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Childhood Executive Function Continues to Predict Outcomes in Young Adult Females with and Without Childhood-Diagnosed ADHD

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Abstract We prospectively followed an ethnically and socioeconomically diverse sample of preadolescent girls with ADHD (n=140) and matched comparison girls (n=88) over a period of 10 years, from middle childhood through late adolescence/young adulthood. Our aim was to examine the ability of childhood measures of executive function (EF) to predict functional outcomes at follow-up. Measures of EF comprised the childhood predictors, with academic, socioemotional, occupational, and global functioning serving as young adult criterion measures. Results indicated that childhood EF – particularly measures of global EF and working memory – predicted academic and occupational functioning across our entire sample (independent of diagnostic group status), but diagnostic status (ADHD versus comparison) moderated the association between (a) working memory and reading achievement and (b) a global EF measure and suspensions/expulsions. That is, in the ADHD group, low working memory predicted poor reading scores and impaired global EF predicted higher suspensions/expulsions, but this was not the case in the comparison group. Overall, these results extend previous findings of associations between EF and adolescent outcomes in girls with and without ADHD into young adulthood. Findings continue to suggest the importance of assessing and developing interventions that target EF impairments early in life in order to prevent long-term difficulties across a range of important functional domains.

Keywords Attention-deficit/hyperactivity disorder (ADHD) · Executive function · Outcomes · Functional skills · Young adulthood · Girls · Females

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Attention-deficit/hyperactivity disorder (ADHD) is a prevalent and impairing neurodevelopmental disorder characterized by developmentally extreme levels of (a) hyperactivity-impulsivity and/or (b) inattention-disorganization (American Psychiatric Association 2000). Individuals with ADHD experience a wide range of impairments including academic and occupational underachievement, high rates of comorbidity, and relationship problems to name a few (Biederman et al. 2008b, 2010; Goodman 2007). Still, little is known about the pathways through which such impairments result. Determining mechanisms underlying the development of functional impairments in individuals with ADHD may prove useful in terms of identifying targets for interventions in order to prevent later difficulties.

A large number of studies have documented executive function (EF) deficits in individuals with ADHD (e.g., Berlin et al. 2003; Scheres et al. 2004; Thorell 2007). Such abilities, which include planning, organization, response inhibition, sustained attention, set shifting, working memory, and reasoning, rely on the prefrontal cortex and its extensive interconnections with other brain regions (Tranel et al. 1994), although it should be noted that there is debate regarding the validity of the EF construct including precisely which abilities fall into this domain (see Jurado and Rosselli

2007). The exact mechanisms underlying these deficits and the role these deficits play in the development of the disorder remain unknown (see Nigg et al. 2005). EF deficits do not characterize all individuals with ADHD (Willcutt et al. 2005), but they appear to be crucial for performing a range of important activities. In particular, EFs have been linked to academic performance (Barry et al. 2002; Biederman et al. 2004; Miller and Hinshaw 2010), social/interpersonal skills (Clark et al. 2002; Diamantopoulou et al. 2007; Gilotty et al. 2002; Miller and Hinshaw 2010; Rinsky and Hinshaw 2011), and global functioning (Miller and Hinshaw 2010).

Previous studies have noted associations between EF and outcomes across a range of populations, including ADHD, yet little is known about the predictive relationships between childhood EF and late adolescent/young adult outcomes in *females* with childhood-diagnosed ADHD. Whereas the transition to young adulthood is known to be a time of critical importance and increased demands (Arnett 2000), extremely few studies have followed cohorts of girls with ADHD into emerging adulthood. Although the literature is limited, it is quite clear that impairment persists into adolescence/young adulthood in childhood-diagnosed girls with ADHD (Biederman et al. 2008a; Wåhlstedt et al. 2008). Such continued impairment extends across multiple domains including ADHD symptoms, academic functioning, comorbid psychopathology, occupational functioning, and romantic and family relationships (Babinski et al. 2011; Biederman et al. 2010; Chronis-Tuscano et al. 2010; Mick et al. 2011).

In addition to academic performance, social/interpersonal skills, and global functioning, several other areas of functioning come into importance in young adulthood, particularly in females. Specifically, suicide risk increases in young adulthood (Centers for Disease Control 2010), and girls diagnosed with ADHD in early childhood have been shown to be at particularly high risk for suicidal ideation and attempts through adolescence (Chronis-Tuscano et al. 2010; Hinshaw et al. 2011), making this an especially salient outcome in samples of females with ADHD. Adolescent girls with ADHD have also been shown to exhibit high rates of self-harm behavior (Rucklidge and Tannock 2001), and EF impairments have been found in adolescents exhibiting non-suicidal self-injury (NSSI) (Fikke et al. 2010). Given the role of EF in self-regulatory processes, including impulse control and emotion regulation (see Barkley 2001; Zelazo and Cunningham 2007), early EF abilities might be predictive of later suicide attempts and NSSI.

Other documented outcomes of ADHD include lower-than-expected occupational and educational attainment, particularly in males (who predominate in follow-up investigations; see Barkley et al. 2008; Biederman et al. 2008a). Deficits in aspects of EF – such as planning, working memory, and sustained attention – could make academic and work-related tasks more difficult, leading to poor performance in both domains. Self-ratings of EF (and, to a lesser extent, EF tests) have recently been associated with occupational functioning in a largely male sample of individuals with ADHD followed into adulthood (Barkley and Fischer 2011). Determining additional predictors is important, particularly in samples of females with ADHD. If EF is indeed such a predictor, it could constitute a relatively specific target for treatments that are component or process focused. Such treatments could have potential for preventing these later ADHD-associated outcomes from arising, particularly if applied early in development.

We previously examined predictive associations between childhood EF and adolescent outcomes in the domains of academic achievement, social functioning, and global functioning, within a large and well-characterized female sample (Miller and Hinshaw 2010). In the present study, we aim to extend this earlier investigation by (a) focusing on young adult outcomes and (b) expanding the outcomes examined. We hypothesize that poorer performance on tasks of EF in childhood – sustained attention, response inhibition, working memory, and a more "global" EF test – will predict worse outcomes in young adulthood across the domains of academic, socioemotional (NSSI/suicide attempts), occupational, and global functioning in girls with and without ADHD. Based on our previous findings that highlight the non-specificity of EF deficits, we hypothesize that these associations will not be moderated by ADHD status, yet still leave open the possibility that the combination of a childhood ADHD diagnosis plus childhood EF deficits could yield particularly poor outcomes. We include key covariates in our analyses (e.g., IQ, diagnostic group status) in order to ascertain the specificity of EF-functional outcome associations.

Method

Overview of Procedure

We utilized data from a longitudinal study of behavioral, neuropsychological, social, and family functioning in 228 girls, 140 with rigorously diagnosed childhood ADHD and 88 matched comparison girls. All participated in summer research programs and extensive testing during childhood (ages 6–12), and they were followed prospectively into adolescence (ages 11–17) and late adolescence/young adulthood (ages 17–23), completing extensive evaluations at each time point.

During the baseline summer programs, we conducted evaluation across multiple key areas of relevance to childhood functioning and performed an extensive neuropsychological battery including EF, language, and motor

speed measures. A multiple-gating procedure was used for screening and diagnostic assessment and the baseline neuropsychological battery was administered when any medicated girls were not receiving stimulant. Well-trained, closely supervised graduate students and bachelor's-level research assistants administered the neuropsychological tests (Hinshaw et al. 2002). At the 5-year follow-up, Miller and Hinshaw (2010) showed the predictive power of baseline EF measures to adolescent functional impairments.

For the 10-year follow up assessments, 216 out of 228 girls (95%) were retained with at least some outcome measures and underwent extensive individual and family evaluation. This high level of participant retention was a function of considerable efforts to contact families who had moved or relocated. The goal was to appraise, via multi-informant and multi-method procedures, levels of symptomatology and adjustment/impairment in key domains of psychiatric, academic, relational, and occupational functioning. The follow-up assessments received full approval from the institution's Committee for the Protection of Human Subjects.

Participants

Recruitment strategies have been described in detail previously (Hinshaw 2002; Hinshaw et al. 2006). Briefly, a multi-gated procedure was used to recruit participants from pediatric practices, school referrals, and community advertisements. Those in the ADHD group had to first surpass sex-specific thresholds for the Swanson, Nolan, and Pelham scale (SNAP-IV; Swanson 1992) and then meet full DSM-IV criteria for ADHD based on the Diagnostic Interview Schedule for Children – Parent version (4th ed., DISC-IV; Shaffer et al. 2000). Those in the comparison group could not meet SNAP-IV or DISC-IV criteria for ADHD. The complete sample consists of 93 girls with ADHD-C, 47 with ADHD-I, and 88 comparison girls, as ascertained at baseline. The comparison sample was matched, at a group level, with the clinical group in terms of both age and ethnicity. This overall sample is both socioeconomically and ethnically diverse (family incomes ranging from public assistance to upper-middle class; 53% White, 27% African-American, 11% Latina, 9% Asian-American). At baseline (summers of 1997, 1998, or 1999), these 228 girls were 6–12 years of age (M=9.6 years). The mean IQ in the comparison group was 112 (SD=12.7) and in the ADHD group was 99.65 (SD=13.6).

At the 10-year follow up, the 216 retained young women were 17–23 years of age (M=19.6 years). Comparisons of the retained sample versus those lost to attrition revealed significant differences for 5 of 23 analyses spanning measures of demographics, core ADHD symptoms, comorbid symptoms, and functional impairments. The non-retained subsample had lower family incomes and Full-Scale IQ scores and higher baseline rates of teacher-rated ADHD, externalizing, and internalizing symptoms. Overall, the follow-up sample appears generally representative, although the non-retained subsample did appear more impaired on several key measures.

Baseline Measures

We selected several well-established and validated measures of EF from the baseline neuropsychological battery based on (a) their conceptual relevance to the EF construct and (b) prior research revealing that these measures were those that best differentiated our youth with ADHD from comparison youth, even with statistical control of demographics and comorbidities.

Conners' Continuous Performance Task (CPT; Conners 1995) The CPT is a computerized task of attentional processing and response inhibition that requires participants to press the spacebar when target letters appears on the screen (all letters except 'X'), and not respond to the letter 'X'. The 14-min task consists of trials which are presented in six blocks (interstimulus intervals: 1 s, 2 s, and 4 s); stimuli are displayed for 250 ms. This task features frequent display of target stimuli (requiring response) and relatively infrequent display of non-targets (requiring non-response), so that the focus is on response inhibition rather than detection of rare stimuli. A neural network including frontal, cingulate, parietal, occipital, and temporal regions as well as the basal ganglia and cerebellum appears to be involved in the performance of this task (Ogg et al. 2008). Two scores were selected for analyses: the percentage of omission errors and the percentage of commission errors. Our prior work has shown significantly higher percentages of these errors in girls with ADHD than in the comparison sample, with effect sizes in the medium range (Hinshaw et al. 2002; Hinshaw et al. 2007). Conners (1995) provided criterion-related validity data for omission and commission errors based on known-groups differentiation. Higher scores indicate worse performance.

Rey Osterrieth Complex Figure (ROCF; Osterrieth 1944) The ROCF is a complex cognitive task that requires an individual to copy and later recall a complex figure composed of 64 segments. We analyze the Copy condition (participants draw the figure with no delay), which appears to tap multiple domains of EF such as planning, working memory, inhibitory control, attention to detail, and organization. ROCF scores have been significantly correlated with other measures of EF (Somerville et al. 2000; Troyer and Wishart 1997; Watanabe et al. 2005) and have been successfully used to distinguish patients with frontal lobe lesions from those without (Lezak 1995), as well as

children with ADHD from those without (Carte et al. 1996; Nigg et al. 1998; Sami et al. 2003). We used the Error Proportion Score (EPS), a validated method of scoring the ROCF (number of errors/total number of segments drawn) that is a measure of efficiency (Sami et al. 2003). The intraclass correlation between pairs of the three primary scorers for the EPS ranged from 0.91 to 0.94 (drawings n= 84–195 across rater pairs). Among all of the EF measures in our battery, the EPS from the ROCF showed the largest effect size (d=0.90) in differentiating the girls with ADHD from the comparison sample during childhood (Hinshaw et al. 2002; Sami et al. 2003). Thus, we contend that the EPS is a superior measure compared to other scoring systems for the ROCF. Higher scores on this measure indicate worse performance.

WISC-III Digit Span - Backward (Wechsler 1991) This is a widely used measure of auditory working memory that requires participants to immediately recall digit sequences of increasing length either in their original presentation order (digits forward) or in their reverse presentation order (digits backward). These abilities rely on frontostriatal and cerebellar regions (Martinussen et al. 2005). Given the importance of manipulation of information to the construct of working memory, we used the 'backward' condition of the Digit Span. We utilized raw scores; higher scores indicate better performance.

Follow-up Measures

The following measures of functional skills at our 10-year follow-up were chosen from an extensive battery to reflect core outcomes of interest (academic, socioemotional, occupational, and global domains) as well as a variety of data collection methods, including objective testing, parent-report, and self-report.

Columbia Impairment Scale (CIS; Bird et al. 1993) The CIS is a 13-item parent-reported scale that assesses functioning across the domains of interpersonal relations, broad psychopathological domains, school/job functioning, and use of leisure time. Parents rated their daughters' impairment for each item using a 5-point scale, yielding an index of global impairment. The CIS has been used extensively in investigations of child and adolescent psychopathology and treatment response. An average of all CIS items was used in analyses as a measure of global functioning; higher scores indicate greater impairment.

Suicide Attempts/NSSI, Suspensions/Expulsions, Employment We collected information from participants and their families covering a range of domains over the years since they were last evaluated. Participants and/or their parents noted the absence or presence of particular behaviors or events in each of the years since their last visit. For example, a participant might note that she attempted suicide in the first and third years, but not the second, fourth, or fifth years. This information was summed for each participant and continuous variables were created to indicate the number of suicide attempts and the number of NSSI "episodes" that had occurred since their last visit; these two variables were summed. This method was also used for suspensions and expulsions. An additional variable–employment status during the most recent year only–was also created (0 for employed, 1 for unemployed).[1] Thus, three variables resulted from this questionnaire: a continuous NSSI/suicide attempts variable, a continuous suspensions/expulsions variable, and a dichotomous employment status variable.

Wechsler Individual Achievement Test (WIAT; Wechsler 1992) The WIAT is a psychometrically sound assessment of academic achievement, with both internal consistency and test-retest reliability estimates are above 0.85 for most composite scores (Wechsler 1992). Both the Word Reading and Math Reasoning subtest scores were used as measures of academic functioning at follow-up.

Covariates

Two key covariates were utilized separately in analyses. First, to indicate intelligence, we entered the Full Scale IQ (FSIQ) score from the Wechsler Intelligence Scale for Children–Third Edition (WISC-III) (Wechsler 1991), which was administered in full to all participants at baseline. Note that the Digit Span subtest, one of our EF measures, is a supplemental test on the WISC-III, so that the FSIQ covariate is independent of Digit Span. Second, to determine whether EF measures provided greater prediction to our young adult criterion measures for girls with childhood-diagnosed ADHD than comparison girls, we entered the baseline variable of group status (ADHD versus comparison). Because of significantly reduced statistical power, differences in ADHD-C versus ADHD-I type were not examined. Furthermore, our past research has revealed no significant ADHD-C versus ADHD-I differences with respect to nearly all correlates or outcomes in our extensive database (Hinshaw 2002; Hinshaw et al. 2006).

Data Analytic Plan

All statistical analyses were performed with SPSS for Macintosh, Version 18. After carefully inspecting data for

[1] Of those participants under age 18 (n=42), 50% were employed. Analyses were conducted including and excluding these girls for the employment status outcome variable.

out-of-range values and pulling 6 outliers in to within 3 *SD* of the mean (all within the CPT omissions variable), we performed Pearson correlations (for continuous criterion variables) or point biserial correlations (for the dichotomous criterion variable) between baseline EF variables and follow-up criterion variables. Following a significant association, we used linear or binary logistic regression with EF measures as predictors and young adult outcome measures as criterion variables, first controlling for IQ and then controlling for group status (ADHD versus comparison), both of which were assessed at baseline. On the basis of these initial regressions, we reasoned that because IQ deficits are inherent to ADHD, controlling for both IQ and group concurrently would constitute overcontrol (see Miller and Chapman 2001). Thus, parallel to our previous report of the adolescent follow-up (Miller and Hinshaw 2010), we emphasize findings with the more stringent covariate of group status. Finally, we added the interaction term of EF predictor x diagnostic group status as the last step in the equation for continuous variables to test for moderation by ADHD status. Moderator analyses were not conducted for the dichotomous employment status variable given that those in the comparison group displayed nearly uniform status. To maintain clinical relevance and remain consistent with our previous report, we conducted regression analyses using single predictor variables. Means, ranges, and *SD*s of all baseline and follow-up variables are displayed in Table 1.

Results

Initial correlations revealed statistically significant associations between several predictor-criterion pairs (Table 2). Two EF variables were significantly correlated with follow-up math and reading scores: ROCF EPS and Digit Span. Baseline ROCF was also significantly correlated with follow-up global functioning scores. Two variables were associated with both NSSI/suicide attempts and suspensions/expulsions: ROCF EPS and CPT commissions. For the dichotomous outcome variable of employment status, the initial point biserial correlation revealed statistically significant associations with baseline ROCF, baseline CPT omissions, and baseline Digit Span. Overall, associations between EF measures and young adult outcome scores were in the small-to-medium range (i.e., r=0.1–0.3; see Cohen 1988).

Results from the linear regression analyses (Table 3) revealed significant predictive associations, when controlling for IQ, between (a) baseline ROCF and follow-up math scores (p=0.032, ΔR^2=0.01), global functioning (p=0.034, ΔR^2= 0.02), NSSI/suicide attempts (p=0.016, ΔR^2=1.90), and suspensions/expulsions (p=0.001, ΔR^2=1.09); (b) baseline Digit Span and follow-up math scores (p=0.035, ΔR^2=0.01); and (c) baseline CPT commissions and follow-up NSSI/suicide attempts (p=0.043, ΔR^2=0.01) and suspensions/expulsions (p=0.011, ΔR^2=0.01). The association between baseline Digit Span and follow-up reading scores did not reach significance (p=0.056, ΔR^2=0.01). When controlling for group status, there were significant predictive associa-

Table 1 Means, ranges, and SDs for baseline and follow-up variables

	Comparison		ADHD	
	n=71–86		n=107–137	
	M (range)	*SD*	*M* (range)	*SD*
Baseline ROCF EPS[a]	0.22 (0.02–0.68)	0.15	0.35 (0.04–0.88)	0.19
Baseline CPT omissions (%)[a]	5.65 (0.31–58)	7.82	11.05 (0.60–86.70)	14.43
Baseline CPT commissions (%)[a]	53.33 (5.60–97.22)	20.76	56.41 (5.56–97.22)	20.99
Baseline Digit Span (backward)[a]	5.01 (2–14)	1.87	4.27 (0–10)	1.69
Follow-up WIAT Math[a]	105.84 (69–128)	12.49	91.19 (47–126)	16.15
Follow-up WIAT Reading[a]	108.68 (76–121)	8.53	97.21 (43–117)	15.07
Follow-up CIS[a]	0.48 (0–2.25)	0.52	1.42 (0–3.92)	0.84
Follow-up NSSI/suicide attempts[a]	0.38 (0–8)	1.24	1.12 (0–12)	2.33
Follow-up suspension/expulsion[a]	0.15 (0–4)	0.60	0.48 (0–4)	0.93
Follow-up employment status[b]	0.25 (0–1)	0.43	0.34 (0–1)	0.47

ROCF Rey-Osterrieth Complex Figure (*EPS* Error Proportion Score); *CPT* Continuous Performance Test; *WIAT* Wechsler Individual Achievement Test; *CIS* Columbia Impairment Scale; *NSSI* Non-Suicidal Self-Injury

[a] Continuous

[b] Dichotomous: 0 = employed, 1 = unemployed

Higher scores on ROCF EPS, CPT omissions, CPT commissions, and CIS indicate greater impairment. Higher scores on Digit Span indicate better performance

Table 2 Correlations between baseline EF variables and follow-up outcome variables

	Follow-up WIAT Math[a]	Follow-up WIAT Reading[a]	Follow-up CIS[a]	Follow-up NSSI/ Suicide Attempts[a]	Follow-up Suspensions/ Expulsions[a]	Follow-up Employment Status[b]
Baseline ROCF EPS[a]	-0.34***	-0.24***	0.23**	0.15*	0.21**	0.28***
Baseline CPT omissions (%)[a]	0.03	0.04	0.05	0.07	0.04	0.21**
Baseline CPT commissions (%)[a]	-0.02	-0.01	0.11	0.14*	0.18*	0.03
Baseline Digit Span (backward)[a]	0.28***	0.26***	-0.11	-0.07	-0.07	-0.20**

Associations are Pearson's correlations between continuous variables and point-biseral correlations between a continuous and a dichotomous variable. *ROCF* Rey-Osterrieth Complex Figure (*EPS* Error Proportion Score); *CPT* Continuous Performance Test. *WIAT* Wechsler Individual Achievement Test; *CIS* Columbia Impairment Scale; *NSSI* Non-Suicidal Self-Injury

[a] Continuous

[b] Dichotomous: 0 = employed, 1 = unemployed

Higher scores on ROCF EPS, CPT omissions, CPT commissions, and CIS indicate greater impairment. Higher scores on Digit Span indicate better performance

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

tions between (a) baseline ROCF and follow-up math scores ($p=0.002$, $\Delta R^2=0.04$) and suspensions/expulsions ($p=0.027$, $\Delta R^2=0.74$); (b) baseline Digit Span and follow-up math ($p=0.002$, $\Delta R^2=0.04$) and reading scores ($p=0.009$, $\Delta R^2=0.03$); and baseline CPT commissions and follow-up suspensions/expulsions ($p=0.014$, $\Delta R^2=0.01$) (see Table 3). The relationship between baseline ROCF and follow-up reading scores did not reach significance ($p=0.092$, $\Delta R^2=0.01$).

Table 3 Linear regression analyses for baseline EF variables and continuous outcome variables

	B (unstandardized)	ΔR^2	Sig.		B (unstandardized)	ΔR^2	Sig.
WIAT Math							
Step 1: IQ	0.73	0.45	0.000**	Step 1: Group	−12.37	0.19	0.000**
Step 2: ROCF EPS	−10.53	0.01	0.032*	Step 2: ROCF EPS	−18.07	0.04	0.002**
Step 1: IQ	0.73	0.44	0.000**	Step 1: Group	−12.17	0.17	0.000**
Step 2: Digit Span (backward)	1.07	0.01	0.035*	Step 2: Digit Span (backward)	1.87	0.04	0.002**
WIAT Reading							
Step 1: IQ	0.53	0.32	0.000**	Step 1: Group	−10.13	0.16	0.000**
Step 2: ROCF EPS	−5.34	0.01	0.244	Step 2: ROCF EPS	−8.69	0.01	0.092
Step 1: IQ	0.47	0.29	0.000**	Step 1: Group	−9.60	0.16	0.000**
Step 2: Digit Span	0.88	0.01	0.056	Step 2: Digit Span	1.28	0.03	0.009**
Columbia Impairment Scale							
Step 1: IQ	−0.01	0.06	0.001**	Step 1: Group	0.90	0.28	0.000**
Step 2: ROCF EPS	0.76	0.02	0.034*	Step 2: ROCF EPS	0.24	0.00	0.437
NSSI/Suicide Attempts							
Step 1: IQ	0.02	0.00	0.427	Step 1: Group	0.56	0.03	0.014*
Step 2: ROCF EPS	1.90	0.03	0.016*	Step 2: ROCF EPS	1.02	0.01	0.191
Step 1: IQ	0.01	0.01	0.300	Step 1: Group	0.71	0.03	0.017*
Step 2: CPT commissions	0.01	0.02	0.043*	Step 2: CPT commissions	−0.01	0.00	0.549
Suspensions/Expulsions							
Step 1: IQ	0.01	0.00	0.660	Step 1: Group	0.23	0.04	0.008**
Step 2: ROCF EPS	1.09	0.05	0.001**	Step 2: ROCF EPS	0.74	0.02	0.027*
Step 1: IQ	0.00	0.00	0.455	Step 1: Group	0.28	0.03	0.012*
Step 2: CPT commissions	0.01	0.03	0.011*	Step 2: CPT commissions	0.01	0.03	0.014*

*$p<0.05$. **$p<0.01$

IQ Intelligence Quotient; *ROCF* Rey-Osterrieth Complex Figure (*EPS* Error Proportion Score); *CPT* Continuous Performance Test; *WIAT* Wechsler Individual Achievement Test; *NSSI* Non-Suicidal Self-Injury

Although effect sizes were small, this pattern of results indicates that baseline EF variables predicted young adult outcomes in academic achievement and suspensions/expulsions over and above IQ or diagnostic group. In all cases of significant predictive associations, better EF scores predicted better adolescent status.

Binary logistic regression results are displayed in Table 4. When controlling for IQ, there were significant predictive associations between baseline ROCF and follow-up employment status (p=0.000), baseline CPT omissions and follow-up employment status (p=0.009), and baseline Digit Span and follow-up employment status (p=0.007). When controlling for group status, all three of the previously significant associations remained significant. We also analyzed predictions between baseline EF and follow-up employment status, excluding participants who were under age 18 at follow-up. Results indicated that, when controlling for IQ or group, baseline ROCF continued to predict follow-up employment status but previously significant associations between baseline CPT omissions/Digit Span and follow-up employment status were no longer significant. Thus, when controlling for the more stringent covariate of diagnostic group in the whole sample, baseline EF variables continued to predict young adult outcomes in employment status and school suspensions/expulsions with small effect sizes. Again, in all cases of significant predictive associations, better EF scores predicted better young adult status.

Moderator analyses revealed that childhood diagnostic group status (ADHD vs. comparison) moderated the association between baseline Digit Span and follow-up reading scores, β=2.19, t(183)=2.30, p=0.023 and between baseline ROCF EPS and follow-up suspensions/expulsions, β=1.46, t(195)=2.04, p=0.043. To detect the direction of moderation, we conducted post-hoc probing as recommended by Holmbeck (2002). As shown in Fig. 1 (baseline Digit Span and follow-up reading scores), the simple slope for the ADHD group was significant (β=0.33, p=0.001) but the simple slope for the comparison group was not (β=0.03, p=0.790). Similarly, as shown in Fig. 2 (baseline ROCF EPS and follow-up suspensions/expulsions), the simple slope for the ADHD group was significant (β=0.26, p=0.003) but the simple slope for the comparison group was not (β=−0.06, p=0.638). Group status did not moderate associations between baseline ROCF and follow-up math scores (p=0.985), reading scores (p=0.814), global functioning (p=0.636), or NSSI/suicide attempts (p=0.316); baseline Digit Span and follow-up math scores (p=0.174); or baseline CPT commissions and follow-up NSSI/suicide attempts (p=0.098) or suspensions/expulsions (p=0.409). Given the lack of moderation for all variables but two, these results are consistent with our previous findings that highlight the non-specificity of EF impairments (Miller and Hinshaw 2010) yet still provide some evidence for moderation of associations between EF abilities and outcomes by ADHD status.

Discussion

We aimed to expand on our previous work in which we found predictive associations between childhood EF and adolescent outcomes in girls with and without ADHD by assessing similar associations using young adult outcomes. In this investigation, featuring a high retention rate of participants during young adulthood, 10 years after baseline ascertainment, we included several new outcome variables of relevance to this developmental period. In general, the results of the present study were consistent with our previous findings in that childhood EF continued to be predictive of later outcomes. As with our previous results using adolescent outcomes, childhood EF scores significantly predicted outcomes in academic achievement when controlling for either IQ or group status. The ROCF – a potentially more "global" measure of EF – was particularly predictive of math achievement in both adolescence and young adulthood. We also found that, controlling for IQ or group status, childhood EF predicted young adult suspensions/expulsions and employment status. Finally, childhood EF was predictive

Table 4 Binary logistic regression analyses for baseline EF variables and employment status outcome variable

	Wald	OR	Sig.	95% CI		Wald	OR	Sig.	95% CI
Step 1: IQ	0.99	1.01	0.321	0.99–1.04	Step 1: Group	0.06	0.92	0.813	0.46–1.84
Step 2: ROCF EPS	15.18	36.70	0.000**	5.99–224.81	Step 2: ROCF EPS	13.73	29.89	0.000**	4.96–180.23
Step 1: IQ	0.06	1.00	0.803	0.98–1.03	Step 1: Group	0.44	1.25	0.506	0.65–2.39
Step 2: CPT omissions (%)	6.93	1.04	0.009**	1.01–1.07	Step 2: CPT omissions (%)	6.22	1.04	0.013*	1.01–1.06
Step 1: IQ	0.50	1.01	0.481	0.99–1.03	Step 1: Group	0.27	1.19	0.606	0.62–2.26
Step 2: Digit Span	7.36	0.74	0.007**	0.59–0.92	Step 2: Digit Span	12.21	1.41	0.000**	1.16–1.72

*p<0.05. **p<0.01

OR Odds Ratio; *IQ* Intelligence Quotient; *ROCF* Rey-Osterrieth Complex Figure (*EPS* Error Proportion Score); *CPT* Continuous Performance Task

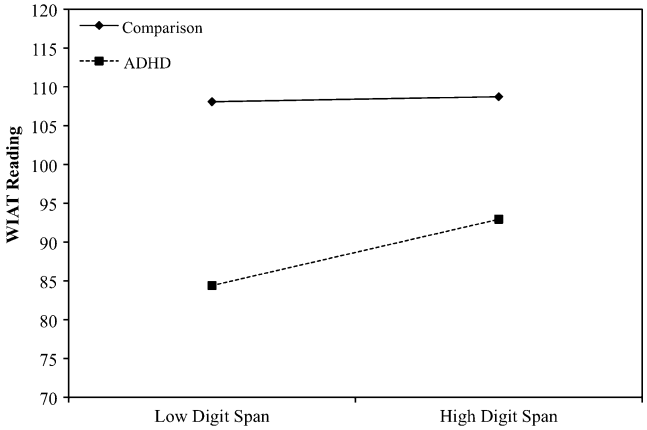

Fig. 1 Follow-up reading scores as a function of baseline working memory for girls with and without ADHD

of young adult NSSI/suicide attempts when controlling for IQ, but this finding was no longer significant when controlling for group status.

Across all young adult outcomes, it appears that the strongest predictors were measures of working memory (Digit Span) and global EF (ROCF EPS). Working memory is involved in keeping rules in mind, manipulating information to achieve a goal, learning, and reasoning (Baddeley 1992). Working memory also interacts with attention (Awh et al. 2005). These abilities all appear important for academic functioning, including standardized measures of achievement, as well as for job performance. For example, if one cannot keep in working memory the instructions for a math test or an important task at work, performance of that task will likely be poor. Along with directly making school or work difficult, these deficits in working memory could indirectly contribute to and interact with decreased motivation and self-worth, potentially resulting in failure to complete work, quitting a job, or being fired. A similar pattern emerged for the ROCF. With

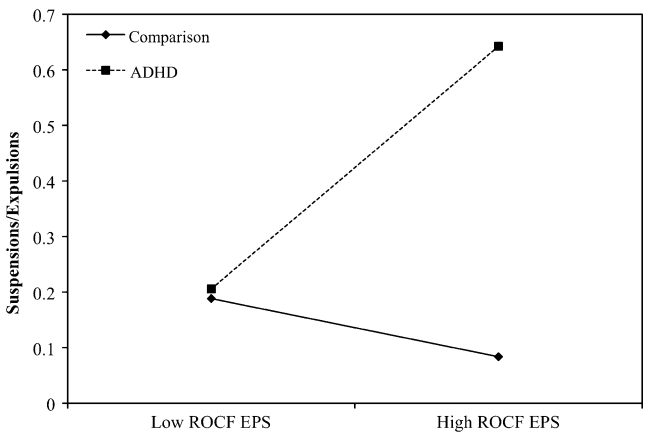

Fig. 2 Follow-up suspensions/expulsions as a function of baseline ROCF EPS for girls with and without ADHD

respect to math achievement, it is possible that the strong visuospatial nature of both the ROCF and math tasks could account for the association between baseline ROCF EPS and follow-up WIAT Math scores. In addition to visuospatial skills, performance on this measure also appears to rely on planning, organization, attention, inhibitory control, and working memory, resulting in our consideration of it as a global measure of EF. Indeed, all of the constructs assessed by the ROCF are likely to be crucial for successful academic and job performance, particularly the ability to plan and organize thoughts and actions.

Some differences did emerge in between our prior results (Miller and Hinshaw 2010) and the present findings. First, a clear difference is the inclusion of additional outcomes that are relevant to young adulthood (i.e., NSSI/suicide attempts, suspensions/expulsions, and occupational functioning). Such additions proved to be fruitful. In particular, a global measure of EF (ROCF) significantly predicted NSSI/suicide attempts over and above IQ but not diagnostic group status. This global measure also predicted suspension/expulsion and employment status over and above both IQ and diagnostic group status, entered separately; the association between ROCF and suspensions/expulsions was moderated by group status. Additionally, a measure of working memory (Digit Span) significantly predicted employment status over and above either IQ or diagnostic group status. CPT commissions – a measure of response inhibition that was exclusively predictive of peer acceptance in adolescence – was predictive of levels of young adult NSSI/suicide attempts when controlling for IQ and suspensions/expulsions when controlling for IQ or group. Finally, a measure of sustained attention (CPT omissions) significantly predicted employment status over and above either IQ or diagnostic group status. These findings suggest the importance of a range of EF skills, including measures of working memory, response inhibition, sustained attention, and a more "global" EF measure (ROCF), in obtaining and maintain employment, maintaining school enrollment, and engaging in NSSI and/or attempting suicide.

In young adulthood, there were no significant associations between baseline EF variables and follow-up global functioning when controlling for group status, and the ROCF was less predictive of global functioning in young adulthood than it had been adolescence. This diminution may be attributable, in part, to the parent-reported nature of our measure of global functioning. Nearly all participants lived with their parents in adolescence, but many had moved away from home in young adulthood, potentially rendering parent report of global functioning less valid. This is a difficult issue to circumvent given the considerable concerns regarding the accuracy of self-report from individuals with ADHD, at least until the age range of the mid-20s (e.g., Barkley et al. 2008). Reports of global

functioning from friends, colleagues, or roommates may provide more valid data.

Finally, we did not include the Cancel Underline task (a measure of inhibitory control) in the present study given that it had poor predictive ability in adolescence, instead including a measure of working memory (Digit Span). This measure of working memory emerged as one of the more predictive measures of young adult outcomes. Whereas all moderator analyses were non-significant in our initial report, diagnostic group status significantly moderated the association between (a) baseline working memory and young adult reading achievement and (b) baseline ROCF and young adult NSSI/suicide attempts herein. In terms of working memory, the association between childhood working memory and young adult reading scores was significant in the ADHD group but not the comparison sample. More specifically, girls with ADHD who had lower Digit Span scores in childhood also had lower follow-up reading scores than those with ADHD and higher childhood Digit Span scores, but this was not the case for the comparison group. Previous investigations have found that working memory ability predicts reading comprehension in children (Cain et al. 2004), although the present study focused on word reading rather than reading comprehension. Perhaps more related to the present study, Berninger et al. (2010) recently found that word working memory contributed to word reading (among other reading outcomes) in second, fourth, and sixth graders. Deficits in working memory, combined with the symptoms of inattention inherent to ADHD, could make it difficult to retain or access speech-based information as well as keep recently read information in mind.

Diagnostic group status also moderated the association between baseline ROCF scores and a continuous follow-up variable measuring the number of suspensions/expulsions in young adulthood. That is, the association between ROCF – a potentially more "global" measure of EF with strong visuospatial components – and young adult suspensions/expulsions was significant in the ADHD group but not the comparison sample. More specifically, girls with ADHD who had higher (worse) ROCF EPS scores in childhood also had higher follow-up levels of suspensions/expulsions than those with ADHD and lower (better) childhood ROCF EPS scores; this was not the case for the comparison group. Individuals with ADHD have significantly higher rates of suspensions and expulsions and lower overall educational attainment than those without ADHD; such outcomes are more common for boys with ADHD than girls with ADHD (Bauermeister et al. 2007). The present findings suggest that deficits in EF may contribute to this higher rate of suspensions/expulsions.

Although diagnostic group status moderated associations between baseline EF variables and outcome measures in two instances, moderation of associations by group status was indeed the exception. In multiple instances, scores on baseline EF measures were predictive of follow-up outcome variables over and above baseline diagnostic group status, suggesting that lower EF scores in childhood are predictive of greater impairment in young adulthood regardless of childhood diagnosis. Such non-specificity in terms of associations between EF problems and later outcomes is consistent with other studies that have found associations between EF and academic outcomes in longitudinal studies of typically developing preschoolers (Bull et al. 2008; Clark et al. 2010). The findings from these studies are suggestive of the importance of screening EF skills at a young age – regardless of psychiatric diagnosis – in order to identify children who may be at risk for developing later deficits across a range of domains.

Several limitations are noteworthy. Most notably, our sample is entirely female, making it difficult to make generalizations to male samples. Second, our EF battery was formulated approximately 15 years ago; newer cognitive neuroscience tasks, not included in our baseline measures, may also be relevant. Third, our sample was primarily clinically-ascertained and the degree to which these associations would appear in a community-based sample of girls with ADHD is unclear. Fourth, we cannot exclude the possibility that there are third factors influencing the associations found in the present study. Finally, we did not examine interactions between EF and other variables of interest in childhood such as parenting practices, although we emphasize the potential importance of this or other moderators in future research. It is likely that complex interactions among sets of variables, including those that measure EF, are particularly good predictors of young adult outcomes.

Much of the extant research focuses on males with ADHD (see Hinshaw and Blachman 2005), and all too little is understood about the longitudinal course of ADHD in females. Prior studies have found similar longitudinal associations in samples consisting of mostly males (e.g., Barkley et al. 2006; Barkley and Fischer 2011) but there is a paucity of research on such associations in entirely female samples. The present study, along with our previous work, reveals that lower EF scores in childhood are predictive of a range of negative outcomes in adolescence and young adulthood in *females* with and without ADHD. Additionally, such deficits may, in some cases, combine with ADHD symptoms giving rise to particularly negative outcomes. Given the clinical impact of ADHD on females as well as the public health importance of this syndrome in females, continued research focusing on its longitudinal course in this subpopulation is sorely needed.

Overall, we found evidence for longitudinal associations between childhood EF and young adult outcomes in a large female sample of girls with and without rigorously-diagnosed childhood ADHD. These results suggest the

potential importance of intervening with EF in childhood to reduce the risk of developing a range of negative outcomes, particularly in those who are at increased risk for such outcomes. Whereas early intervention is commonly regarded as imperative in other neurodevelopmental disorders such as autism spectrum disorders (see Dawson 2008), there has been less focus on utilizing principles from prevention science in ADHD. Yet some investigators are beginning to suggest that early intervention may be key to reducing symptoms and decreasing negative outcomes in individuals with ADHD as well (Jones et al. 2007; Sonuga-Barke and Halperin 2010). Developing tools to assess and treat EF deficits in young children exhibiting symptoms of ADHD may be valuable. Unknown is whether integration of interventions that target EF deficits (e.g., cognitive training programs) with current evidence-based treatments (i.e., medication and behavioral interventions) early in development will provide additional reduction of symptoms and decrease risk for negative outcomes. Yet given that EF impairments in individuals with ADHD are not uncommon and appear predictive of a range of long-term negative outcomes in both adolescence and young adulthood, we believe that further work addressing these clinically and conceptually important questions is warranted.

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