Published in final edited form as:

Child Neuropsychol. 2011 July ; 17(4): 368–390. doi:10.1080/09297049.2010.544649.

Linkages Between Childhood Executive Functioning and Adolescent Social Functioning and Psychopathology in Girls with ADHD

Jenna R. Rinsky and Stephen P. Hinshaw

University of California, Berkeley

Abstract

We followed an ethnically and socioeconomically diverse sample of preadolescent girls with ADHD ($n=140$) and matched comparison girls ($n=88$) over a period of five years, from middle childhood through early/mid-adolescence, with the aim of determining whether childhood levels of executive function (EF) would predict adolescent multi-informant outcomes of social functioning and psychopathology, including comorbidity between externalizing and internalizing symptomatology. Predictors were well-established measures of planning, response inhibition, and working memory, along with a control measure of fine motor control. Independent of ADHD vs. comparison group status, (a) childhood planning and response inhibition predicted adolescent social functioning and (b) childhood planning predicted comorbid internalizing/externalizing disorders in adolescence. Subgroup status (ADHD-Combined, ADHD-Inattentive, and comparison) moderated the relationship between childhood planning and adolescent internalizing/externalizing comorbidity, with the Combined type revealing particularly strong associations between baseline planning and adolescent comorbidity. Mediation analyses indicated that adolescent social functioning mediated the prediction from childhood EF to comorbidity at follow-up; in turn, in the girls with ADHD, adolescent comorbidity mediated the prediction from childhood EF to social functioning at follow-up. We conclude that childhood interventions should target EF impairments in addition to behavioral symptoms.

Executive functions (EF) comprise a group of high-level cognitive processes essential for complex cognition, such as developing and undertaking goal-directed behaviors, sustaining attention and behavior, monitoring progress, and modifying behavior flexibly in response to changing demands (Carpenter, Just, & Reichle, 2000; Collette, Hogge, Salmon, & Van Der Linden, 2006). These activities are critical for assessing and responding to the kinds of problems that are naturally encountered in life and for making quick decisions and judgments in novel, fast-paced situations, such as social interactions. Executive dysfunction may manifest in everyday life as low impulse control, inability to plan and follow through with essential activities, and problems abiding by the rules of social interaction. Surprisingly little is known about the predictive linkages between EF and social, behavioral, and emotional outcomes, particularly in individuals who are at high risk for EF deficits, such as those with attention-deficit/hyperactivity disorder (ADHD). Girls with ADHD are of particular interest in this regard, given increased interest in their long-term outcomes (Biederman et al., 2010; Hinshaw, Owens, Sami, & Fargeon, 2006) and given evidence that the social problems of girls with ADHD are particularly salient (Hinshaw & Blachman, 2005).

Although EF deficits are held to be pivotal for ADHD, they are a feature of only a subgroup of individuals with this condition (Miller, Gelfand, & Hinshaw, 2010; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005a). ADHD and EF deficits may therefore have partially independent consequences for later development. Indeed, EF deficits are associated with poor behavioral, social, and occupational outcomes even in non-ADHD populations (Biederman et al., 2006; Riggs, Blair, & Greenberg, 2003). Furthermore, EF deficits may persist into young adulthood independent of the course of ADHD, at least in boys (Biederman et al., 2009). Thus, disentangling the relative impact of childhood ADHD and EF on later social outcomes and psychopathology is essential, particularly in girls. Our key aim is to examine the predictive validity of three discrete forms of EF – planning, response inhibition, and working memory – that are consistently found to be impaired in the ADHD population, even after controlling for potential shared variance with age, intelligence, reading achievement, and comorbidities (Willcutt et al., 2005a). Theoretical and statistical models (Barkley, 1997; Kipp, 2005; Willcutt et al., 2005b) suggest the utility of separate consideration of such EFs, including genetic, lesion, and neurophysiological data that attest to their partial independence (e.g., Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Castellanos & Tannock, 2002; Hanna-Pladdy, 2007).

The vast majority of children with ADHD experience continuing impairments in psychosocial adjustment through adolescence (Hinshaw et al., 2006) and still a majority through adulthood (Faraone, Biederman, & Mick, 2006; Mannuzza, Klein, & Moulton, 2003). The persistence of ADHD is associated with poor psychosocial outcomes as well as high rates of comorbidity with substance abuse, mood and anxiety disorders, and oppositional-defiant and conduct disorders (Biederman et al., 2006; Greene, Biederman, Faraone, Sienna, & Garcia-Jetton, 1997; Hinshaw et al., 2006). Less well known, however, are the consequences of early ADHD and associated EF difficulties on important social outcomes and psychopathology.

Regarding the social domain, there is a considerable literature illustrating the profoundly negative impact of childhood ADHD symptoms on social functioning, both concurrently (e.g., Greene et al., 2001; Nijmeijer et al., 2008) and longitudinally (e.g., Bagwell, Molina, Pelham, & Hoza, 2001; Wahlstedt, Thorell, & Bohlin, 2008). Compared to youth without the diagnosis, children and adolescents with ADHD have frequent conflicts with agemates, are more likely to be rejected by peers, have fewer friendships, and have more difficulty keeping friends (Bagwell et al., 2001; Blachman & Hinshaw, 2002; Nijmeijer et al., 2008). Such social difficulties might be linked to EF deficits commonly identified in the ADHD population (Willcutt et al., 2005a). For example, planning may be critical for identifying the optimal action in a given social situation; response inhibition is likely to be crucial for inhibiting an inappropriate behavioral response (Barkley, 1997; Hughes, 1998; Kipp, 2005). Optimal social interaction may also depend on an intact working memory, which is essential for recalling what was last said in conversation and for holding response choices in mind until it becomes appropriate to speak.

Literature examining the relative contributions and interactive effects of ADHD symptoms and EF deficits on social functioning is scarce, limited to concurrent levels of functioning or longitudinal studies of two years or fewer (Biederman et al., 2006; Diamantopoulou, Rydell, Thorell, & Bohlin, 2007; Wahlstedt, Thorell, & Bohlin, 2008). Furthermore, relevant investigations (Diamantopoulou et al., 2007; Wahlstedt et al., 2008) have used single measures of social functioning, either peer sociometrics or adult ratings of social functioning. We examine the predictive validity of EF with respect to social outcomes five years later, using multi-informant, multi-method measures of social functioning.

As for later psychopathology, childhood ADHD is associated with a wide range of later behavioral and emotional problems. Still, it is not known whether EF deficits underlie or exacerbate this risk. In studies examining concurrent functioning, EF deficits have been shown to be associated with poor emotion regulation in children with ADHD (Walcott & Landau, 2004) and to be linked with multiple comorbidities (Fischer et al., 2005; Jonsdottir, Bouma, Sergeant, & Scherder, 2006). In community samples, EF predicts the development of later externalizing and internalizing problems (Martel et al., 2007; Riggs et al., 2003), and interventions targeting executive functioning prevent the development of later internalizing and externalizing psychopathology (Riggs, Greenberg, Kusche, & Pentz, 2006).

Psychopathology and social success are closely linked. Social functioning in childhood predicts the development of both internalizing and externalizing psychopathology, both in community samples (Laird, Jordan, Dodge, Pettit, & Bates, 2001; Pedersen, Vitaro, Barker, & Borge, 2007) and in samples of youth with ADHD (Greene et al., 1997; Greene et al., 2001; Mikami & Hinshaw, 2006). In turn, children who display externalizing behavior or who are overly sad or anxious tend to have a smaller social circle and fewer close friends (Deater-Deckard, 2001; Laird et al., 2001). Overall, it is possible that adolescent social functioning will mediate the impact of childhood EF on adolescent psychopathology and that, in turn, adolescent psychopathology will mediate the effect of childhood EF on adolescent social functioning.

Our key aim is to extend previous literature by examining whether, in a prospective, longitudinal investigation of girls with ADHD and a matched comparison sample, (a) childhood EF deficits predict adolescent social functioning; (b) childhood EF deficits predict adolescent internalizing and externalizing psychopathology as well as their comorbidity; and (c) adolescent social functioning and psychopathology reciprocally mediate each other in terms of prediction from childhood EF. Our sample is large and well-characterized (see Hinshaw, 2002; Hinshaw et al., 2002; Hinshaw et al., 2007). Recent research reveals the promise of examining EF deficits in girls with ADHD as predictors of key outcomes (Miller & Hinshaw, 2010). In addition, given theorizing and speculation that subtypes of ADHD differing on levels of hyperactive-impulsive behavior (i.e., ADHD-Combined type vs. ADHD-Inattentive type) may differ qualitatively (e.g., Milich, Balentine, & Lynam, 2001), we examine subtype differences regarding EF-related prediction of adolescent psychopathology and social functioning.

We hypothesize that poor performance on EF tasks in childhood will predict poor social functioning and psychopathology during adolescence among girls with and without ADHD but that these predictive associations will be particularly salient in the girls with ADHD. That is, we predict that ADHD will serve as a moderator of the relationship between childhood EF and adolescent social outcomes and psychopathology, as the sum of ADHD symptomatology and EF deficits should predict more problematic outcomes than will each considered separately. We also predict that the Combined type of ADHD will feature stronger associations between EF and adolescent social and psychopathology than will the Inattentive subtype, given evidence that children with the Combined subtype have (a) poorer planning and inhibitory skills (Hinshaw et al., 2002; Solanto et al., 2007), (b) higher rates of peer rejection (Hinshaw, 2002), and (c) poorer emotional regulation and higher rates of comorbid psychopathology (Hinshaw, 2002; Maedgen & Carlson, 2000; Miller, Nigg, & Faraone, 2007).

Method

Overview of Procedure

We utilized data from a longitudinal study of the behavioral, executive, social, emotional, and family functioning of 228 girls, 140 with rigorously diagnosed ADHD and 88 matched comparison girls. Data were first collected at baseline (Wave 1), when the girls were 6–12 years old. At this time, they attended research summer camps where behavioral and interpersonal functioning was closely studied and extensive neuropsychological testing was performed. Hinshaw (2002) provides extensive detail on the multi-informant, multiple-gating procedures used for screening, formal diagnostic assessment, and symptom assessment at baseline. To promote generalizability of the ADHD sample, children with common comorbidities (disruptive behavior disorders, anxiety disorders, depression) were not excluded. Although comparison girls could not meet criteria for ADHD, some level of other behavioral disturbance was allowed, to prevent inclusion of a “supernormal” comparison sample. During the summer programs, we emphasized multi-domain assessment of key aspects of childhood behavioral, social, and neuropsychological functioning. Neuropsychological batteries were completed when any girls currently receiving stimulant medication had experienced a 24-hour washout. Staff performing neuropsychological testing were well-trained graduate students and B.A.-level research assistants, closely supervised and unaware of participants' diagnostic status.

At the five-year follow up, evaluations were performed on 209 out of 228 of the original girls (92%), who were then between 11.3–18.2 years of age ($M=14.2$). The retained sample was statistically indistinguishable from those lost to attrition with regard to nearly all baseline variables examined (Hinshaw et al., 2006; Hinshaw et al., 2007). Procedures received full approval of the UC Berkeley Committee for the Protection of Human Subjects.

Participants

The complete sample consists of 93 girls with ADHD-Combined type, 47 with ADHD-Inattentive type, and 88 comparison girls, who represented a diverse range of ethnic and socioeconomic backgrounds. The sample was 53% Caucasian, 27% African-American, 11% Latina, and 9% Asian-American, and family incomes ranged from public assistance to upper-middle class (see Hinshaw, 2002). Comparison girls were screened to match the ADHD sample at a group level with respect to age and ethnicity. Participants with an IQ lower than 70, overt neurological damage, psychosis, or pervasive developmental disorder were excluded.

Because some assessments occurred via home visits or telephone interviews ($n = 7$), full neuropsychological assessment was not possible. In addition, some measures were missing because of fatigue and refusal, and in other instances (i.e., Conners' CPT; Conners, 1995), computer failures precluded full data collection. Hence, the sample size for our present battery ranges from 186–200 (see Hinshaw et al., 2006 and Hinshaw et al., 2007 for complete characterization of the follow-up sample).

Baseline Measures

We selected well-established measures from the baseline neuropsychological battery based on their ability to tap different types of executive functioning and to distinguish the ADHD from the comparison sample (as well as ADHD subtypes) at baseline.

Test of Planning

Rey Osterrieth Complex Figure (ROCF; Osterrieth, 1944): This classic test requires the participant to copy and later recall and draw again a complex, abstract figure composed of

64 intersecting segments. We analyzed the Copy condition. Multiple scoring systems have been developed to tap EF function on the ROCF, but the Error Proportion Score (EPS)—the proportion of errors to the total number of segments drawn—has been shown to specifically capture planning skills through measuring the efficiency of the (visuo-motor) construction process (Sami, Carte, Hinshaw, & Zupan, 2003). It discriminated ADHD from comparison girls in our baseline sample with at least a medium effect size, even with control of performance IQ, fine motor speed, and comorbidities (Sami et al., 2003). It also distinguished girls with ADHD-Combined type from those with the Inattentive type, with the former featuring a higher proportion of errors (Hinshaw et al., 2002). The intraclass correlations between pairs of three primary scorers for the EPS ranged from .91–.94.

Test of Response Inhibition

Conners' Continuous Performance Task (CPT; Conners, 1995): The CPT is a computer-based test tapping response inhibition. It requires the child to push the space bar every time a target letter is presented on the screen (all letters except 'X') and to not respond to the letter 'X.' The 14-minute task consists of trials presented in 6 blocks (interstimulus intervals 1, 2, or 4 s), with a stimulus display time per letter of 250 ms. We examined Commission errors, which reflect impulsivity, represented by the percentage of key presses for non-targets out of the total number of non-targets presented. The CPT is a particularly accurate measure of response inhibition as opposed to visual detection, because there are relatively frequent displays of target stimuli (requiring a response) and relatively infrequent displays of non-targets (requiring inhibition of a response). Prior research has revealed that, at baseline, girls with ADHD made a higher percentage of commission errors than the comparison girls, with effect sizes in the medium range (Hinshaw et al., 2002). In addition, CPT commission errors were able to distinguish girls with ADHD-Combined type from those with ADHD-Inattentive type, with the former featuring a higher percentage of commission errors (Hinshaw et al., 2002; see also Conners, 1995, for information on known-groups differentiation).

Tests of Working Memory

Wechsler Intelligence Scale for Children (WISC-III): Digit Span (Wechsler, 1991): This widely used measure of auditory working memory requires children to immediately recall digit sequences of increasing length either in their original order (Digits Forward) or in reverse order (Digits Backward). Working memory is considered to be a critical component or correlate of EF (Scheres et al., 2004; Willcutt, Pennington, Olson, Chhabildas, & Huslander, 2005c). Digits Forward is thought to involve rehearsal of the contents of working memory; Digits Backward likely involves the additional component of manipulation or sequencing (e.g., Lewis, Nikolova, Chang, & Weekes, 2008). Split-half reliabilities average .85 across the age span of the standardization sample (Wechsler, 1991). We analyzed standard scores ($M = 10$, $SD = 3$) so that mean levels would be clinically interpretable. Because Digit Span is a supplemental test of the WISC-III, it is therefore independent of FSIQ scores. Standardized scores from Digits Forward and Digits Backward were summed to form a composite measure of working memory; this procedure led to enhanced reliability.

Test of Fine Motor Control

Grooved Pegboard (GPB; Knights & Norwood, 1979): We selected the GPB to measure complex fine-motor coordination and psychomotor speed, to control for the impact of these constructs on ROCF EPS and CPT commission errors (see above). That is, we wanted to determine whether measures of EF would predict adolescent outcome measures above and beyond the impact of graphomotor speed, which has also been found to be impaired in children with ADHD (Hinshaw et al., 2002; Meyer, & Sagvolden, 2006). Here, participants

place 25 pegs into a board, first with the preferred hand and then with the non-preferred hand. We analyzed the time to completion for the faster-hand speed, which was the right hand for 86% of our participants (see Hinshaw et al., 2002).

Follow-Up Measures

The following measures of social functioning and externalizing and internalizing psychopathology at our 5-year follow-up were chosen because they reflected the outcomes of interest and because they spanned multiple informants (parent, teacher, and self-reports).

Measures of Social Functioning

Dishion Social Preference Scale (DSPS; Dishion & Kavanagh, 2003): The DSPS is a three-item, teacher-completed measure of the proportion of peers who accept, reject, or ignore the target individual, with each item rated on a 1–5 point scale. We derived a widely used and well-validated social preference score by subtracting the *reject* rating from the *accept* rating (Coie, Dodge, & Coppotelli, 1982; Lahey et al., 2004). Obtaining sociometric appraisals directly from schoolmates is considered the “gold standard” for measuring peer preference, but obtaining schoolwide peer nominations for a middle and high school sample was prohibitive. Still, Dishion and Kavanagh (2003) reported moderately strong correlations of these items with peer-derived sociometric indicators, suggesting that the DSPS provides a valid approximation of peer ratings.

Social Skills Rating System (SSRS; Gresham & Elliot, 1990): Parent report on the SSRS was used to tap cooperation, self-control, and assertiveness. We used the Total Social Skills subscale, which is internally consistent ($\alpha = .91$) and has been shown to differentiate clinical from control samples, with criterion validity in the current sample demonstrated through correlation with CBCL Social Competence subscale ($r = .65$).

Social Relationships Questionnaire (SRQ): This parent-report measure assesses an adolescent's relationship with peers and friends. It contains 12 items, each of which is measured on a 1–4 point scale. Two factors were derived from a principal components analysis, Peer Conflict ($\alpha = .83$) and Friendship ($\alpha = .77$). These factors were each used as measures of separate components of social functioning (see Hinshaw et al., 2006, for further details).

Child Behavior Checklist and Teacher Report Form (CBCL, TRF, Achenbach, 1991, 1991b): These widely used scales comprise measures of adaptive behavior as well as eight narrowband factors and two broadband factors of Externalizing and Internalizing symptoms. On the parent-report CBCL/4–18, we used the adaptive behavior measure “Total Competence” and the narrowband scale “Social Problems” to assess social interaction with peers. We also used the teacher-report (TRF) “Behaving Appropriately” scale, one of four adaptive behavior scales, designed to assess a child's behavior around peers. All CBCL scales have excellent internal consistency and test-retest reliability as well as validity. The CBCL contains 113 items, each of which is rated on a 0–2 metric. We used age-standardized *T* scores in all analyses.

These seven measures of social functioning (DSPS; SSRS “Total Social Skills”; SRQ “Has Friends and “Peer Conflict” factors; CBCL “Total Competence” and “Social Problems” measures; and TRF “Behaving Appropriately” scale) were z-scored and summed to form a multi-informant, multi-measure composite of social functioning. The SRQ “Peer Conflict” measure was reverse-scored, so that higher scores equate to better performance. Alpha reliability analyses indicate that the composite of these seven measures is internally consistent (Cronbach's $\alpha = .88$)

Measures of Internalizing and Externalizing Symptomatology

Diagnostic Interview Schedule for Children – 4th edition (DISC-IV; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000): This well-validated, highly structured diagnostic interview was administered separately to parents and adolescents. It provides both categorical diagnoses and symptom counts for the major disorders in the Diagnostic and Statistical Manual of Mental Disorders (4th ed., *DSM-IV*; American Psychiatric Association, 2000). In this report, we use parent reports and consider disorders present within the preceding year (rather than lifetime diagnoses, which would have been problematic for a longitudinal investigation).

Child Behavior Checklist (CBCL; Achenbach, 1991b): The CBCL contains broadband factors of Externalizing (Aggressive Behavior and Delinquent Behavior scales) and Internalizing (Withdrawn, Somatic Problems, and Anxious/Depressed Behavior scales).

Children's Depression Inventory (CDI; Kovacs, 1992): This widely used self-report instrument contains 27 items, scored on a 0–2 scale, that assess symptoms of depression in children. Its psychometric properties meet the standards set by other instruments in the field; internal consistency ranges from .71–.87 and test-retest reliability averages .70 (Kovacs, 1992).

For an adolescent to be characterized as having an internalizing disorder, she had to meet criteria for one or more of the following disorders on the DISC-IV (generalized anxiety disorder (GAD), obsessive-compulsive disorder (OCD), social phobia, panic disorder, depression, and/or dysthymia), have a score greater than or equal to 65 on the Internalizing factor of the CBCL, or have a score greater than or equal to 20 on the CDI. In order for an adolescent to be diagnosed with an externalizing disorder (other than ADHD), she had to meet criteria for oppositional-defiant disorder (ODD) or conduct disorder (CD) on the DISC-IV, or she had to have a score greater than or equal to 65 on the Externalizing factor of the CBCL. Comorbidity was defined as the presence of both Internalizing and Externalizing psychopathology, as defined above.

Covariates

In all regressions, we entered the baseline variable of “group” status (ADHD versus comparison) as the first step and interacted it with the relevant EF predictor. We performed parallel procedures, in separate regression, for the “subgroup” variable (Combined, Inattentive, and comparison), examining only the interaction term (subgroup × EF variable) in exploratory analyses. Because ADHD symptoms and EF impairments are linked to poor performance on tests of intelligence (Barkley, 1997), controlling for IQ may remove a portion of the variance shared between ADHD and EF deficits (Willcutt et al., 2005a). Because control of both IQ and diagnostic group status may constitute overcontrol, we did not include IQ as a covariate.

Data Analytic Plan

All statistical analyses were performed with SPSS for Macintosh, Version 16. After carefully inspecting data for out-of-range values and determining that no significant outliers existed, the initial data analytic step was to perform linear regressions to test the predictive association between specific childhood EFs – planning, response inhibition, and working memory, as well as fine motor skill – and adolescent social functioning and psychopathology (as criterion measures), controlling for group status (ADHD vs. comparison). In predictions of social functioning, each childhood EF (and the control variable, fine motor skill) was entered into a regression model as a predictor. The criterion variable was the social functioning composite score (hereafter, social functioning),

constructed from measures at the 5-year follow-up. Parallel procedures were used with respect to the three criterion measures of psychopathology (presence of externalizing disorders, internalizing disorders, or both— comorbidity). We then performed parallel, exploratory analyses with subgroup (assessed at baseline) entered as the first step (instead of group status). This subgroup factor was also entered as an interactive term with each respective EF/neuropsychological variable. In the case of any significant interactions, we conducted post-hoc moderation analyses using the methods of Holmbeck (2002). Specifically, we computed separate regression equations for the two ADHD subgroups and the comparison group and plotted each of the regression equations, using data at the intercept and one standard deviation above and below the mean. Here, we reverse-scored the Planning measure for ease of interpretation, so that higher scores would indicate better EF.

Finally, we tested the hypothesis that, in terms of prediction from childhood EF, effects on social functioning would mediate ultimate effects on psychopathology, and vice versa. In other words, in absence of additional prospective data (e.g., a third wave in early adulthood, which is currently in progress) or a specific hypothesis that social functioning is necessary for psychopathology (or vice versa), we predicted that each adolescent factor would mediate the other. We tested this conjecture via linear regression, conditional on a three-variable path model. Because social functioning and psychopathology were both measured at the same timepoint (adolescence), only partial mediation could be determined. We performed regression analyses where planning was the independent variable. In the first analysis, adolescent comorbidity was entered as the dependent variable and adolescent social functioning the hypothesized mediator; in the second, the dependent variable and hypothesized mediator were switched. Each regression was computed across both groups and then separately in the ADHD and comparison groups. Mediation analyses were conducted using the Sobel Test (Sobel, 1982; MacKinnon, Warsi, & Dwyer, 1995), assessing whether the indirect effect of the predictor on the criterion variable via the mediator significantly differs from zero.

Results

Does executive functioning in childhood predict social functioning in adolescence?

With control of group (ADHD) status, the linear regression analyses, displayed in Table 1, revealed significant predictive associations between (a) baseline response inhibition and follow-up social functioning ($p = .022$) and (b) baseline planning and follow-up social functioning ($p = .038$). There was a marginally significant predictive association between baseline working memory and follow-up social functioning ($p = .082$). The fine motor control (control) variable did not show significant predictive associations with the social functioning criterion measure. More specifically, better performance on the baseline EF measures of response inhibition and planning predicted better social outcomes in adolescence, even taking into account ADHD vs. comparison status. Yet diagnostic group status (ADHD vs. comparison, evaluated at baseline) did not significantly interact with either baseline response inhibition ($p = .536$) or baseline planning ($p = .130$). Thus, baseline ADHD status did not moderate the predictive associations between baseline EF variables and adolescent social functioning.

In the exploratory analyses examining moderation by subgroup (ADHD-Combined, ADHD-Inattentive, and comparison) status, results indicated that subgroup status at baseline did not moderate the relationship between any of the baseline EF variables and follow-up social functioning, as indicated by non-significant statistical interactions (see Table 1).

Does executive functioning in childhood predict adolescent psychopathology?

With control of group status, the linear regression analyses, displayed in Table 2, revealed a marginally significant predictive association between baseline working memory and the presence of an internalizing disorder at follow-up ($p = .054$). Whereas no significant predictive associations between baseline EF variables and the presence of an externalizing disorder at adolescent follow-up were found, for comorbidity as the follow-up variable, a significant predictive association between baseline planning and follow-up comorbidity was found ($p = .036$). The response inhibition and fine motor control (control) variables did not show predictive associations with any of the measures of adolescent psychopathology. Thus, better performance on baseline working memory and planning predicted lower incidence of adolescent internalizing disorders and comorbidity, respectively, with control of ADHD status at baseline.

Moderator analyses revealed that diagnostic group status (ADHD vs. comparison, evaluated at baseline) did not interact with baseline working memory in predicting follow-up internalizing ($p = .500$) or with baseline planning in predicting follow-up comorbidity ($p = .099$). With respect to subgroup (ADHD-Combined, ADHD-Inattentive, and comparison), we found that baseline subgroup status moderated the relationship between baseline planning and follow-up internalizing psychopathology ($p = .040$) and comorbidity ($p = .015$). Post-hoc interaction analyses, displayed in Figures 1 and 2, suggest that the predictive associations between baseline planning and follow-up internalizing and comorbidity were largely driven by the Combined subgroup. Significance tests for each slope indicate that the simple slope for the Combined group was significant for the association between baseline planning and both the internalizing ($t_{197} = -2.411, p = .017$) and comorbidity ($t_{196} = -3.058, p = .003$) follow-up criterion variables.

Does adolescent social functioning mediate the relationship between childhood EF and adolescent psychopathology?

We tested the hypothesis that adolescent social functioning would partially mediate the association between childhood planning and adolescent comorbidity (Figure 3). Following Baron and Kenny's (1986) procedure for estimating mediational effects using a series of regression analyses, we found that, collapsing across ADHD and comparison groups, the strength of the association between childhood planning and adolescent comorbidity was reduced to non-significance when adolescent social functioning was included in the equation ($p = .305$). As recommended by Baron and Kenny, the Sobel test was used to determine if the reduction in prediction was statistically significant. Adolescent social functioning significantly mediated the effect of childhood planning on adolescent comorbidity ($t = 3.20, p = .001$).

Although the planning $\times$ group interaction term was not significant, interaction tests of moderator variables may lack statistical power (McClelland & Judd, 1993). Thus, we performed a separate mediation analysis in each group (ADHD versus comparison), because childhood planning had yielded a statistically significant association with adolescent comorbidity in the initial analysis. In the ADHD group, once adolescent social functioning was included in the model, the effect of childhood planning on adolescent comorbidity was reduced to non-significance ($p = .225$). The Sobel test indicated that the reduction in prediction was statistically significant ($t = 2.13, p = .030$). But in the comparison group alone, the data did not meet the prerequisites for mediation. In other words, because childhood planning did not predict adolescent comorbidity ($p = .933$), there were no grounds to conduct a mediation analysis.

Does adolescent psychopathology mediate the relationship between childhood EF and adolescent social functioning

We also tested the hypothesis that adolescent comorbidity would partially mediate the association between childhood planning and adolescent social functioning (Figure 4). Collapsing across ADHD and comparison groups, the strength of the association between childhood planning and adolescent social functioning was reduced but remained significant when adolescent comorbidity was included ($p = .008$). The Sobel test indicated that the reduction in prediction was statistically significant, suggesting that adolescent social functioning partially mediated the effect of childhood planning on adolescent comorbidity ($t = -3.05, p = .002$).

We again tested the mediation analysis separately in the ADHD and comparison groups. In the ADHD group, once adolescent comorbidity was in the model, the effect of childhood planning on adolescent social functioning was reduced to non-significance ($p = .140$). The Sobel test indicated that the reduction in prediction was statistically significant ($t = -2.00, p = .045$). However, because childhood planning did not predict adolescent social functioning in the comparison group ($p = .646$), there were no grounds to conduct a mediation analysis. Overall, results suggest that adolescent comorbidity significantly mediated the association between childhood planning and adolescent social functioning, but only in the ADHD group. Together, the two mediation analyses suggest that adolescent social functioning and psychopathology reciprocally mediate the relationship of each other, in terms of predictions from childhood EF.

Discussion

Our core objective was to determine whether, in girls with and without ADHD, childhood levels of EF (planning, response inhibition, and working memory, along with a control variable of fine motor control) would predict adolescent social and psychopathology-related outcomes, *over and above effects of ADHD status per se*. First, under tight statistical control, childhood EF (planning and response inhibition) predicted adolescent social functioning, with a marginally significant effect of childhood working memory on this outcome. There is specificity here: fine motor control, which was impaired in the baseline sample (Hinshaw et al., 2002), did not predict social functioning at adolescence; only EF measures were predictive. Neither childhood ADHD status nor ADHD subgroup moderated the association between childhood EF and adolescent social functioning; poorer scores on EF measures predicted poorer social functioning in *all* girls, indicating that childhood EF impacts upon adolescent social functioning *independently* from ADHD status.

As for adolescent psychopathology, childhood planning predicted the presence of internalizing-externalizing comorbidity, and working memory marginally predicted the presence of an adolescent internalizing disorder. Diagnostic group status (ADHD vs. comparison) did not emerge as a statistically significant moderator of these predictive associations, but diagnostic subgroup (ADHD-Combined, ADHD-Inattentive, and comparison) significantly moderated the association between planning and adolescent comorbidity as well as internalizing pathology. Here, effects were particularly salient in the Combined subgroup, indicating that EF and symptoms of ADHD-Combined type were additive in predicting adolescent psychopathology. Finally, mediation analyses indicated that, in the ADHD group, adolescent social functioning mediated the impact of childhood planning on adolescent psychopathology and, in turn, adolescent psychopathology mediated the effect of childhood planning on adolescent social functioning, suggesting that social functioning and psychopathology are interdependent.

These results are consistent with the idea that executive functions are crucial for the development of appropriate social functions. That is, the abilities to plan possible actions in a given social context, inhibit an inappropriate response, recall what was last said in conversation, and hold possible response choices in memory until it becomes appropriate to speak may lay the foundation for greater perspective-taking, more reciprocal interaction, greater prosocial behavior, and greater peer acceptance later in life. This perspective is consistent with research showing that EFs are involved in social abilities (Diamantopoulou et al., 2007; Wahlstedt et al., 2008) and that EF difficulties alone can have a negative social impact (Biederman et al., 2006). In fact, the present results suggest that childhood EF deficits have an additive impact on adolescent social functioning above that of ADHD symptoms alone. Thus, interventions targeting ADHD symptoms in children at high risk for problems with peers may not be sufficient to prevent poor social outcomes in adolescence; EF difficulties may need to be addressed specifically.

In terms of adolescent psychopathology across the entire sample, findings suggest that better planning and working memory skills are associated with a lower incidence of psychopathology in girls both with and without ADHD (see Martel et al., 2007; Riggs et al., 2003). That childhood planning and working memory skills, but not response inhibition, were related to adolescent psychopathology suggests that executive functions related to *cognition* may be more critical for later emotional functioning than executive functions related more directly to *behavior* (such as inhibiting a response tendency). In other words, difficulty in planning and in maintaining task-relevant information at the forefront of one's mind may be more critical for ultimate emotion regulation than difficulty in inhibiting a behavioral response per se.

None of the childhood EF measures predicted the presence of an externalizing disorder at adolescent follow-up. One reason could be that girls' externalizing problems may be more closely related to social-environmental factors than to intraindividual/ "biological" factors such as executive functioning (Beauchaine, Hong, & Marsh, 2008; Raaijmakers et al., 2008), highlighting the importance of studying sex-specific etiological pathways. Childhood planning did, however, predict the presence of comorbid internalizing and externalizing psychopathology in adolescence, which may reflect a tendency for poorer executive functioning to relate to the degree of psychopathology (Brunnekreef, et al., 2007). In fact, children with both internalizing and externalizing problems often show more severe and chronic impairments than children with either set of problems alone (Verhulst & Van der Ende, 1993). Particularly poor EF has been linked to internalizing/externalizing comorbidity (e.g., Kusche, Cook, & Greenberg, 1993), although studies to date have measured only concurrent EF and psychopathology. The present results extend the literature by demonstrating a five-year predictive developmental association between EF and comorbid internalizing/externalizing psychopathology.

ADHD status moderated the relationship between baseline planning and follow-up (a) internalizing psychopathology and (b) comorbidity. These associations were "driven" by the Combined subgroup: girls in the subgroup with planning deficits had the highest levels of such pathology in adolescence. These findings echo research showing that children and adults with the ADHD-Combined type demonstrate particularly poor neuropsychological performance (Hinshaw et al., 2002; Houghton et al., 1999) and high rates of internalizing and externalizing psychopathology (Hinshaw et al., 2006; Miller et al., 2007). Evidence also exists that girls with the Combined type of ADHD may demonstrate poorer neuropsychological performance than boys with the ADHD-Combined type (Wodka et al., 2008), highlighting the importance of examining potentially unique etiological pathways in girls vs. boys.

In terms of prediction from childhood EF to either adolescent social functioning or psychopathology, effects on social functioning partially explained the ultimate effects on psychopathology, and vice versa, with results salient for the ADHD group only. Thus, for girls with ADHD, poor childhood planning skills contribute to impaired social functioning as well as to comorbid internalizing/externalizing psychopathology in adolescence. However, the effect of impaired childhood planning skills on these adolescent outcomes could be partially accounted for by the effects that poor adolescent social functioning and adolescent comorbid psychopathology have on each other. The interplay between these two factors may be particularly salient for girls with ADHD, who are already at high risk for comorbidity (Hinshaw, 2002; Quinn, 2000) and whose intrusive, impulsive behavior and difficulty sustaining and switching attention during social interactions tend to alienate peers (Blachman & Hinshaw, 2002; Nijmeijer, 2008). Girls, in particular, tend to be especially sensitive to disruptive behavior and difficulty abiding by the rules of social interactions (Diamantopoulou et al., 2007) and are more likely than boys to engage in relational aggression toward other girls (Zalecki & Hinshaw, 2004).

Peer relationships become particularly critical by adolescence, coinciding with a time at which rates of complex psychopathology increase substantially, particularly in girls (Steinberg & Morris, 2001; Zahn-Waxler, Klimes-Dougan, & Slaterry, 2000). Adolescent girls who struggle to make or keep close friends are more vulnerable to psychosocial stressors than they were earlier in life (Buhrmester, 1990; Wilkinson, 2004), putting them at greater risk for both internalizing and externalizing psychopathology (Ritakallio et al., 2010; Steinberg & Morris, 2001). In turn, adolescents with externalizing behaviors such as aggression and those whose depression and anxiety interfere with their ability to reach out to peers are less likely to have close, fulfilling friendships (Chen, Cohen, Johnson & Kasen, 2009; Nijmeijer, 2008). Interventions targeting both peer relationships and psychopathology may be particularly critical during adolescence, a stress-sensitive developmental period during which life experiences may trigger latent genetic liabilities (Walker, Sabuwalla, & Huot, 2004).

Several limitations are salient. First, the present sample was derived clinically, so the degree to which these predictive associations are representative of the population of girls with ADHD across the U.S. is not clear. However, the sample was recruited from multiple sources and included a wide range of socioeconomic and ethnic diversity (Hinshaw, 2002). Second, because the sample was entirely female, the findings cannot be assumed to generalize to boys with ADHD. Third, reduced sample sizes lowered statistical power for the subgroup contrast, limiting our ability to detect significant differences between subgroups. Similarly, a larger sample size may have provided the power necessary to clarify marginally significant results such as those for childhood working memory in predictions of adolescent social functioning and psychopathology. Fourth, we note that executive functioning is a complex concept that is not fully captured by the methods employed in our study. Although our intention was to examine the relationship of *specific aspects* of childhood executive functioning to adolescent social functioning and psychopathology, there may in fact be other aspects of EF or ways of examining the construct that may prove more germane in future longitudinal studies. However, we note that the finding of clear positive results five years later from neuropsychological tests highlights the significance of the findings. Fifth, although the composite measure of social functioning provided multi-method ratings of social behavior and peer acceptance, we were not able to specify particular aspects or mechanisms of social functioning that might disrupt peer interactions (e.g., Hartup, 2005). Finally, in the absence of data from the ongoing ten-year follow-up of this sample, we could not test a truly prospective mediational analysis, as adolescent social functioning and psychopathology were concurrently assessed.

Overall, childhood EF has implications for adolescent social functioning and psychopathology. Indeed, early executive deficits associated with ADHD may be more predictive of adolescent outcomes than are early symptoms themselves. Because approximately half of individuals with ADHD display clear EF deficits (Nigg et al., 2005), identifying factors responsible for later social, occupational, and emotional impairment in this population is essential. It may be useful to develop interventions that address EF impairments in childhood in order to decrease the probability of poor social functioning and comorbidity later in life. Direct EF interventions such as computerized EF training and school-based curricula addressing integration between affect, behavior, and cognition have yielded improvements in EF (Diamond, Barnett, Thomas, & Munro, 2007; Riggs et al., 2006), although there is a lack of research on long-term outcomes and controversy over how improvement of EF might be expected to affect a child's overall functioning. In addition, given evidence for reciprocal mediation between adolescent social functioning and comorbidity, interventions implemented during adolescence to improve social skills and treat psychopathology are important to consider. Additional longitudinal work investigating the relative importance of childhood and concurrent functioning for adolescent and adult outcomes is of high priority.

Acknowledgments

Work on this article was supported by National Institute of Mental Health Grant R01 MH45064. We wish to thank the many staff whose dedicated work contributed to the database represented in this paper, with special appreciation to Liz Owens for her unmatched skill with respect to program management and data analysis. We also give our heartfelt thanks to the girls and families who participated in our research summer camps and whom we plan on following well into adulthood.

References

- Achenbach, TM. Manual for the Child Behavior Checklist/4–18 and 1991 profile. University Associates in Psychiatry; Burlington, VT: 1991a.
- Achenbach, TM. Manual for the Teacher Report Form and 1991 profile. University Associates in Psychiatry; Burlington, VT: 1991b.
- American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4th ed., text rev.. Author; Washington, DC: 2000.
- Bagwell CL, Molina BSG, Pelham WE, Hoza B. Attention-deficit hyperactivity disorder and problems in peer relations: Predictions from childhood to adolescence. *Journal of the American Academy of Child & Adolescent Psychiatry*. 2001; 40:1285–1292. [PubMed: 11699802]
- Barkley RA. Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*. 1997; 121:65–94. [PubMed: 9000892]
- Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*. 1986; 51:1173–1182. [PubMed: 3806354]
- Beauchaine TP, Hong J, Marsh P. Sex differences in autonomic correlates of conduct problems and aggression. *Journal of the American Academy of Child and Adolescent Psychiatry*. 2008; 47(7): 788–796. [PubMed: 18520959]
- Biederman J, Petty C, Fried R, Fontanella J, Doyle AE, Seidman LJ, et al. Impact of psychometrically defined deficits of executive functioning in adults with attention deficit hyperactivity disorder. *American Journal of Psychiatry*. 2006; 163:1730–1738. [PubMed: 17012683]
- Biederman J, Petty CR, Ball SW, Fried R, Doyle AE, Cohen D, et al. Cognitive deficits in attention deficit/hyperactivity disorder related to the course of the disorder? A prospective controlled follow-up study of grown up boys with persistent and remitting course. *Psychiatry Research*. 2009; 170(2–3):177–182. [PubMed: 19900713]

- Biederman J, Petty CR, Monuteaux MC, Fried R, Byrne D, Mirto T, et al. Adult psychiatric outcomes of girls with attention deficit hyperactivity disorder: 11-year follow-up in a longitudinal case-control study. *American Journal of Psychiatry*. 2010; 167(4):409–417. [PubMed: 20080984]
- Blachman DR, Hinshaw SP. Patterns of friendship among girls with and without attention-deficit/hyperactivity disorder. *Journal of Abnormal Child Psychology*. 2002; 30(6):625–640. [PubMed: 12481976]
- Brunnekreef JA, De Sonnevile LMJ, Althaus M, Minderaa RB, Oldehinkel AJ, Verhulst FC, et al. Information processing profiles of internalizing and externalizing behavior problems: Evidence from a population-based sample of preadolescents. *Journal of Child Psychology and Psychiatry*. 2007; 48(2):185–193. [PubMed: 17300557]
- Buhrmester D. Intimacy of friendship, interpersonal competence, and adjustment during preadolescence and adolescence. *Child Development*. 1990; 61(4):1101–1111. [PubMed: 2209180]
- Burgess PW, Alderman N, Evans J, Emslie H, Wilson BA. The ecological validity of tests of executive function. *Journal of the International Neuropsychological Society*. 1998; 4(6):547–558. [PubMed: 10050359]
- Carpenter PA, Just MA, Reichle ED. Working memory and executive function: Evidence from neuroimaging. *Current Opinion in Neurobiology*. 2000; 10(2):195–199. [PubMed: 10753796]
- Castellanos FX, Tannock R. Neuroscience of attention-deficit/hyperactivity disorder: The search for endophenotypes. *Nature Reviews Neuroscience*. 2002; 3:617–628.
- Chen H, Cohen P, Johnson JG, Kasen S. Psychiatric disorders during adolescence and relationships with peers from age 17 to age 27. *Social Psychiatry and Psychiatric Epidemiology*. 2009; 44(3):223–230. [PubMed: 18670727]
- Coie JD, Dodge KA, Coppotelli H. Dimensions and types of social status: A cross-age perspective. *Developmental Psychology*. 1982; 18:557–570.
- Collette F, Hogge M, Salmon E, Van Der Linden M. Exploration of the neural substrates of executive functioning by functional neuroimaging. *Neuroscience*. 2006; 139(1):209–221. [PubMed: 16324796]
- Conners, CK. Conners' Continuous Performance Test computer program: User's manual. Multi-Health Systems; Toronto, Ont., Canada: 1995.
- Deater-Deckard K. Annotation: Recent research examining the role of peer relationships in the development of psychopathology. *Journal of Child Psychology and Psychiatry*. 2001; 42:565–579. [PubMed: 11464962]
- Denckla MB. Research on executive functioning in a neurodevelopmental context: Application of clinical measures. *Developmental Neuropsychology*. 1996; 12:5–15.
- Diamantopoulou S, Rydell A-M, Thorell LB, Bohlin G. Impact of executive functioning and symptoms of attention deficit hyperactivity disorder on children's peer relations and school performance. *Developmental Neuropsychology*. 2007; 32(1):521–542. [PubMed: 17650992]
- Diamond A, Barnett WS, Thomas J, Munro S. Preschool program improves cognitive control. *Science*. 2007; 318:1387–1388. [PubMed: 18048670]
- Dishion, TJ.; Kavanagh, K. Intervening in adolescent problem behavior: A family-centered approach. Guilford; New York: 2003.
- Faraone SV, Biederman J, Mick E. Age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies. *Psychological Medicine*. 2006; 36(2):159–165. [PubMed: 16420712]
- Fischer M, Barkley R, Smallish L, Fletcher K. Executive functioning in hyperactive children as young adults: Attention, inhibition, response perseveration, and the impact of comorbidity. *Developmental Neuropsychology*. 2005; 27:107–133. [PubMed: 15737944]
- Greene RW, Biederman J, Faraone SV, Sienna M, Garcia-Jetton J. Adolescent outcome of boys with attention-deficit/hyperactivity disorder and social disability: Results from a 4-year longitudinal follow-up study. *Journal of Consulting and Clinical Psychology*. 1997; 65(5):758–767. [PubMed: 9337495]

- Greene RW, Biederman J, Faraone SV, Monuteaux MC, Mick E, DuPre EP, et al. Social Impairment in girls with ADHD: Patterns, gender comparisons, and correlates. *Journal of the American Academy of Child and Adolescent Psychiatry*. 2001; 40(6):704–710. [PubMed: 11392349]
- Gresham, FM.; Elliot, SN. *Social Skills Rating System: Parent, teacher, and child forms*. American Guidance Systems; Circle Pines, MN: 1990.
- Hanna-Pladdy B. Dysexecutive syndromes in neurological disease. *Journal of Neurologic Physical Therapy*. 2007; 31(3):119–127. [PubMed: 18025957]
- Hinshaw SP. Preadolescent girls with attention-deficit/hyperactivity disorder: we. Background characteristics, comorbidity, cognitive and social functioning, and parenting practices. *Journal of Consulting and Clinical Psychology*. 2002; 70(5):1086–1098. [PubMed: 12362959]
- Hinshaw, SP.; Blachman, D. Attention-deficit/hyperactivity disorder. In: Bell-Dolan, D.; Foster, S.; Mash, EJ., editors. *Handbook of behavioral and emotional problems in girls*. Kluwer Academic/Plenum; New York: 2005. p. 117-147.
- Hinshaw SP, Carte ET, Fan C, Jassy JS, Owens EB. Neuropsychological functioning of girls with attention-deficit/hyperactivity disorder followed prospectively into adolescence: Evidence for continuing deficits? *Neuropsychology*. 2007; 21(2):263–273. [PubMed: 17402826]
- Hinshaw SP, Carte ET, Sami N, Treuting JJ, Zupan BA. Preadolescent girls with attention-deficit/hyperactivity disorder: II. Neuropsychological performance in relation to subtypes and individual classification. *Journal of Consulting and Clinical Psychology*. 2002; 74:489–499. [PubMed: 16822106]
- Hinshaw SP, Owens E, Sami N, Fargeon S. Prospective follow-up of girls with attention-deficit/hyperactivity disorder into adolescence: Evidence for continuing cross-domain impairment. *Journal of Consulting and Clinical Psychology*. 2006; 74(3):489–499. [PubMed: 16822106]
- Holmbeck GN. Post-hoc probing of significant moderational and mediational effects in studies of pediatric populations. *Journal of Pediatric Psychology*. 2002; 27(1):87–96. [PubMed: 11726683]
- Houghton S, Douglas G, West J, Whiting K, Wall M, Langsford S, et al. Differential patterns of executive function in children with attention-deficit hyperactivity disorder according to gender and subtype. *Journal of Child Neurology*. 1999; 14(12):801–805. [PubMed: 10614567]
- Hughes C. Executive function in preschoolers: Links with theory of mind and verbal ability. *British Journal of Developmental Psychology*. 1998; 16:233–253.
- Jonsdottir S, Bouma A, Sergeant JA, Scherder EJA. Relationships between neuropsychological measures of executive function and behavioral measures of ADHD symptoms and comorbid behavior. *Archives of Clinical Neuropsychology*. 2006; 21:383–394. [PubMed: 16876383]
- Knights, RM.; Norwood, JA. *A neuropsychological test battery for children: Examiner's manual*. Knights Psychological Consultants; Ottawa, Ontario, Canada: 1979.
- Kovacs, M. *Manual: Children's Depression Inventory*. Multihealth Systems; Toronto, Canada: 1992.
- Kusche CA, Cook ET, Greenberg MT. Neuropsychological and cognitive functioning in children with anxiety, externalizing, and comorbid psychopathology. *Journal of Clinical Child Psychology*. 1993; 22:172–195.
- Laird RD, Jordan KY, Dodge KA, Pettit GS, Bates JE. Peer rejection in childhood, involvement with antisocial peers in early adolescence, and the development of externalizing behavior problems. *Developmental Psychopathology*. 2001; 13(2):337–354.
- Lahey BB, Pelham WE, Loney J, Kipp H, Ehrhardt A, Lee SS, et al. Three-year predictive validity of *DSM-IV* attention-deficit/hyperactivity disorder in children diagnosed at 4–6 years of age. *American Journal of Psychiatry*. 2004; 161:2014–2020. [PubMed: 15514401]
- Lewis RS, Nikolova A, Chang DJ, Weekes NY. Examination stress and components of working memory. *Stress*. 2008; 11(2):108–114. [PubMed: 17853071]
- MacKinnon DP, Warsi G, Dwyer JJ. A simulation study of mediated effect measures. *Multivariate Behavioral Research*. 1995; 30:41–62. [PubMed: 20157641]
- Maedgen JW, Carlson CL. Social functioning and emotional regulation in the attention deficit hyperactivity disorder subtypes. *Journal of Clinical Child Psychology*. 2000; 29(1):30–42. [PubMed: 10693030]

- Mannuzza S, Klein RG, Moulton JL III. Persistence of attention-deficit/hyperactivity disorder into adulthood: What have we learned from the prospective follow-up studies? *Journal of Attention Disorders*. 2003; 7(2):93–100. [PubMed: 15018358]
- Martel MM, Nigg JT, Wong MW, Fitzgerald HE, Jester JM, Puttler L, et al. Childhood and adolescent resiliency, regulation, and executive functioning in relation to adolescent problems and competence in a high-risk sample. *Development and Psychopathology*. 2007; 19:541–563. [PubMed: 17459183]
- McClelland GH, Judd CM. Statistical difficulties in detecting interactions and moderator effects. *Psychological Bulletin*. 1993; 114:376–390. [PubMed: 8416037]
- Meyer A, Sagvolden T. Fine motor skills in South African children with symptoms of ADHD: Influence of subtype, gender, age, and hand dominance. *Behavioral and Brain Functions*. 2006; 9:2–33.
- Milich R, Balentine A, Lynam DR. ADHD combined type and inattentive type are distinct and unrelated disorders. *Clinical psychology: science and practice*. 2001; 8:463–488.
- Miller, M.; Gelfand, J.; Hinshaw, S. Attention-Deficit/Hyperactivity Disorder. In: Davis, Andrew S., editor. *Handbook of pediatric neuropsychology*. Springer; New York: 2010. p. 565–579.
- Miller M, Hinshaw SP. Does childhood executive function predict adolescent functional outcomes in girls with ADHD? *Journal of Abnormal Child Psychology*. 2010; 38:315–326. [PubMed: 19960365]
- Miller TW, Nigg JT, Faraone SV. Axis I and II comorbidity in adults with ADHD. *Journal of Abnormal Psychology*. 2007; 116(3):519–528. [PubMed: 17696708]
- Nijmeijer JS, Minderaa RB, Buitelaar JK, Mulligan A, Hartman CA, Hoekstra PJ. Attention-deficit/hyperactivity disorder and social dysfunctioning. *Clinical Psychology Review*. 2008; 28:692–708. [PubMed: 18036711]
- Osterrieth PA. Le test de copie d'une figure complexe [A test of copying a complex figure]. *Archives de Psychologie*. 1944; 30:206–256.
- Pedersen S, Vitaro F, Barker ED, Borge A. The timing of middle-childhood peer rejection and friendship: Linking early behavior to early-adolescence adjustment. *Child Development*. 2007; 78:1037–1051. [PubMed: 17650124]
- Quinn PO. Attention-deficit/hyperactivity disorder and its comorbidities in women and girls: An evolving picture. *Current Psychiatry Reports*. 2008; 10:419–423. [PubMed: 18803916]
- Raaijmakers MA, Smidts DP, Sergeant JA, Maassen GH, Posthumus JA, van Engeland J, et al. Executive functions in preschool children with aggressive behavior: Impairments in inhibitory control. *Journal of Abnormal Child Psychology*. 2008; 36:1097–1107. [PubMed: 18437548]
- Riggs NR, Blair CB, Greenberg MT. Concurrent and 2-year longitudinal relations between executive function and the behavior of 1st and 2nd grade children. *Child Neuropsychology*. 2003; 9:267–276. [PubMed: 14972705]
- Riggs NR, Greenberg MT, Kusche CA, Pentz MA. The mediational role of neurocognition in the behavioral outcomes of a social-emotional prevention program in elementary school students: Effects of the PATHS curriculum. *Prevention Science*. 2006; 7:91–102. [PubMed: 16572300]
- Ritakallio M, Luukkaala T, Marttunen M, Peltkonen M, Kaltiala-Heino R. Comorbidity between depression and antisocial behaviour in middle adolescence: The role of perceived social support. *Nordic Journal of Psychiatry*. 2010; 64(3):164–171. [PubMed: 20446886]
- Sami N, Carte ET, Hinshaw SP, Zupan BA. Performance of girls with ADHD and comparison girls on the Rey-Osterrieth Complex Figure: Evidence for executive processing deficits. *Child Neuropsychology*. 2003; 9:237–254. [PubMed: 14972703]
- Scheres A, Oosterlaan J, Geurts H, Morein-Zamir S, Meiran N, Schut H, et al. Executive functioning in boys with ADHD: Primarily an inhibition deficit. *Archives of Clinical Neuropsychology*. 2004; 19:569–594. [PubMed: 15163457]
- Shaffer D, Fisher P, Lucas CP, Dulcan MK, Schwab-Stone ME. NIMH Diagnostic Interview Schedule for Children Version IV (NIMH DISC-IV): Description, differences from previous versions, and reliability of some common diagnoses. *Journal of the American Academy of Child & Adolescent Psychiatry*. 2000; 39:28–38. [PubMed: 10638065]

- Sobel, ME. Asymptotic confidence intervals for indirect effects in structural equation models. In: Leinhardt, S., editor. *Sociological Methodology* 1982. American Sociological Association; Washington, DC: 1982. p. 290-312.
- Solanto MV, Gilbert SN, Raj A, Zhu J, Pope-Boyd S, Stepak B, et al. Neurocognitive functioning in AD/HD, predominately inattentive and combined subtypes. *Journal of Abnormal Child Psychology*. 2007; 35:729–744. [PubMed: 17629724]
- Steinberg L, Morris AS. Adolescent development. *Annual Review of Psychology*. 2001; 52:83–110.
- Verhulst FC, Van der Ende J. 'Comorbidity' in an epidemiological sample: A longitudinal perspective. *Journal of Child Psychology and Psychiatry*. 1993; 34:767–783. [PubMed: 8340444]
- Wahlstedt C, Thorell LB, Bohlin G. ADHD symptoms and executive function impairment: Early predictors of later behavioral problems. *Developmental Neuropsychology*. 2008; 33(2):160–178. [PubMed: 18443975]
- Walcott CM, Landau S. The relation between disinhibition and emotion regulation in boys with attention deficit hyperactivity disorder. *Journal of Clinical Child and Adolescent Psychology*. 2004; 33:772–782. [PubMed: 15498744]
- Walker EF, Sabuwalla Z, Huot R. Pubertal neuromaturation, stress sensitivity, and psychopathology. *Development and Psychopathology*. 2004; 16:807–824. [PubMed: 15704816]
- Wechsler, D. Wechsler Intelligence Scale for Children. 3rd ed.. Psychological Corporation; San Antonio, TX: 1991.
- Willcutt, EG.; Brodsky, K.; Chhabildas, N.; Shanahan, M.; Yerys, B.; Scott, A., et al. The neuropsychology of ADHD: Validity of the executive function hypothesis. In: Gozal, D.; Molfese, D., editors. *Attention deficit hyperactivity disorder: From genes to patients*. Humana Press; Totowa, NJ: 2005b. p. 185-213.
- Willcutt EG, Doyle AE, Nigg JT, Faraone SV, Pennington BF. Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry*. 2005a; 57:1336–1346. [PubMed: 15950006]
- Willcutt EG, Pennington B, Olson R, Chhabildas N, Hulslander J. Neuropsychological analyses of comorbidity between reading disability and attention deficit hyperactivity disorder: In search of the common deficit. *Developmental Neuropsychology*. 2005c; 27:1–10.
- Wilkinson RB. The role of parental and peer attachment in the psychological health and self-esteem of adolescents. *Journal of Youth and Adolescence*. 2004; 33:479–493.
- Wodka EL, Mostofsky SH, Prahme C, Gidley Larson JC, Loftis C, Denckla MB, et al. Process examination of executive function in ADHD: Sex and subtype effects. *Clinical Neuropsychology*. 2008; 22:826–841.
- Zahn-Waxler C, Klimes-Dougan B, Slattery MJ. Internalizing problems of childhood and adolescence: Prospects, pitfalls, and progress in understanding the development of anxiety and depression. *Development and Psychopathology*. 2000; 12:443–466. [PubMed: 11014747]
- Zalecki C, Hinshaw SP. Overt and relational aggression in girls with attention-deficit hyperactivity disorder. *Journal of Clinical Child and Adolescent Psychology*. 2004; 33:131–143.

Figure 1.

Regression lines for relations between the executive function of Planning during childhood and the presence of an internalizing disorder during adolescence as moderated by ADHD subgroup (ADHD-Combined, ADHD-Inattentive, and comparison), a 2-way interaction. b = unstandardized regression coefficient (i.e., simple slope); SD = standard deviation.

Figure 2.

Regression lines for relations between the executive function of Planning during childhood and the presence of comorbidity between internalizing and externalizing disorders during adolescence as moderated by ADHD subgroup (ADHD-Combined, ADHD-Inattentive, and comparison), a 2-way interaction. b = unstandardized regression coefficient (i.e., simple slope); SD = standard deviation.

Figure 3.

Mediated models for childhood planning, adolescent social functioning, and comorbidity between internalizing and externalizing disorders during adolescence. β coefficients for childhood planning are direct effects above the path and mediated effects below the path. * = $p < .05$; ** = $p < .01$, *** = $p < .001$.

Figure 4.

Mediated models for childhood planning, adolescent comorbidity, and adolescent social functioning. β coefficients for childhood planning are direct effects above the path and mediated effects below the path. $* = p < .05$; $** = p < .01$, $*** = p < .001$.

Table 1

Linear regression analyses for baseline EF variables and adolescent social functioning

	β	R ² Change	Sig.	β	R ² Change	Sig.
Response Inhibition (RI)						
Step 1: Group	-.600	.360	.000**	-.606	.367	.000**
Step 2: RI	-.158	.025	.022*	-.097	.005	.161
Step 3: Group x RI	-.067	.002	.536	.016	-.005	.875
Planning						
Step 1: Group	-.582	.339	.000**	-.584	.341	.000**
Step 2: Planning	-.150	.021	.038*	-.133	.016	.068
Step 3: Group x Planning	-.186	.010	.130	-.126	.001	.276
Working Memory (WM)						
Step 1: Group	-.578	.334	.000**	-.602	.363	.000**
Step 2: WM	-.133	.017	.082	-.136	.017	.069
Step 3: Group x WM	.010	.000	.935	-.049	.001	.649
Fine Motor Control (FMC)						
Step 1: Group	-.577	.333	.000**	-.583	.340	.000**
Step 2: FMC	-.086	.007	.222	-.123	.015	.077
Step 3: Group x FMC	-.158	.006	.266	-.174	.010	.150

*
 $p < .05$.**
 $p < .01$

Table 2

Linear regression analyses for baseline EF variables and adolescent psychopathology

Internalizing				
	β	R ² Change	Sig.	
Response Inhibition (RI)				
Step 1: Group	.247	.061	.000**	Step 1: Subgroup .253 .064 .000**
Step 2: RI	.086	.007	.219	Step 2: RI .068 .005 .334
Step 3: Group x RI	-.039	.001	.730	Step 3: Subgroup x RI -.025 .000 .817
Planning				
Step 1: Group	.261	.068	.000**	Step 1: Subgroup .272 .074 .000**
Step 2: Planning	.111	.011	.126	Step 2: Planning .101 .009 .171
Step 3: Group x Planning	.139	.006	.274	Step 3: Subgroup x Planning .242 .019 .040*
Working Memory (WM)				
Step 1: Group	.246	.060	.001**	Step 1: Subgroup .279 .078 .000**
Step 2: WM	.146	.020	.054	Step 2: WM .147 .020 .048*
Step 3: Group x WM	.078	.002	.500	Step 3: Subgroup x WM .040 .001 .711
Fine Motor Control (FMC)				
Step 1: Group	.258	.066	.000**	Step 1: Subgroup .271 .074 .000**
Step 2: FMC	-.021	.001	.762	Step 2: FMC -.011 .000 .875
Step 3: Group x FMC	-.069	.001	.605	Step 3: Subgroup x FMC .095 .003 .418
Externalizing				
	β	R ² Change	Sig.	
Response Inhibition (RI)				
Step 1: Group	.507	.257	.000**	Step 1: Subgroup .475 .225 .000**
Step 2: RI	.040	.001	.519	Step 2: RI .002 .000 .972
Step 3: Group x RI	-.033	.001	.744	Step 3: Subgroup x RI -.055 .001 .574
Planning				

Externalizing					
	β	R ² Change	Sig.	β	R ² Change
Step 1: Group	.483	.233	.000**	.459	.211
Step 2: Planning	.084	.006	.203	.081	.006
Step 3: Group x Planning	.151	.007	.195	.104	.003
Working Memory (WM)					
Step 1: Group	.534	.285	.000**	.524	.275
Step 2: WM	.034	.001	.604	.018	.000
Step 3: Group x WM	-.015	.000	.880	-.007	.000
Fine Motor Control (FMC)					
Step 1: Group	.485	.235	.000**	.457	.209
Step 2: FMC	-.087	.007	.169	-.060	.004
Step 3: Group x FMC	-.002	.000	.990	.026	.000
Comorbidity					
	β	R ² Change	Sig.	β	R ² Change
Response Inhibition (RI)					
Step 1: Group	.299	.089	.000**	.314	.099
Step 2: RI	.041	.002	.557	.017	.000
Step 3: Group x RI	.009	.000	.935	.016	.000
Planning					
Step 1: Group	.312	.097	.000**	.333	.111
Step 2: Planning	.151	.020	.036*	.135	.015
Step 3: Group x Planning	.207	.012	.099	.282	.027
Working Memory (WM)					
Step 1: Group	.326	.106	.000**	.381	.145
Step 2: WM	.076	.006	.310	.082	.006
Step 3: Group x WM	.108	.004	.340	.060	.002
Fine Motor Control (FMC)					
Step 1: Group	.326	.106	.000**	.381	.145
Step 2: WM	.076	.006	.310	.082	.006
Step 3: Group x WM	.108	.004	.340	.060	.002

Comorbidity						
	β	R ² Change	Sig.	β	R ² Change	Sig.
Step 1: Group	.309	.095	.000**	.333	.111	.000**
Step 2: FMC	-.043	.002	.531	-.031	.001	.644
Step 3: Group x FMC	.016	.000	.908	.145	.006	.221

* $p < .05$.
** $p < .01$