.6)

ADHD, Attention deficit hyperactivity disorder; WAIS-III, Wechsler Adult Intelligence Scale – Third Edition (Wechsler, 1993).

Values given as mean (standard deviation).

* $p < 0.01$, ** $p < 0.001$.

The Developmental Scoring System (DSS) for the ROCF (Holmes-Bernstein & Waber, 1996) was used to assess the organization, style and accuracy of the drawings. The dependent variables were (*a*) the organization scores for the copy and recall conditions and (*b*) the accuracy scores for the copy and recall conditions. The Seidman auditory working memory continuous performance task (Seidman CPT) was also administered.

Quality of life was assessed with the short-form version of the Quality of Life Enjoyment and Satisfaction Questionnaire (Q-LES-Q; Endicott *et al*. 1993). The Q-LES-Q is a 16-item self-report instrument that evaluates enjoyment and satisfaction in various areas of daily functioning, including physical health, work, social relationships, family, and general activities. Each item is scored using a five-point Likert scale (1 = very poor; 5 = very good), where higher scores indicate greater enjoyment and satisfaction. SES was assessed with the Hollingshead scale (Hollingshead, 1975).

Procedures

After the diagnostic interview, adults with ADHD completed the psychological tests in one session. Participants were not asked to refrain from taking medication prior to the psychological testing. Current treatment was therefore considered an independent variable and analyzed (see below).

Using a method with a precedence in the literature (Biederman *et al*. 2004, 2006*b*), we computed a binary measure of deficits of executive dysfunction. For each of the executive functioning dependent variables, we defined poor performance as a score <1.5 standard deviations from the mean for normally distributed variables or within the poorest seventh percentile of performance for non-normally distributed variables. We then created binary impairment indicators for the executive function variables for all subjects (ADHD and control). Thus, we could sum the number of variables for which any given subject performed poorly based on the cut-offs. We defined a subject as having executive dysfunction if two or more tests showed impairment (Doyle *et al*. 2000).

Statistical analyses

Initially, χ^2 analyses were used to compare our high-IQ groups on sex distribution. No differences existed between the two groups in sex distribution ($\chi^2 = 0.33$, $p = 0.57$). ANOVAs were then used to compare our high-IQ groups on IQ and age. No IQ differences existed between the two groups [$F(1, 115) = 0.01$, $p = 0.97$]. Adults with ADHD were older than high-IQ control participants [$F(1, 115) = 10.47$, $p < 0.01$, $\eta^2 = 0.08$]. Thus, age was entered as a covariate in all subsequent analyses. See Table 1 for background data.

None of our 53 high-IQ control participants were being treated with either psychotherapy or pharmacotherapy. Of our 64 high-IQ ADHD participants, the majority ($n = 35$, 54.7%) were not being currently treated with either psychotherapy or pharmacotherapy. A combined psychotherapy/pharmacotherapy treatment was being used by 17 participants (26.6%). Ten high-IQ adults with ADHD (15.6%) were being treated with medications only and two adults with ADHD (3.1%) were treated with psychotherapy only.

Psychotherapy is not known to reliably affect performance on psychological tests of executive functioning. However, though inconsistent, there are some data suggesting that pharmacotherapy can improve performance on psychological tests of executive functioning (Vance *et al*. 2003; Biederman *et al*. 2008*b*). Thus, performance on the six psychological test-dependent variables was compared between those

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with ADHD prescribed medication ($n=27$) and those who were not prescribed medication ($n=37$). No age differences were present between the two ADHD groups [$F(1, 62)=0.45$, $p=0.51$]. Thus, age was not entered as a covariate. Similarly, the omnibus MANOVA was not significant [$F(15, 44)=0.95$, $p=0.48$], suggesting that the two groups (meds/no meds) performed comparably on the psychological tests.

As reported previously (Antshel *et al*. 2009), major depressive disorder, obsessive–compulsive disorder and generalized anxiety disorder diagnoses were higher in high-IQ adults with ADHD than high-IQ controls. To assess the contribution of psychiatric co-morbidity on our executive function test performance, we compared those high-IQ adults with ADHD and psychiatric co-morbidity ($n=42$) to those high-IQ adults with ADHD without psychiatric co-morbidity ($n=22$). The omnibus MANOVA was not significant [$F(15, 44)=2.43$, $p=0.11$], suggesting that the two groups (co-morbidity/no co-morbidity) performed comparably on the psychological tests.

Next, to assess our *a priori* hypothesis, we conducted an omnibus MANCOVA using age as a covariate on the dependent variables from the six psychological tests. If this analysis was significant, follow-up univariate ANCOVA tests were planned. To assess our binary executive dysfunction variable, we conducted a logistic regression using our binary variable as the outcome variable and group (ADHD, control) as the predictor.

To assess the relationship between performance on executive functioning tests and functional/quality of life variables, we used linear regression for continuous outcomes (e.g. number of speeding tickets) and ordinal logistic regression for ordinal outcomes (e.g. self-report on the Q-LES-Q). Only those psychological tests that differentiated high-IQ control and ADHD participants were included as predictors. Two separate series of regressions were performed: one with group status (ADHD, control) and age entered first, followed by the psychological test scores, followed by the interaction between age, group status and psychological test scores. The other regression entered age and the psychological test scores only. In this way, we could assess the independent contribution of age, ADHD status, the psychological test performance and also the interaction between the three.

Results

High-IQ ADHD versus *high-IQ Control*

The omnibus MANCOVA on the six psychological test-dependent variables was significant [Wilk's $\lambda=0.23$, $F(24, 88)=4.29$, $p<0.01$, $\eta^2=0.46$]. Follow-up univariate ANCOVAs revealed several group differences (listed largest to smallest) including ROCF Copy Organization [$F(2, 114)=8.20$, $p<0.01$, $\eta^2=0.14$], CVLT Words Correct List A Short Delay [$F(2, 114)=6.42$, $p<0.01$, $\eta^2=0.10$], Auditory CPT Memory Task Hits [$F(2, 14)=6.42$, $p<0.01$, $\eta^2=0.10$], WCST Conceptual Level Response Percentage [$F(2, 114)=5.08$, $p<0.01$, $\eta^2=0.09$], Stroop Color–Word T-Score [$F(2, 114)=4.63$, $p<0.01$, $\eta^2=0.09$], WCST Non-perseverative Errors [$F(2, 114)=4.80$, $p<0.01$, $\eta^2=0.08$], Auditory CPT Memory Task – Number Correct [$F(2, 114)=9.62$, $p<0.002$, $\eta^2=0.08$], Stroop Interference T-Score [$F(2, 114)=8.18$, $p<0.005$, $\eta^2=0.07$], CVLT Words Correct List B [$F(2, 114)=3.77$, $p=0.02$, $\eta^2=0.06$], ROCF Delay Organization Score [$F(2, 114)=3.16$, $p=0.04$, $\eta^2=0.05$], Auditory CPT Interference Task – Number Correct [$F(2, 114)=4.69$, $p=0.03$, $\eta^2=0.04$], and WAIS-III Digit Symbol – Coding Scaled Score [$F(2, 114)=2.60$, $p=0.04$, $\eta^2=0.04$]. See Table 2 for complete psychological test results.

Five high-IQ adults with ADHD and one high-IQ control participant were categorized as having executive functioning deficits based upon our binary definition. There were no differences between groups ($\chi^2=1.81$, $p=0.18$).

Associations of psychological test performance and functioning

Regressions with ADHD as a predictor

The ordinal logistic regressions for 12 of the 16 Q-LES-Q items were statistically significant. However, this significance was based on the group variable (ADHD, control) and not the psychological test scores or the interaction between group and psychological test scores. Thus, in both groups, psychological test performance was not predictive of Q-LES-Q ratings. Age was not a predictor of any of the Q-LES-Q ratings.

The logistic regression for history of arrests was significant (Wald $\chi^2=34.85$, $p<0.01$); however, similar to the Q-LES-Q ratings, this significance was based on the group variable (ADHD, control) and not the psychological test scores or the interaction between group and psychological test scores. The logistic regression for receiving academic tutoring during primary or secondary school was significant (Wald $\chi^2=21.60$, $p<0.01$). However, once again, this significance was based on the group variable (ADHD, control) and not the psychological test scores or the interaction between group and psychological test scores. The logistic regression for repeating a grade during primary or secondary school failed to reach significance (Wald $\chi^2=1.71$, $p=0.19$). Age was not a

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Table 2. *Psychological test performance*

Variable	High-IQ ADHD	High-IQ Control
WAIS-III Digit Span Scaled Score	13.1 (2.8)	12.8 (2.9)
WAIS-III Arithmetic Scaled Score	12.5 (2.0)	13.1 (1.4)
WAIS-III Digit Symbol – Coding Scaled Score	11.1 (2.8)	12.4 (2.9)*
WAIS-III Symbol Search Scaled Score	11.0 (1.9)	11.5 (2.2)
ROCF Copy Organization Score	9.9 (3.0)	11.5 (2.1)***
ROCF Delay Organization Score	8.3 (4.0)	10.0 (3.9)*
Stroop Word T-Score	48.9 (8.1)	49.2 (7.8)
Stroop Color T-Score	45.9 (7.0)	48.3 (8.5)
Stroop Color–Word T-Score	44.7 (5.0)	50.2 (9.0)**
Stroop Interference T-Score	52.2 (7.2)	56.0 (6.9)**
WCST Perseverative Errors	9.0 (7.3)	7.5 (6.4)
WCST Non-perseverative Errors	9.6 (10.5)	7.0 (6.7)**
WCST Conceptual Level Response Percentage	76.4 (18.1)	80.7 (12.2)*
WCST Number of Failures to Maintain Set	0.5 (0.8)	0.3 (0.6)
WCST Number of Categories Completed	5.8 (0.8)	5.9 (0.3)
WCST Learning to Learn	0.3 (3.6)	0.3 (2.2)
CVLT Words Correct List A Trial 1	7.8 (2.1)	8.6 (2.4)
CVLT Words Correct List A Trial 5	13.8 (1.9)	14.0 (2.2)
CVLT List A Total T-Score	48.6 (13.0)	51.5 (13.7)
CVLT Words Correct List B	7.4 (2.4)	8.4 (2.1)*
CVLT Words Correct List A Short Delay	12.8 (2.2)	13.7 (2.1)**
CVLT Words Correct List A Long Delay	13.0 (2.5)	13.7 (2.5)
CLVT Semantic Cluster Total	23.7 (12.9)	27.2 (14.1)
Auditory CPT – Vigilance Task Correct	28.5 (3.9)	29.4 (0.9)
Auditory CPT – Memory Task Correct	19.6 (4.1)	21.6 (2.5)**
Auditory CPT – Interference Task Correct	25.2 (6.5)	27.7 (5.5)*

ADHD, Attention deficit hyperactivity disorder; WAIS-III, Wechsler Adult Intelligence Scale – Third Edition; ROCF, Rey–Osterrieth Complex Figure Test; WCST, Wisconsin Card Sorting Test; CVLT, California Verbal Learning Test; CPT, continuous performance task.

Values given as group mean (standard deviation).

* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

predictor of any of the functional measures in the logistic regressions.

The linear regression with group status and age on number of speeding tickets was significant [$F(2, 114)=21.24$, $p<0.01$, $R^2=0.31$]. The model benefited from the addition of the psychological test variables [$F(10, 105)=2.25$, $p=0.02$, $R^2=0.45$]. The only psychological test score that was predictive of the number of speeding tickets was CVLT List A Short Delay Correct ($\beta=-0.248$, $p=0.01$). No other psychological test variables reached significance in the model. The linear regression with group status and age on number of traffic accidents was significant [$F(2, 114)=31.49$, $p<0.01$, $R^2=0.39$]. The model did not benefit from the addition of the psychological test variables [$F(10, 105)=1.22$, $p=0.28$, $R^2=0.42$]. No psychological test variables reached significance in the model.

The ordinal logistic regression with group status and age on the Hollingshead occupational code was significant (Wald $\chi^2=12.89$, $p<0.01$). No psychological test variables reached significance in the model. Occupational status was predicted best by group status (Control > ADHD). Finally, the ordinal logistic regression with group status and age on the Hollingshead educational code failed to reach significance (Wald $\chi^2=0.37$, $p=0.55$). None of the variables, including group status, age or psychological test variables, predicted educational status.

Regressions without ADHD as a predictor

Similar to the regressions with ADHD as a predictor, the ordinal logistic regressions for 12 of the 16 Q-LES-Q items were statistically significant. Once again,

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age was not a predictor of any of the Q-LES-Q ratings. Multiple psychological test scores predicted Q-LES-Q ratings. Psychological tests that predicted three or more Q-LES-Q domains (e.g. work, social, mood, etc.) at the $p<0.01$ level were the WAIS-III Digit Symbol – Coding Scaled Score, ROCF Copy Organization Score and multiple CVLT variables (CVLT Words Correct List A Trial 1, Correct List A Trial 5, List A Total T-Score, List A Short Delay and Semantic Cluster Total). Across all variables, associations were positive: weaker performance on the psychological test was associated with lower Q-LES-Q ratings. No other psychological test scores were predictive of Q-LES-Q ratings in the ordinal regression.

The logistic regression for history of arrests was significant (Wald $\chi^2=23.05$, $p<0.01$); predictors at the $p<0.01$ level included Stroop Color–Word T-Score and Auditory CPT – Interference Task Correct. Across both variables, weaker performance was associated with more arrests. The logistic regression for receiving academic tutoring during primary or secondary school was significant (Wald $\chi^2=12.76$, $p<0.01$). The ROCF Copy Organization Score and multiple CVLT variables (CVLT Words Correct List A Trial 1, Correct List A Trial 5, List A Total T-Score, List A Short Delay and Semantic Cluster Total) were significant predictors at the $p<0.01$ level. Across all variables, weaker performance was associated with receiving academic tutoring during primary or secondary school. The logistic regression for repeating a grade during primary or secondary school failed to reach significance (Wald $\chi^2=1.45$, $p=0.26$). Age was not a predictor of any of the functional measures in the logistic regressions.

The linear regression with psychological test scores and age on number of speeding tickets was significant [$F(11,104)=16.32$, $p<0.01$, $R^2=0.38$]. Once again, the ROCF Copy Organization Score and multiple CVLT variables (CVLT Words Correct List A Trial 1, Correct List A Trial 5, List A Total T-Score, List A Short Delay and Semantic Cluster Total) were negative predictors at the $p<0.01$ level. The Stroop Color–Word T-Score and Auditory CPT – Interference Task Correct were also negative predictors at the $p<0.01$ level. The linear regression with psychological test scores and age on number of traffic accidents was significant [$F(11,104)=14.03$, $p<0.01$, $R^2=0.32$]. The ROCF Copy Organization Score and the Stroop Color–Word T-Score were negative predictors at the $p<0.01$ level. Age was not a predictor of any of the functional measures in the linear regressions.

The ordinal logistic regression with psychological test scores and age on the Hollingshead occupational code was significant (Wald $\chi^2=10.76$, $p<0.01$). The ROCF Copy Organization Score and multiple CVLT variables (CVLT Words Correct List A Trial 1, Correct List A Trial 5, List A Total T-Score, List A Short Delay and Semantic Cluster Total) were negative predictors at the $p<0.01$ level. Finally, the ordinal logistic regression with psychological test scores and age on the Hollingshead educational code failed to reach significance (Wald $\chi^2=0.43$, $p=0.76$). Neither age nor psychological test variables predicted educational status.

Discussion

High-IQ adults with ADHD performed less well relative to high-IQ control participants on multiple psychological tests of executive functioning. In addition, high-IQ adults with ADHD reported lower quality of life and had less positive functional outcomes.

Psychological test performance on tests of executive functioning was a significant predictor of functional outcomes. This is consistent with our report of psychological test performance on executive functioning tests in the average-IQ adult ADHD population; in that report (Biederman *et al*. 2006*b*), deficits of executive functioning were associated with lower academic achievement, irrespective of ADHD status. Average-IQ adults with ADHD with deficits of executive functioning also had a significantly lower SES and a significant functional morbidity beyond the diagnosis of ADHD alone. In that report, 31% of average-IQ adults with ADHD met a binary definition of executive dysfunction. Using the same binary definition of executive dysfunction, only 8% of high-IQ adults with ADHD met the binary definition of executive dysfunction.

In the current study, inhibition (assessed with the Stroop Color and Word Test) and the organizational aspects of memory (assessed with the ROCF and the CVLT) were more impaired in high-IQ adults with ADHD relative to high-IQ controls. Despite these group differences, the mean performance of high-IQ adults with ADHD was solidly average on these select measures of executive functioning. This suggests that, unlike average-IQ adults with ADHD who have below-average means on tests of executive functioning (Biederman *et al*. 2006*b*), high-IQ adults with ADHD may not be as impaired on these same psychological tests. This is possibly due to the typically moderate amount of covariation of executive functioning and IQ (Seidman *et al*. 1998; Kremen *et al*. 2008).

A meta-analysis of 33 published studies on neuropsychological performance in adults with ADHD reported medium to large effect sizes on CPT omission errors and small to medium effect sizes for CPT commission errors (Hervey *et al*. 2004). We found small to

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medium effect sizes on CPT omission errors but no significant group differences on CPT commission errors. Hervey *et al.* (2004) found that response inhibition is a second domain of executive dysfunction in adults with ADHD, as demonstrated by the small effect sizes on the Stroop Color and Word Interference Test. Our high-IQ data similarly demonstrated small to medium effect sizes on the same Stroop test.

Cognitive flexibility, an executive function that is impaired in pediatric ADHD samples, is reported to be intact in adults with ADHD (Hervey *et al.* 2004). High-IQ adults with ADHD did not make more perseverative errors on the WCST (yet did make more non-perseverative errors).

A third domain of cognition that is affected in ADHD is memory, most commonly assessed in adults with ADHD by the CVLT, ROCF and WAIS-III. Hervey *et al.*'s meta analysis reported small to medium effect sizes on CVLT and ROCF variables. Our data suggest that memory is indeed impacted by the presence of ADHD in high-IQ samples with medium effect sizes. Nonetheless, overall performance was still in the average range. This stands in contrast to the average-IQ adult ADHD literature, which has reported below-average means on tests of memory (Biederman *et al.* 2006*b*).

Similar to high-IQ pediatric ADHD (Mahone *et al.* 2002), performance on the ROCF copy trial may be a particularly sensitive measure to the diagnosis of ADHD in high-IQ adults. While still performing solidly average, high-IQ adults with ADHD performed less well on the ROCF copy organization, suggesting that clinicians may want to consider the ROCF in their evaluations, particularly measurement of organizational ability (Teknos *et al.* 2003). Similarly, others (Downey *et al.* 1997; Hervey *et al.* 2004) have reported that CVLT performance is reduced in average-IQ adult ADHD. Our data suggest that the same trend holds true in the high-IQ adult ADHD population.

In our overall sample, the ROCF and CVLT were the best predictors of functioning. Both psychological tests are thought to be relatively complex and having a strategy is thought to improve performance on both the ROCF (Holmes-Bernstein & Waber, 1996) and the CVLT (Delis *et al.* 1988). It is possible that this relative complexity of the ROCF and the CVLT is responsible for best predicting real-world functioning.

These data raise interesting questions about the relationship between IQ, executive functioning and real-world functioning. The relationship between IQ and executive function is a 'complex and overlapping' relationship (Denckla, 1996); whereas some research suggests that performance on psychological tests of executive functioning correlates highly with IQ in children with ADHD (Reader *et al.* 1994), others (Schuck & Crinella, 2005) have demonstrated the relative independence of IQ and executive functioning as interpreted from rather modest correlations ($r \leqslant -0.22$) between IQ and several executive functioning measures. Thus, it is not surprising that performance on tests of executive functioning in high-IQ adults with ADHD is (*a*) worse than control performance yet (*b*) still solidly average. Nevertheless, these data do suggest that ADHD, even in a high-IQ population, may modestly lower executive functioning.

These data also have clinical implications. In both high-IQ groups, psychological test performance on several measures of executive functioning was associated with real-world functioning. This suggests that, for clinicians working with high-IQ adults with ADHD, the use of psychological test performance on the ROCF and CVLT may best predict real-world functioning. These two psychological tests, although able to statistically predict functioning, should complement and not replace self- and collateral report of functioning (Barkley & Murphy, 2006).

Another relevant clinical implication relates to the academic accommodations that are often used by adults with ADHD. In the USA, the Americans with Disabilities Act of 1990 (ADA), including changes made by the ADA Amendments Act of 2008 (P.L. 110–325), asserts that ADHD is a psychiatric disability and educational accommodations, such as additional time on examinations such as the Law School Admission Test (LSAT) or the Medical College Admission Test (MCAT), may be granted to adults with ADHD. Psychological testing is often required by colleges/universities to support the validity of an ADHD diagnosis. Others (Harrison *et al.* 2007; Sullivan *et al.* 2007) have suggested that the promise of academic accommodations raises the question of possible malingering of ADHD.

Our data highlight the complexity of addressing this issue for high-IQ individuals. On the one hand, high-IQ ADHD is significantly associated with executive dysfunction and adverse outcomes, which would suggest that accommodations would be warranted. On the other hand, the average performance of the high-IQ adults with ADHD was well within the average range, which suggests that many high-IQ adults with ADHD are functioning in the normal range even though this is lower than expected given their IQ. This latter point raises the question of whether high-IQ adults with ADHD warrant accommodations that are legally mandated for students whose disorder causes impairments that are outside the normal range of functioning. This is undoubtedly a very complex issue, similar to diagnosing a learning disability in the context of intellectual giftedness (Lovett

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& Lewandowski, 2006). The recent amendments to the ADA may change the standard of comparison, as to whether the peer group is the total age band or the peer group is the specific academic or occupational group (which would have a major impact on the determination of accommodations).

Our findings must be considered in light of some methodological limitations. Although we controlled statistically for age differences, the ADHD group was significantly older than the non-ADHD group. The fact that the older age of the ADHD cohort did not affect the findings is interesting and should be investigated more completely using a longitudinal sample. Similarly, participants with ADHD were predominantly recruited through clinical referrals; we do not know to what degree our findings can be generalized to samples of non-referred adults with ADHD in the community. In addition, rather than administering a full WAIS-III battery, an abbreviated intelligence assessment, based on the Vocabulary and Block Design scores, was included. Nonetheless, there are strong correlations between these subtests and Verbal and Performance IQ respectively (Wechsler, 1993). Furthermore, some of the additional WAIS-III subscales that are incorporated into the IQ calculation when the full battery is administered reflect key measures of working memory and processing speed that are outcomes of the current study. Thus, the use of Vocabulary and Block Design as an IQ proxy is arguably appropriate for our analyses. Finally, our results may have been different if we had operationalized a high IQ in a different manner (e.g. a full-scale IQ $\geqslant$115 or a full-scale $\geqslant$130).

Despite these shortcomings, our data suggest that high-IQ control participants perform better on several psychological tests than high-IQ adults with ADHD. However, high-IQ adults with ADHD still performed in the average range across all psychological tests. Finally, in both groups, psychological test performance on several measures of executive functioning was associated with real-world functioning.

Declaration of Interest

None.

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