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The Association of Executive Functioning With Academic, Behavior, and Social Performance Ratings in Children With ADHD

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Abstract

This study investigated the association of a performance-based measure of executive functioning (EF) with academic, social, and behavioral performance ratings in a convenience sample of 153 children aged 5 to 12 (78% male, 83% Caucasian) diagnosed with attention-deficit/hyperactivity disorder (ADHD). Multivariate regression showed that above and beyond age and ADHD severity, poorer EF performance was uniquely associated with more impairment in reading, written expression, and math by teacher report, and more impairment in the overall school and reading domains by parent report. ADHD symptoms were more strongly associated with ratings of impairment in social relationships, organized peer activities, and classroom behaviors than EF performance. Age did not moderate the findings, but younger children were rated as having more trouble with participation in organized activities by parents, as more likely to disrupt class by teachers, and to have problematic relationships with peers by parents and teachers. EF and academic performance appeared worst in the groups seen as highly symptomatic and impaired by both parents and teachers, and by teachers only. EF deficits may be a specific risk factor for academic impairment in children with ADHD.

Keywords

ADHD, neuropsychology, academics

Executive Functioning (EF) Is Critical for Child Functioning

EF refers to neurocognitive processes that are necessary for the goal-directed modulation of attention and behavior, which are essential for successful functioning in multiple domains (e.g., academic, social, behavioral). Distinct yet interrelated processes such as working memory, inhibitory control, and cognitive flexibility make up overall EF (Anderson, 2002; Carlson & Zelazo, 2014; Miyake et al., 2000). Working memory is the ability to temporarily hold and manipulate task-relevant information in mind to guide present or future actions (Baddeley, 2012; Carlson, 2003; Diamond, 2013). Inhibitory control (e.g., response inhibition and interference control) refers to the ability to resist temptations or acting impulsively (Barkley, 2005; Carlson, 2003; Diamond, 2013). Cognitive flexibility refers to the ability to quickly and flexibly adapt to changed circumstances (Carlson, 2003; Diamond, 2013; Zelazo & Muller, 2002). Higher order EFs such as reasoning, problem solving, and planning are built from these core EFs (Collins & Koechlin, 2012; Lunt et al., 2012). EFs are required to perform most academic tasks and are critical to the acquisition of complex cognitive tasks such as math computation and reading (Cirino & Willcutt, 2017; De Weerdt et al., 2013; Lefevre et al., 2013; Raghubar et al., 2010). In fact, EF is a significant predictor of language, math, and literacy skills (Bull et al., 2008; McClelland et al., 2007; Monette et al., 2011). EF is also strongly associated with social and emotional functioning (Best et al., 2009). For example, EFs are needed to assess and respond to situations that are naturally encountered in life, such as 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 (Rinsky & Hinshaw, 2011).

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EF Deficits and Academic Challenges in Children With Attention-Deficit/ Hyperactivity Disorder (ADHD)

Children diagnosed with ADHD often demonstrate EF deficits in a variety of domains (Willcutt et al., 2005). Perhaps due to these EF deficits, multiple studies demonstrate that children with ADHD struggle academically (Barry et al., 2002; DuPaul et al., 2001; Polderman et al., 2010; Sayal, 2008; Spira & Fischel, 2005). In fact, up to 30% of children with ADHD perform less well academically than would be predicted by their age and IQ (Thorell, 2007). Estimates of the overlap between ADHD and underachievement in school-aged children range from 10% to 50%, depending on the definition of learning problems used (Daley & Birchwood, 2010). Some studies examining the contribution of EF to ADHD-related academic performance in children with ADHD show that those children with both ADHD and EF deficits are at increased risk for academic impairment compared with children with ADHD without EF deficits (Biederman et al., 2004; Loo et al., 2007; Miller et al., 2012; Vexelman & Tannock, 2011). It has also been suggested that EF deficits are causally related to both academic performance and ADHD symptoms in children with ADHD such that they mediate the association between ADHD and academic performance (Antonini et al., 2016; Rogers et al., 2011; Thorell, 2007). EF deficits are also associated with generally disruptive behaviors (Huang-Pollock et al., 2009), non-cooperative behavior (Ciairano et al., 2007), and ADHD symptomatology (Nigg et al., 2005).

EF Deficits and Social Challenges in Children With ADHD

EF is also associated with social functioning in youth with ADHD. For example, working memory (Chiang & Gau, 2014; Kofler et al., 2011) and higher order EFs such as planning, organization, and strategy generation (Clark et al., 2002) have been associated with social competence in youth with ADHD. Furthermore, childhood EFs including working memory and response inhibition positively predicted peer acceptance in adolescence (Miller & Hinshaw, 2010). Relatedly, performance on EF tasks, such as working memory measures, mediated the effect of ADHD on social problems (Tseng & Gau, 2013), although not always (Huang-Pollock et al., 2009). A recent study showed that EF deficits were as predictive of social dysfunction as parent- and teacher-rated ADHD symptoms (Kofler et al., 2018). It has also been suggested that deficits in EF may mediate or underlie the link between ADHD and social problems (Tseng & Gau, 2013).

Assessment of EF Is Critical and Multiple Informants Can Help

Research showing that children with ADHD and EF deficits are at increased risk for academic and social impairments suggests the need to incorporate an assessment of EF into clinical evaluations of children suspected of having ADHD. Evidence-based assessment for ADHD involves determining whether both symptoms and impairments are present across settings (Pelham et al., 2005). Thus, it is crucial to collect information about a child's functioning from multiple informants. The primary measures collected as part of an ADHD evaluation in clinical practice are typically completed by the child's parents and teachers (Pelham et al., 2005). While parent and teacher rating scales of EF exist, they do not necessarily correspond with performance-based measures of EF (Toplak et al., 2013). A quick and easily administered direct assessment of EF that could be used with children across a broad age range would permit the addition of another important informant, the child, to the formal evaluation process. In fact, it has been argued that a performance-based assessment may inform the identification of clinically relevant behaviors in children, presuming clinical utility can be demonstrated (Frick, 2000).

The *Minnesota Executive Function Scale* (MEFS): A Direct Assessment of EF

The MEFS (Carlson & Zelazo, 2014), an app based on the *Dimensional Change Card Sort Task* (Zelazo, 2006), provides a direct assessment of a child's cognitive flexibility, working memory, and inhibitory control. Deficits in working memory (Kofler et al., 2014) and inhibition (Barkley, 1997; Shanahan et al., 2008) are considered to be core deficits in ADHD, and cognitive flexibility, working memory, and inhibitory control have all been linked to academic (Alloway & Alloway, 2010; Preston et al., 2009; Roberts et al., 2017; Thorell, 2007) and social (Chiang & Gau, 2014; Kofler et al., 2011; Miller & Hinshaw, 2010; Tseng & Gau, 2013) impairments in ADHD. While weaknesses in inhibitory control and working memory are consistently found, there is significant heterogeneity in the EF deficits observed in children with ADHD (Willcutt et al., 2005). Thus, an important appeal to using the MEFS is that it generates an age-normed single score that captures deficits in three of the EF domains shown to be impaired in ADHD (i.e., cognitive flexibility, working memory, and inhibitory control), across a broad age range (ages 2 to adult). Notably, a recent meta-analysis did not find evidence for specific EFs to be associated with reading and/or math; instead results showed that all EFs were correlated with reading and math achievement (Jacob & Parkinson, 2015).

Direct Assessment of EF May Help Resolve Informant Discrepancies

The addition of the MEFS collected directly from the child also allows for an examination of how the addition of an EF assessment can inform our understanding of behavior in different contexts. Specifically, the MEFS may allow the

opportunity to investigate how a child's symptoms, as reported by parents and teachers, are associated with performance on a cognitive task. It is well known that when multiple informants (e.g., parent, teacher) complete ADHD rating scales, there are often discrepant findings (De Los Reyes et al., 2019; Narad et al., 2015). It is important to not underestimate the meaning of such discrepancies and to use them to understand the child's functioning more fully (Talbott et al., 2018). In fact, it is likely that when discrepancies are observed, they reflect real-world variations in children's behaviors exhibited across contexts (De Los Reyes et al., 2009). The MEFS may provide some useful information regarding the child's behavior in another context that may be utilized to understand functioning and resolve potentially discrepant ratings between parents and teachers. In fact, De Los Reyes et al. (2009) argued that discrepancies may be a marker for severity of dysfunction. For example, informant discrepancies would be expected in milder forms of disruptive behaviors, because the child being rated discrepantly by informants exhibits less impairing behavior overall. Thus, the nature and extent of a child's disruptive behavior may be "missed" or differentially interpreted across varying situations. In contrast, higher informant agreement would be expected for children with more severe impairments. As their disruptive behaviors would likely be exhibited at higher frequencies and in more extreme forms, it is more likely to be seen and rated by multiple informants. Thus, we intend to explore whether MEFS performance and impairment vary by severity (i.e., neither parents nor teachers reported high symptoms and impairments; only parents reported high symptoms and impairments; only teachers reported high symptoms and impairments; or both parents and teachers reported high symptoms and impairments).

Rationale for Exploring Age as a Moderator

It is important to consider the role of development in this line of inquiry given that developmental studies show a protracted course of EF development beginning in early childhood and continuing into early adolescence (Anderson, 2002; Huizinga et al., 2006; Zelazo & Carlson, 2012). There are known developmental improvements in the development of EF component processes including inhibition, working memory, and cognitive flexibility from age 5 to early adolescence (Anderson, 2002; Best et al., 2009), which are the EFs measured by the MEFS. Given that EF is associated with important developmental outcomes (Anderson, 2002; Zelazo & Carlson, 2012), it is important to consider whether the age of the child moderates the association between EF and impairment. Arguably, one might expect older children with the most developed EF to have lower impairment ratings.

Research Questions

Our research questions are as follows:

Research Question 1: Is MEFS performance associated with parent and teacher performance ratings in academic and classroom behavior domains?

We hypothesized that poor performance on the MEFS would be associated with worse academic and classroom behavior performance ratings.

Research Question 2: Is MEFS performance associated with parent and teacher social performance ratings?

We hypothesized that poor performance on the MEFS would be associated with worse social performance.

Research Question 3: Does age moderate the association between MEFS performance and impairment?

We hypothesized that older children with higher MEFS scores would have less impairment than younger children with lower MEFS scores.

Research Question 4: Do EF deficits and ratings of academic, social, and classroom behavior functioning differ as a function of informant/severity?

We would expect the poorest MEFS performance in the group rated as the most symptomatic and impaired by both parents and teachers (De Los Reyes et al., 2009).

Method

Participants

Participants ($n = 213$) presented for an ADHD assessment and agreed to have their data included in a clinical registry. The use of the clinical registry for this study was approved by the hospital Institutional Review Board. For this particular study, we included only children who were diagnosed with ADHD in the age range of 5 to 12 ($n = 159$; $M = 7.64$ years, $SD = 1.68$ years). This age range was selected because there were very few children over the age of 12 ($n = 5$) and because there were significant missing data for children under 5 years of age on the academic performance variables. The majority were male (79.1%) and Caucasian (83.2%), African American (14.1%), or biracial (2.5%). With regard to grade, 29.5% were in kindergarten, with the remaining students in elementary (69.8%) or middle (0.7%) school. An ADHD diagnosis was established by licensed clinical psychologists. The diagnostic process included a clinic-developed semi-structured interview assessing ADHD symptoms and additional *Diagnostic and Statistical*

Manual of Mental Disorders (*DSM*) criteria for ADHD (i.e., age of onset, presence of symptoms across two or more settings, functional impairments, and ruling out possible other causes—for example, mood, anxiety, and adjustment—for ADHD symptomatology). Interview information was supplemented by the *Vanderbilt ADHD Diagnostic Rating Scale* (Wolraich et al., 1998) completed separately by parents and teachers, the *Child Behavior Checklist and Teacher Report Form* (Achenbach, 1991), a clinic-developed early developmental history questionnaire, and a child behavioral observation session. Comorbid diagnoses were infrequent and included oppositional defiant disorder (9.2%), an anxiety disorder (5.5%), a depressive disorder (1%), or an adjustment disorder (1.4%). Rates of comorbidities are relatively low, which may partly be because the intake team at the children's hospital is trained to triage referrals, with severe behavior problems being referred to other divisions (e.g., psychiatry).

Design and Procedure

Families presented to an outpatient clinic specializing in pediatric ADHD. Parents attended an initial visit during which consent was obtained and a diagnostic evaluation was conducted. One to two weeks after the initial visit, a second visit occurred with the same licensed psychologist during which behavioral observations with the child were conducted and the EF task was administered. Prior to the initial visit, parent and teacher rating scales were collected via an online portal.

Measures

ADHD symptoms. Parents and teachers completed the *Vanderbilt ADHD Diagnostic Parent Rating Scale* (VADPRS) and *Vanderbilt ADHD Diagnostic Teacher Rating Scale* (VADTRS), respectively; (Wolraich et al., 1998). The VADPRS and VADTRS include items assessing the 18 *DSM* symptoms of ADHD (4-point scale ranging from 0 = "never" to 3 = "very often"), and these items were averaged in the present study (Parent α = .90, Teacher α = .93). The factor structure, internal consistency, and reliability of the VADPRS and VADTRS are acceptable and consistent with *DSM* and other accepted measures of ADHD for children pre-Kindergarten through 14 years of age (Bard et al., 2013; Wolraich et al., 2003, 2013).

Impairment. The VADPRS and VADTRS include 16 individual items assessing performance in academic, interpersonal, and behavioral domains. Performance ratings are given on a 5-point Likert-type scale of *excellent* (1), *above average* (2), *average* (3), *somewhat of a problem* (4), and *problematic* (5), and the items are examined at an individual level. Parents rate performance in the following eight domains: *overall school performance*, *reading*, *writing*, *math*, *relationships with parents*, *relationships with siblings*, *relationships with peers*, and *participation in organized peer activities*. Teachers rate performance in the following eight domains: *reading, written expression, math, relationships with peers, following directions, disrupting class, assignment completion*, and *organizational skills*. Criterion validity for these items has been established via correlations between performance item scores and the presence of problems in academic or behavioral performance in children in Kindergarten and later (Kharamin et al., 2018; Wolraich et al., 1998). Also, the Vanderbilt performance items have been shown to have clinical utility in predicting learning disabilities in youth with ADHD (Langberg et al., 2010). Higher scores indicate worse performance or greater impairment. Unfortunately, there is limited overlap between the items parents and teachers complete limiting the ability to directly examine informant discrepancies.

EF. The MEFS™ app (Carlson & Zelazo, 2014) requires children to sort a variety of cards based on the dimensions of the target cards (e.g., color and shape) that are graded in difficulty level. At each level, children sort virtual cards into two boxes according to specific rules (e.g., "If it's red put it here, but if it's blue put it here") and switch rules with increasing difficulty across levels. The MEFS starts at an age-dependent level and adapts to each child's abilities. Children must be correct on at least four out of five trials to move forward. If children fail the starting level, the program automatically goes back to an easier level until the child's current level of functioning is reached. The MEFS has been used with more than 7,000 children and been found to be reliable (test–retest intraclass correlation coefficient [ICC] = .93; Beck et al., 2011) and valid (highly correlated with the *NIH Toolbox Dimensional Card Sort Task*, weakly correlated with IQ, strongly predictive of literacy and math; Carlson & Harrod, 2013; Meuwissen, 2017), and to capture well-known age trends in EF (Reflection Sciences, 2017). A total score based on accuracy and response time is computed and then, based on the norming sample using the smoothed percentiles as the baseline, a standard score is calculated. Higher standard scores indicate better EF.

Statistical Analysis

Research Question 1: *Is MEFS performance associated with parent and teacher performance ratings in academic and classroom behavior domains? and* **Research Question 2:** *Is MEFS performance associated with parent and teacher social performance ratings?* To explore these questions, we first conducted Pearson's correlations between MEFS performance and parent and teacher ratings of performance to ensure that MEFS performance was associated with performance at the bivariate

Table 1. Inter-Correlations Between Executive Function Performance and Parent and Teacher Vanderbilt Performance Ratings.

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. MEFS	—															
2. School—p	−.23*	—														
3. Reading—p	−.19*	.65*	—													
4. Writing—p	−.11	.53*	.55*	—												
5. Math—p	−.16	.47*	.46*	.44*	—											
6. Parents—p	.04	.01	−.06	.06	.04	—										
7. Siblings—p	−.05	.09	−.04	.08	.03	.82*	—									
8. Peers—p	.05	.10	−.21*	−.01	−.07	.54*	.61*	—								
9. Organized—p	−.06	.09	−.24*	−.03	−.04	.29*	.35*	.60*	—							
10. Reading—t	−.24*	.52*	.69*	.40*	.37*	−.19*	−.20*	−.27*	−.32*	—						
11. Math—t	−.31*	.45*	.45*	.38*	.52*	−.04	−.12	−.18*	−.18	.74*	—					
12. Writing—t	−.29*	.46*	.48*	.46*	.32*	−.10	−.11	−.13	−.15	.67*	.67*	—				
13. Peers—t	−.16	.17*	.02	−.04	−.07	.10	.09	.31*	.23*	.02	.04	.19*	—			
14. Directions—t	−.34*	.34*	.05	.15	.12	−.11	−.09	.09	.18*	.23*	.30*	.28*	.37*	—		
15. Disrupting—t	−.21*	.17*	−.06	−.11	.00	.06	.15	.23*	.21*	.06	.01	.05*	.39*	.65*	—	
16. Assign—t	−.21*	.29*	.11	.13	.06	−.24*	−.17	−.03	.21*	.31*	.22*	.32*	.21*	.58*	.39*	—
17. Org—t	−.18*	.20*	.04	.15	.07	−.14	−.15	−.02	.18*	.19*	.19*	.34*	.20*	.59*	.36*	.72*

Note. MEFS = *Minnesota Executive Function Scale; p* = parent; *t* = teacher; 2 = overall school performance; 6 = relationship with parents; 7 = relationship with siblings; 8 and 13 = relationship with peers; 9 = participation in organized activities; 14 = following directions; 15 = disrupting class; 16 = assignment completion; 17 = organizational skills.
*$p < .05$.

level. We then computed a single multivariate regression with MEFS performance predicting parent and teacher performance items; parent-reported ADHD symptoms, teacher-reported ADHD symptoms, and age were each included as independent variables alongside MEFS performance to examine whether MEFS scores were associated with the outcome variables above and beyond ADHD symptoms and age. That is, we examined whether there were unique effects of MEFS scores in relation to academics, classroom behavior, and social performance. Multivariate multiple regression was used for two reasons. First, response variables that are correlated at non-zero values should be allowed to correlate in a multivariate analysis rather than be treated as independent and analyzed in several univariate analyses. Second, such an analysis requires missing data to be handled with maximum likelihood estimation rather than multiple imputation (Enders et al., 2020). The multivariate regression analysis was performed in Mplus via 5,000 bootstrap replications to obtain empirical rather than estimated standard errors (Chernick, 2011). Bootstrapping was utilized because structural equation modeling (SEM) was required to estimate multivariate models with missing data, and sample sizes of <500 in SEM models are considered questionable (Paxton et al., 2001). The VADTRS and VADPRS performance items were rated on a 1 to 5 Likert-type scale, which violates the assumption of a normally distributed continuous response variable. Thus, these response variables were log-transformed (Duan, 1983; Olsen & Schafer, 2001). The *p* values for these analyses were corrected for multiple comparisons using false discovery rate (FDR) procedures (Benjamini & Hochberg, 1995). Specifically, these procedures are used to reduce the number of false positive findings that may occur by chance. Standardized coefficients are reported in the tables, while unstandardized coefficients and related confidence intervals (CIs) are reported in the text.

Research Question 3: *Does age moderate the association between MEFS performance and impairment?* To explore whether age moderated the association of MEFS and Vanderbilt performance ratings, we reran the multivariate regression described above but also included an additional MEFS by age interaction term in the model.

Research Question 4: *Do EF deficits and ratings of academic, social, and classroom behavior functioning differ as a function of informant/severity?* To explore whether associations between EF deficits and ratings of academic and social functioning differed as a function of informant, we divided the participants into four groups: (a) neither parents nor teachers reported high symptoms and impairments; (b) only parents reported high symptoms and impairments; (c) only teachers reported high symptoms and impairments; and (d) both parents and teachers reported high symptoms and impairments. High symptoms was defined as an ADHD mean score $\geq$2.0 (i.e., symptoms occur often or very often on the VADPRS and/or VADTRS), while high impairment was defined as a mean performance rating (averaged across all domains of impairment) $>$3 (i.e., somewhat of a problem or problematic). Descriptive statistics for the MEFS and performance ratings were computed for the four groups.

Missing data. Pairwise missing data varied between 0.7% and 13.1% for any single variable. Tests of patterns of missingness showed that children with missing data did not differ significantly from those with complete data with regard to age, sex, race, ADHD subtype, or comorbid diagnoses (all *p*s $\geq$ .10). Missing data for multivariate regression analyses were handled via maximum likelihood estimation (Enders, 2010; Graham, 2012).

Results

Research Question 1: *Is MEFS Performance Associated With Parent and Teacher Performance Ratings in Academic and Classroom Behavior Domains?*

Correlations. As seen in Table 1, MEFS performance was significantly negatively correlated with parent performance ratings for overall school performance and reading, and with teacher ratings of impairment in all academic and classroom behavior domains; poorer MEFS performance was associated with greater impairment. Parent ratings of impairment in overall school performance were positively correlated with both parent and teacher impairment ratings in reading, writing, and math. Similarly, parent impairment ratings in each academic domain were significantly positively correlated (*r*s $>$ .4) with teacher impairment ratings in the corresponding academic domain.

Multivariate regression. Results of the regression (see Table 2) revealed that, above and beyond age and ADHD symptoms, poorer MEFS performance was uniquely associated with worse academic performance ratings in the domains of overall school performance ($B = -.01$, 95% CI = [–.011, .002]) and reading ($B = -.01$, 95% CI = [–.017, –.002]) by parent, and with teacher ratings of worse performance in reading ($B = -.01$, 95% CI = [–.013, –.002]), math ($B = -.01$, 95% CI = [–.013, –.004]), and written expression ($B = -.01$, 95% CI = [–.009, –.001]) as well as for following directions ($B = -.003$, 95% CI = [–.005, –.001]). ADHD severity and age were not significantly associated with parent-rated academic performance items.

Above and beyond age and ADHD symptoms, MEFS performance was not uniquely associated with teacher classroom behavior performance ratings, other than following directions ($B = -.003$, 95% CI = [–.005, –.001]), which was more strongly associated with teacher ADHD ratings ($B = .18$, 95% CI = [.139, .225]). In fact, higher teacher

Table 2. Multivariate Regression: Executive Function Performance Predicting Parent and Teacher Vanderbilt Performance Ratings.

Parent	Overall school performance (academic) $R^2 = .09$	Reading (academic) $R^2 = .05$	Writing (academic) $R^2 = .06$	Mathematics (academic) $R^2 = .04$	Relationship with parents (social) $R^2 = .12$	Relationship with siblings (social) $R^2 = .14$	Relationship with peers (social) $R^2 = .14$	Participation in organized activities (social) $R^2 = .19$
Predictor	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)
MEFS	−.21 (.08)*	−.22 (.08)*	−.14 (.08)	−.15 (.11)	−.11 (.08)	−0.15 (.08)	.03 (.07)	.03 (.06)
ADHD p	.14 (.09)	−.03 (.08)	.12 (.08)	.11 (.07)	.33 (.07)*	.34 (.07)*	.25 (.07)*	.25 (.09)*
ADHD t	.11 (.09)	−.06 (.09)	−.03 (.08)	.00 (.09)	−.11 (.09)	−.05 (.09)	.09 (.11)	.04 (.11)
Age	−.03 (.08)	.03 (.08)	.18 (.07)	.10 (.09)	−.08 (.07)	−.08 (.08)	−.20 (.07)*	−.30 (.08)*
Predictor	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)
Teacher	Reading (academic) $R^2 = .06$	Math (academic) $R^2 = .09$	Written expression (academic) $R^2 = .07$	Relationship With peers (social) $R^2 = .13$	Following directions (classroom bx) $R^2 = .46$	Disrupting class (classroom bx) $R^2 = .52$	Assignment completion (classroom bx) $R^2 = .21$	Organizational skills (classroom bx) $R^2 = .27$
MEFS	−.23 (.08)*	−.29 (.08)*	−.24 (.09)*	−.09 (.07)	−.16 (.01)*	.05 (.07)	−.02 (.07)	−.03 (.09)
ADHD p	−.02 (.07)	−.03 (.08)	.03 (.07)	.03 (.08)	−.04 (.06)	−.03 (.06)	−.07 (.08)	.01 (.06)
ADHD t	.04 (.09)	.02 (.09)	.06 (.10)	.18 (.07)*	.60 (.05)*	.69 (.04)*	.44 (.07)*	.50 (.07)*
Age	.00 (.08)	.04 (.08)	.06 (.09)	−.22 (.08)*	−.06 (.07)	−.13 (.05)*	−.04 (.07)	−.01 (.08)

Note. All *p* values are corrected using false discovery rate procedures; standardized estimates are reported. *SE* = standard error; MEFS = *Minnesota Executive Function Scale*; ADHD = attention-deficit/hyperactivity disorder; bx = behavior, p = parent; t = teacher.
*$p < .05$.

ADHD ratings were significantly associated with more impairment in all classroom behaviors including disrupting class (B =.41, 95% CI = [.323, .493]), assignment completion (B =.19, 95% CI = [.123, .256]), and organizational skills (B =.18, 95% CI = [.121, .238]) as rated by teachers. ADHD severity and age were not significantly associated with teacher-rated academic or classroom behavior performance items with the exception of disrupting class; younger children were rated as more disruptive than older children (B = –.03, 95% CI = [–.054, –.006]).

Research Question 2: *Is MEFS Performance Associated With Parent and Teacher Social Performance Ratings?*

Correlations. As seen in Table 1, MEFS performance was not significantly correlated with parent (i.e., relationship with siblings, peers, or parents; participation in organized activities) or teacher (i.e., relationship with peers) social performance ratings. Parent ratings of impairment with peer relationships were significantly positively correlated with teacher ratings of impairment in peer relationships.

Multivariate regression. Results of the regression (see Table 2) revealed that, above and beyond age and ADHD symptoms, poorer MEFS performance was not uniquely associated with parent social performance ratings. However, higher parent ADHD ratings were significantly associated with more impairment in relationships with siblings (B =.31, 95% CI = [.173, .453]), relationships with peers (B =.20, 95% CI = [.083, .313]), and participation in organized activities (B =.20, 95% CI = [.060, .335]) as rated by parents. Also, younger children were more likely to be rated by their parent as having impairment in relationships with peers (B = –.05, 95% CI = [–.086, –.011]) and participation in organized activities (B = –.08, 95% CI = [–.117, –.034]).

Results of the regression (see Table 2) revealed that, above and beyond age and ADHD symptoms, poorer MEFS performance was not uniquely associated with teacher social performance ratings. Higher teacher ADHD ratings (B =.09, 95% CI = [.027, .153]) and younger age (B = –.04, 95% CI = [–.075, –.013]) were significantly associated with more impairment in relationships with peers as rated by teachers.

Research Question 3: *Does Age Moderate the Association Between MEFS Performance and Impairment?*

The MEFS by age interaction term was not significant for any variable, and the pattern of results remained the same as in the regression that did not include the MEFS by age interaction term.

Table 3. Descriptive Statistics by Severity and Informant.

	Neither rated symptoms *and* impairment		Only parent rated symptoms *and* impairment		Only teacher rated symptoms *and* impairment		Both rated symptoms *and* impairment	
Measure	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)
MEFS	110	99.1 (10.4)	18	95.8 (12.4)	19	91.6 (8.2)	6	88.5 (13.4)
Parent								
Overall school	104	3.2 (0.9)	17	4.7 (0.5)	19	3.9 (0.7)	6	4.8 (0.4)
Reading	102	3.0 (1.2)	17	4.5 (0.7)	19	3.6 (0.5)	6	4.8 (0.4)
Writing	105	3.5 (0.9)	18	4.7 (0.5)	19	3.8 (0.5)	6	4.5 (0.5)
Mathematics	101	3.0 (1.0)	16	4.0 (1.0)	19	3.3 (1.0)	6	4.7 (0.5)
Rel. with parent	106	2.6 (1.2)	18	3.3 (1.3)	15	2.2 (1.2)	6	2.5 (1.0)
Rel. with siblings	100	2.8 (1.1)	16	3.4 (1.3)	15	2.5 (1.1)	5	2.2 (0.8)
Rel. with peers	108	3.0 (1.0)	18	3.4 (1.2)	19	2.5 (1.1)	6	3.0 (1.1)
Organized activities	94	3.2 (1.0)	17	3.4 (1.4)	17	2.7 (1.1)	5	3.4 (0.9)
Teacher								
Reading	99	3.2 (1.1)	15	4.2 (0.8)	19	4.7 (0.5)	5	5.0 (0.0)
Math	99	3.2 (0.9)	12	3.9 (1.0)	17	4.6 (0.6)	5	4.8 (0.4)
Written expression	102	3.8 (0.9)	15	4.4 (0.7)	19	4.8 (0.4)	6	5.0 (0.0)
Rel. with peers	110	3.4 (1.0)	17	3.5 (0.7)	19	3.8 (1.1)	6	4.3 (0.8)
Following directions	110	4.2 (0.8)	17	4.3 (0.8)	19	4.9 (0.3)	6	4.8 (0.4)
Disrupting class	105	3.9 (1.2)	16	3.4 (1.4)	19	5.0 (0.2)	6	4.7 (0.8)
Assignment completion	106	3.8 (1.0)	17	4.1 (0.8)	19	4.8 (0.5)	6	4.5 (0.5)
Organizational skills	105	3.9 (0.9)	17	4.1 (0.8)	19	4.6 (0.8)	5	4.6 (0.5)

Note. MEFS = *Minnesota Executive Function Scale*; Rel. = relationship.

Research Question 4: *Do EF Deficits and Ratings of Academic, Social, and Classroom Behavior Functioning Differ as a Function of Informant/Severity?*

As can be seen in Table 3, the majority of children fell into the "neither parents nor teachers reported high symptoms and impairments" group, with very few children falling into the "both parents and teachers reported high symptoms and impairments" group. The relatively small sample size in the four groups precludes formal statistical analysis. However, it appears that the most severe group (i.e., both parents and teachers reported high symptoms and impairments) and the group rated as having high symptoms and impairments by only their teacher generally had the lowest MEFS scores. In addition, the most severe group also had the highest academic impairment scores by both parent and teacher report. Also, the least severe group had the highest MEFS scores.

Discussion

In the current study, we investigated the association between performance on the MEFS and parent and teacher ratings of performance in academic, social, and behavioral domains in children diagnosed with ADHD. This preliminary work is important as no studies have used the MEFS to explore this question in school-aged children (regardless of diagnosis). As hypothesized, above and beyond ADHD severity and age, poorer performance on the MEFS was uniquely associated with poorer performance ratings in the areas of reading, written expression, and math by teacher report, and parent ratings of worse performance in the overall school and reading domains. However, ADHD symptoms were more strongly associated with parent and teacher ratings of problematic social functioning and ratings of problematic classroom behaviors than MEFS performance. Age did not moderate these findings. Finally, although only a small percentage of the sample was rated as severely impaired by both their parent and teacher (3.9%), those students and those rated as severely impaired by only their teacher (12.4%) appeared to have the poorest MEFS performance. This suggests the MEFS, an independent measure of psychosocial functioning (i.e., independent from rater), may be a useful tool for interpreting informant differences (De Los Reyes et al., 2019). Replication is warranted given that this sample of ADHD children was relatively mild, the standardized coefficients for the MEFS were relatively small although statistically significant, and that there are many other factors that may contribute to the association between EF and academic, social, and behavioral functioning which were not available for this sample.

Research Question 1: *Is MEFS Performance Associated With Parent and Teacher Performance Ratings in Academic and Classroom Behavior Domains?*

Our hypothesis regarding EF being associated with greater academic impairment was supported; however, we did not find support for EF to be significantly associated with classroom behavior performance ratings. These findings add to a growing body of evidence indicating the importance of EF for academic performance in children with ADHD, over and above ADHD symptomatology (Biederman et al., 2004; Loo et al., 2007; Miller et al., 2012; Vexelman & Tannock, 2011). The fact that this relation was particularly observed in teacher performance ratings is important because teachers have a normative group to which to compare children, and therefore a good sense of whether a child's performance in a particular academic domain is problematic or not (Amador-Campos et al., 2006). Furthermore, teachers are able to observe student performance on a more comprehensive sample of academic content than that captured by a standardized achievement test (Kowalski et al., 2018). Therefore, their ratings can provide insight into the students' "teachability" or ability to succeed in the regular education classroom (Kowalski et al., 2018). Thus, the use of the Vanderbilt performance items yields clinically useful information from the teachers' perspective, particularly because these items have been shown to be associated with academic and learning problems (Langberg et al., 2010; Wolraich et al., 1998).

The fact that the MEFS provides a single score reflecting a combination of cognitive flexibility, working memory, and inhibition precludes investigation into which specific EF deficits contribute to academic impairment. However, there is no universality of EF deficits among individuals with ADHD (Roberts et al., 2017; Willcutt et al., 2005). Furthermore, most studies support the view that EF consists of related but separable components (Lee et al., 2013) and purport that a common mechanism (or mechanisms) underlies all EF processes (Miyake et al., 2000). Finally, a meta-analysis with typically developing children showed that the association between EF and achievement does not vary by age, measurement type, achievement measure, or measurement occasion (Jacob & Parkinson, 2015). Thus, the derivation of a single score capturing EF in domains known to be impaired in ADHD is not necessarily problematic. Relatedly, using a task-based measure of EF provides a direct measure of the constructs in question. Although behavioral ratings of EF have been argued to have higher ecological validity than performance-based measures of EF (Barkley & Fischer, 2011), a more recent review concluded that both provide important, non-redundant information (Toplak et al., 2013). More specifically, performance-based measures of EF can provide insight into the information processing systems in the brain, while ratings of daily-life EF provide more information about rational goal pursuit (Toplak et al., 2013). We speculate that the fact that MEFS scores, obtained in a structured context designed to optimize child performance, were specifically associated with academic performance ratings, after accounting for ADHD, provides evidence that the efficiency of cognitive processing is important for academic functioning. However, as we are unable to assess for causality given the cross-sectional nature of the sample, this hypothesis is tentative. It may also be that there is no causal relationship between MEFS performance and academic impairment, and that some other construct contributes to lower performance on the MEFS and in school.

These findings are consistent with other studies utilizing the MEFS and related tasks (e.g., *Dimensional Change Card Sort Task*) which have reported an association between EF and academic performance in typically developing children. For example, kindergarten MEFS performance uniquely predicted *Woodcock–Johnson Tests of Achievement, Third Edition*, Applied Problems subtest scores in the first grade, even after controlling for number sense (Hassinger-Das et al., 2014). A subsequent investigation with preschoolers replicated this finding (Prager et al., 2016), suggesting that poor performance on the MEFS is associated with deficits on quantitative reasoning tasks, including counting and story problems. Pre-admission MEFS performance has also been shown to predict kindergarten reading levels (Reflection Sciences, 2014–2016). No studies were found investigating this association in elementary or middle school–aged children.

These findings are also consistent with work showing that EF deficits are associated with reading, writing, and math deficits (Biederman et al., 2004; Loo et al., 2007; Miller et al., 2012; Rogers et al., 2011; Vexelman & Tannock, 2011) and with teacher ratings of school functioning (Diamantopoulou et al., 2007) in children with ADHD. The relations we observed for MEFS and academic impairment ratings held even after accounting for ADHD symptoms which suggests that children with ADHD may have specific cognitive deficits that impair academic skills in addition to the potential contributions of behavior to academic performance. This hypothesis is supported by a study showing that core deficits in EF were more associated with academic competence than with psychopathology (including inattention, impulsivity, and hyperactivity) in children with ADHD (Mattison & Mayes, 2012).

Our hypothesis that MEFS performance would be significantly associated with teacher-rated classroom behavior problems was not supported, with the exception of following directions, which was more strongly associated with ADHD. This suggests that classroom behavior problems are related to ADHD behaviors and not necessarily EF deficits, which are more associated with academic performance. It should be noted, however, that there is strong content

similarity between items (e.g., fails to finish work—ADHD symptom and assignment completion—performance item). Alternatively, the lack of association between MEFS performance and classroom behavior problem ratings may be related to the distinction between "cool" and "hot" EFs. Cool EFs are non-emotionally laden functions that are typically subserved by the dorsolateral prefrontal cortex, which has strong connections to the thalamus, basal ganglia, hippocampus, and association areas of the neocortex thought to be important for cognition (Zelazo & Muller, 2002). In contrast, hot EFs refer to the cognitive abilities needed for motivationally or emotionally salient decision making and goal setting (Zelazo & Muller, 2002). Imaging research suggests that these abilities are subserved by regions in the brain such as the orbitofrontal and ventromedial regions of the prefrontal cortex, which have connections to the amygdala and limbic system implicated in emotional processing (Phan et al., 2004). There is some research suggesting cool EF may be more related to academic achievement than hot EF (Brock et al., 2009), while hot EF may be more associated with emotion regulation and behavior (Calkins & Marcovitch, 2010). Thus, the lack of association may be related to our choice of EF measure; the MEFS would be considered a cool EF measure. Additional research using measures of both cool and hot EF is needed to confirm or refute this hypothesis.

Research Question 2: *Is MEFS Performance Associated With Parent and Teacher Social Performance Ratings?*

Our hypothesis that EF would be associated with social functioning was not supported. In fact, ADHD symptoms were more strongly associated with parent and teacher ratings of problematic social relationships and parent ratings of challenges with participating in organized peer activities. There is significant variability in the way in which social impairments are defined and measured, and this work suggests that ADHD symptoms impact parent and teacher perceptions of relationships with peers, parents, and siblings, more than EF deficits. Our findings are consistent with other studies that reported EFs did not mediate the relationship between ADHD and social adjustment as indexed by parent and teacher report (Biederman et al., 2004; Diamantopoulou et al., 2007; Huang-Pollock et al., 2009). Perhaps this is not surprising given that not all children with ADHD present with EF deficits, but most children with ADHD have social problems (Hoza, 2007; Hoza et al., 2005). The failure to find a significant association between EF and social functioning may also reflect that the Vanderbilt performance items (i.e., relationship with peers) are too global and do not capture the full range of behaviors important for social competence.

Research Question 3: *Does Age Moderate the Association Between MEFS Performance and Impairment?*

Although improvements in EF are expected in the 5- to 12-year-old age range (Best et al., 2009), we did not find evidence that age was a significant moderator. This may reflect that the MEFS generates a standardized, age-normed score using an algorithm which takes into account trends in EF development (Reflection Sciences, 2017). Alternatively, it may be that children with ADHD do not show the same rate of growth in EF as their typically developing peers. Certainly developmental delays in brain maturation, particularly in frontal regions, are known to be important for EF in children with ADHD (Shaw et al., 2006, 2007, 2008). Additional work is needed to evaluate the veracity of this hypothesis. Although age was not a significant moderator, we found effects of age in the multivariate regression such that younger children were rated as having more trouble with participation in organized activities by parents, as more likely to disrupt class by teachers, and to have problematic relationships with peers as rated by their parents and teachers than were older children.

Research Question 4: *Do EF Deficits and Ratings of Academic, Social, and Classroom Behavior Functioning Differ as a Function of Informant/Severity?*

Our exploration of whether MEFS performance varied as a function of informant and child severity showed that children rated by both parents and teachers as most symptomatic and severely impaired and children rated by only their teachers as most symptomatic and severely impaired had the lowest MEFS scores. This suggests that the most severe children as reported by both parent and teacher or teacher-only are more likely to have EF deficits associated with academic impairment. These findings are consistent with De Los Reyes et al.'s (2009) argument that informant discrepancies may be a marker for severity of dysfunction. Specifically, higher informant agreement is expected for children with more severe impairments, due to the increased likelihood that their disruptive behaviors are exhibited at higher frequencies and in more extreme forms that are more likely to be seen and rated by multiple informants. However, this conclusion is based on a very small sample and a qualitative inspection of tabulated data. If this pattern is replicated in a larger sample with formal statistics, such as the polynomial regression model suggested by Laird and De Los Reyes (2013) to investigate informant discrepancy hypotheses, the MEFS could be a valuable clinical tool to identify those children most at risk for academic impairment in the school setting. In addition, in cases where

parents and teachers do not agree, additional weight could be placed on the teacher ratings if a child's MEFS performance is also low. This is consistent with the Operations Triad theory espoused by De Los Reyes et al. (2019) which suggests that informant discrepancies can be meaningful if the informants' report is related to measures of other contracts identified a priori as supportive evidence of measure validity. They argue that if informant discrepancies yield systematic information about psychosocial domains, then magnitudes or levels of these discrepancies should covary with basic characteristics of both the constructs/domains assessed by informants' reports as well as the context where informants observe behavior. Given that EF deficits are clearly associated with academic performance in ADHD (Biederman et al., 2004; Loo et al., 2007; Miller et al., 2012; Vexelman & Tannock, 2011), it may not be surprising that both MEFS performance and academic performance ratings were worse in the "only teachers reported high symptoms and impairments" subgroup. Again, replication is needed given the very small sample size in these groups.

Limitations

These findings must be interpreted in the context of study limitations. Because data were derived from a clinic registry, there was limited information available regarding the sample other than basic demographics. We did not have objective measures of functional impairment such as grades for assessing academic impairment or standardized measures of academic performance, nor did we have information on IQ, learning disability status, or utilization of special education services. The sample had relatively low rates of comorbidity; thus, these results may not be generalizable to children with comorbid diagnoses who are often characterized as having increased severity of academic and social impairment (Booster et al., 2012; DuPaul et al., 2018; Reid et al., 2015). However, it should be noted that even children characterized as having mild ADHD (via latent class analysis) still demonstrate significant academic problems, and that educational and cognitive disabilities in ADHD are not accounted for by comorbidities (Todd et al., 2002). In addition, no information was available about parent education, environmental stimulation within the home and neighborhood, community resources, and many other factors likely to directly influence children's EF development and academic performance. Also, we did not have a control group, which precludes our ability to investigate whether these findings are unique to children with ADHD. Finally, although our findings are consistent with the EF literature, the amount of variance explained in the multivariate regression and the standardized coefficients reported in Table 2 are relatively small, which suggests additional factors may be important to consider in understanding the association between EF and academic performance.

Implications for Practice

The findings of this study suggest that adding a performance-based measure of EF may have clinical utility in the diagnostic process for ADHD. Our data show that poor EF is associated with worse academic performance ratings, particularly for children who are seen as more severely symptomatic and impaired by both parents and teachers. These results also suggest that the MEFS may be a useful tool for screening children for EF deficits, although additional investigation on the psychometrics and predictive validity of the MEFS is needed. While constituting too small of a proportion of our sample to allow for statistical analysis, the descriptive finding that the lowest MEFS scores were obtained by children who were rated as having the most severe levels of ADHD symptoms and impairments by both their parent and teacher or by only their teacher suggests that MEFS scores may be useful in interpreting discrepancies between parent and teacher ratings (i.e., those children with the poorest MEFS performance are more likely to exhibit impaired behaviors in the school context reflected in teachers' academic performance ratings). However, further research using larger samples that allow for statistical analysis of informant discrepancies is needed to determine whether inclusion of the MEFS into clinical assessments of ADHD is warranted. If these results are replicated, it may be important for children who have impaired EF as measured by the MEFS to be more closely assessed for academic impairment and to receive targeted treatments as necessary (e.g., academic tutoring and classroom behavioral interventions).

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References

Achenbach, T. (1991). *Integrative guide for the 1991 CBCL/4-18, YSR, & TRF profiles*. University of Vermont Department of Psychiatry.

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology*, *106*(1), 20–29. https://doi.org/10.1016/j.jecp.2009.11.003

Amador-Campos, J. A., Forns-Santacana, M., Guardia-Olmos, J., & Pero-Cebollero, M. (2006). DSM-IV attention deficit hyperactivity disorder symptoms: Agreement between informants in prevalence and factor structure at different ages. *Journal of Psychopathology & Behavior Assessment*, *28*(1), 23–32. https://doi.org/10.1007/s10862-006-4538-x

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, *8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724

Antonini, T. N., Kingery, K. M., Narad, M. E., Langberg, J. M., Tamm, L., & Epstein, J. N. (2016). Neurocognitive and behavioral predictors of math performance in children with and without ADHD. *Journal of Attention Disorders*, *20*(2), 108–118. https://doi.org/10.1177/1087054713504620

Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual Reviews in Psychology*, *63*, 1–29. https://doi.org/10.1146/annurev-psych-120710-100422

Bard, D. E., Wolraich, M. L., Neas, B., Doffing, M., & Beck, L. (2013). The psychometric properties of the Vanderbilt attention-deficit hyperactivity disorder diagnostic parent rating scale in a community population. *Journal of Developmental and Behavioral Pediatrics*, *34*(2), 72–82. https://doi.org/10.1097/DBP.0b013e31827a3a22

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Barkley, R. A. (2005). *ADHD and the nature of self control*. Guilford Press.

Barkley, R. A., & Fischer, M. (2011). Predicting impairment in major life activities and occupational functioning in hyperactive children as adults: Self-reported executive function (EF) deficits versus EF tests. *Developmental Neuropsychology*, *36*(2), 137–161. https://doi.org/10.1080/87565641.2010.549877

Barry, T. D., Lyman, R. D., & Klinger, L. G. (2002). Academic underachievement and attention-deficit/hyperactivity disorder: The negative impact of symptom severity on school performance. *Journal of School Psychology*, *40*(3), 259–283. https://doi.org/10.1016/S0022-4405(02)00100-0

Beck, D. M., Schaefer, C., Pang, K., & Carlson, S. M. (2011). Executive function in preschool children: Test-retest reliability. *Journal of Cognitive Development*, *12*(2), 169–193. https://doi.org/10.1080/15248372.2011.563485

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, Series B*, *57*, 289–300. https://doi.org/10.1111/j.2517-6161.1995.tb02031.x

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review*, *29*(3), 180–200. https://doi.org/10.1016/j.dr.2009.05.002

Biederman, J., Monuteaux, M. C., Doyle, A. E., Seidman, L. J., Wilens, T. E., Ferrero, F., Morgan, C. L., & Faraone, S. V. (2004). Impact of executive function deficits and attention-deficit/hyperactivity disorder (ADHD) on academic outcomes in children. *Journal of Consulting and Clinical Psychology*, *72*(5), 757–766. https://doi.org/10.1037/0022-006X.72.5.757

Booster, G. D., DuPaul, G. J., Eiraldi, R., & Power, T. J. (2012). Functional impairments in children with ADHD: Unique effects of age and comorbid status. *Journal of Attention Disorders*, *16*(3), 179–189. https://doi.org/10.1177/1087054710383239

Brock, L. L., Rimm-Kaufman, S. E., Nathanson, L., & Grimm, K. J. (2009). The contributions of "hot" and "cool" executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly*, *24*(3), 337–349. https://doi.org/10.1016/j.ecresq.2009.06.001

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology*, *33*(3), 205–228. https://doi.org/10.1080/87565640801982312

Calkins, S. D., & Marcovitch, S. (2010). Emotion regulation and executive functioning in early development: Integrated mechanisms of control supporting adaptive functioning. In S. D. Calkins & M. A. Bell (Eds.), *Child development at the intersection of emotion and cognition* (pp. 37–58). American Psychological Association.

Carlson, S. M. (Ed.). (2003). Executive function in context: Development, measurement, theory, and experience. *Monographs of the Society for Research in Child Development*, *68*(3), 138–151.

Carlson, S. M., & Harrod, J. (2013, April). *Validation of the Executive Function Scale for early childhood* [Paper symposium presentation]. Biennial Meeting of the Society for Research in Child Development, Seattle, WA.

Carlson, S. M., & Zelazo, P. D. (2014). *Minnesota Executive Function Scale: Test manual*. Reflection Sciences.

Chernick, M. R. (2011). *Bootstrap methods: A guide for practitioners and researchers* (Vol. 619). John Wiley.

Chiang, H. L., & Gau, S. S. (2014). Impact of executive functions on school and peer functions in youths with ADHD. *Research in Developmental Disabilities*, *35*(5), 963–972. https://doi.org/10.1016/j.ridd.2014.02.010

Ciairano, S., Visu-Petra, L., & Settanni, M. (2007). Executive inhibitory control and cooperative behavior during early school years: A follow-up study. *Journal of Abnormal Child Psychology*, *35*(3), 335–345. https://doi.org/10.1007/s10802-006-9094-z

Cirino, P. T., & Willcutt, E. G. (2017). An introduction to the special issue: Contributions of executive function to academic skills. *Journal of Learning Disabilities*, *50*(4), 355–358. https://doi.org/10.1177/0022219415617166

Clark, C., Prior, M., & Kinsella, G. (2002). The relationship between executive function abilities, adaptive behaviour, and academic achievement in children with externalising behaviour problems. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *43*(6), 785–796. https://doi.org/10.1111/1469-7610.00084

Collins, A., & Koechlin, E. (2012). Reasoning, learning, and creativity: Frontal lobe function and human decision-making. *PLOS*

Biology, *10*(3), Article e1001293. https://doi.org/10.1371/journal.pbio.1001293

Daley, D., & Birchwood, J. (2010). ADHD and academic performance: Why does ADHD impact on academic performance and what can be done to support ADHD children in the classroom? *Child: Care, Health, and Development*, *36*(4), 455–464. https://doi.org/10.1111/j.1365-2214.2009.01046.x

De Los Reyes, A., Cook, C. R., Gresham, F. M., Makol, B. A., & Wang, M. (2019). Informant discrepancies in assessments of psychosocial functioning in school-based services and research: Review and directions for future research. *Journal of School Psychology*, *74*, 74–89. https://doi.org/10.1016/j.jsp.2019.05.005

De Los Reyes, A., Henry, D. B., Tolan, P. H., & Wakschlag, L. S. (2009). Linking informant discrepancies to observed variations in young children's disruptive behavior. *Journal of Abnormal Child Psychology*, *37*(5), 637–652. https://doi.org/10.1007/s10802-009-9307-3

De Weerdt, F., Desoete, A., & Roeyers, H. (2013). Working memory in children with reading disabilities and/or mathematical disabilities. *Journal of Learning Disabilities*, *46*(5), 461–472. https://doi.org/10.1177/0022219412455238

Diamantopoulou, S., Rydell, A. M., Thorell, L. B., & Bohlin, G. (2007). Impact of executive functioning and symptoms of attention deficit hyperactivity disorder on children's peer relations and school performance. *Developmental Neuropsychology*, *32*(1), 521–542. https://doi.org/10.1080/87565640701360981

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Duan, N. (1983). Smearing estimate: A nonparametric retransformation method. *Journal of the American Statistical Association*, *78*(383), 605–610. https://doi.org/10.1080/01621459.1983.10478017

DuPaul, G. J., McGoey, K. E., Eckert, T. L., & VanBrakle, J. (2001). Preschool children with attention-deficit/hyperactivity disorder: Impairments in behavioral, social, and school functioning. *Journal of the American Academy of Child & Adolescent Psychiatry*, *40*(5), 508–515. https://doi.org/10.1097/00004583-200105000-00009

DuPaul, G. J., Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2018). Eight-year latent class trajectories of academic and social functioning in children with attention-deficit/hyperactivity disorder. *Journal of Abnormal Child Psychology*, *46*(5), 979–992. https://doi.org/10.1007/s10802-017-0344-z

Enders, C. K. (2010). *Applied missing data analysis*. Guilford Press.

Enders, C. K., Du, H., & Keller, B. T. (2020). A model-based imputation procedure for multilevel regression models with random coefficients, interaction effects, and nonlinear terms. *Psychol Methods*, *25*(1), 88–112. https://doi.org/10.1037/met0000228

Frick, P. J. (2000). Laboratory and performance-based measures of childhood disorders: Introduction to the special section. *Journal of Clinical Child Psychology*, *29*(4), 475–478. https://doi.org/10.1207/S15374424JCCP2904_2

Graham, J. W. (2012). *Missing data: Analysis and design*. Springer.

Hassinger-Das, B., Jordan, N. C., Glutting, J., Irwin, C., & Dyson, N. (2014). Domain-general mediators of the relation between kindergarten number sense and first-grade mathematics achievement. *Journal of Experimental Child Psychology*, *118*, 78–92. https://doi.org/10.1016/j.jecp.2013.09.008

Hoza, B. (2007). Peer functioning in children with ADHD. *Journal of Pediatric Psychology*, *32*(6), 655–663. https://doi.org/10.1093/jpepsy/jsm024

Hoza, B., Mrug, S., Gerdes, A. C., Hinshaw, S. P., Bukowski, W. M., Gold, J. A., Kraemer, H. C., Pelham, W. E., Jr., Wigal, T., & Arnold, L. E. (2005). What aspects of peer relationships are impaired in children with attention-deficit/hyperactivity disorder? *Journal of Consulting and Clinical Psychology*, *73*(3), 411–423. https://doi.org/10.1037/0022-006X.73.3.411

Huang-Pollock, C. L., Mikami, A. Y., Pfiffner, L., & McBurnett, K. (2009). Can executive functions explain the relationship between Attention Deficit Hyperactivity Disorder and social adjustment? *Journal of Abnormal Child Psychology*, *37*(5), 679–691. https://doi.org/10.1007/s10802-009-9302-8

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, *44*(11), 2017–2036. https://doi.org/10.1016/j.neuropsychologia.2006.01.010

Jacob, R., & Parkinson, J. (2015). The potential for school-based interventions that target executive function to improve academic achievement: A review. *Reviews in Educational Research*, *85*(4), 512–552. https://doi.org/10.3102/0034654314561338

Kharamin, S., Malekzadeh, M., Khabazi, J., & Khabazi, R. (2018). Psychometric properties of Iranian version of Vanderbilt ADHD Teacher Rating Scale (VADTRS). *Journal of Research in Medical and Dental Science*, *6*(5), 1–6.

Kofler, M. J., Alderson, R. M., Raiker, J. S., Bolden, J., Sarver, D. E., & Rapport, M. D. (2014). Working memory and intra-individual variability as neurocognitive indicators in ADHD: Examining competing model predictions. *Neuropsychology*, *28*(3), 459–471. https://doi.org/10.1037/neu0000050

Kofler, M. J., Harmon, S. L., Aduen, P. A., Day, T. N., Austin, K. E., Spiegel, J. A., Irwin, L., & Sarver, D. E. (2018). Neurocognitive and behavioral predictors of social problems in ADHD: A Bayesian framework. *Neuropsychology*, *32*(3), 344–355. https://doi.org/10.1037/neu0000416

Kofler, M. J., Rapport, M. D., Bolden, J., Sarver, D. E., Raiker, J. S., & Alderson, R. M. (2011). Working memory deficits and social problems in children with ADHD. *Journal of Abnormal Child Psychology*, *39*(6), 805–817. https://doi.org/10.1007/s10802-011-9492-8

Kowalski, K., Brown, R. D., Pretti-Frontczak, K., Uchida, C., & Sacks, D. F. (2018). The accuracy of teachers' judgments for assessing young children's emerging literacy and math skills. *Psychology in the School*, *55*, 997–1012. https://doi.org/10.1002/pits.22152

Laird, R. D., & De Los Reyes, A. (2013). Testing informant discrepancies as predictors of early adolescent psychopathology: Why difference scores cannot tell you what you want to know and how polynomial regression may. *Journal of Abnormal Child Psychology*, *41*(1), 1–14. https://doi.org/10.1007/s10802-012-9659-y

Langberg, J. M., Vaughn, A. J., Brinkman, W. B., Froehlich, T., & Epstein, J. N. (2010). Clinical utility of the Vanderbilt ADHD Rating Scale for ruling out comorbid learning disorders. *Pediatrics*, *126*(5), e1033–e1038. https://doi.org/10.1542/peds.2010-1267

Lee, K., Bull, R., & Ho, R. M. (2013). Developmental changes in executive functioning. *Child Development*, *84*(6), 1933–1953. https://doi.org/10.1111/cdev.12096

Lefevre, J. A., Berrigan, L., Vendetti, C., Kamawar, D., Bisanz, J., Skwarchuk, S. L., & Smith-Chant, B. L. (2013). The role of executive attention in the acquisition of mathematical skills for children in Grades 2 through 4. *Journal of Experimental Child Psychology*, *114*(2), 243–261. https://doi.org/10.1016/j.jecp.2012.10.005

Loo, S. K., Humphrey, L. A., Tapio, T., Moilanen, I. K., McGough, J. J., McCracken, J. T., Yang, M. H., Dang, J., Taanila, A., Ebeling, H., Jarvelin, M. R., & Smalley, S. L. (2007). Executive functioning among Finnish adolescents with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *46*(12), 1594–1604. https://doi.org/10.1097/chi.0b013e3181575014

Lunt, L., Bramham, J., Morris, R. G., Bullock, P. R., Selway, R. P., Xenitidis, K., & David, A. S. (2012). Prefrontal cortex dysfunction and "jumping to conclusions": Bias or deficit? *Journal of Neuropsychology*, *6*(1), 65–78. https://doi.org/10.1111/j.1748-6653.2011.02005.x

Mattison, R. E., & Mayes, S. D. (2012). Relationships between learning disability, executive function, and psychopathology in children with ADHD. *Journal of Attention Disorders*, *16*(2), 138–146. https://doi.org/10.1177/1087054710380188

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology*, *43*(4), 947–959. https://doi.org/10.1037/0012-1649.43.4.947

Meuwissen, A. S. (2017, October). *The psychometrics of the Minnesota Executive Function Scale*. Strengthening the Measurement Toolbox: Development and Validation of Technology-based Executive Function and Cognitive Assessments Biennial Meeting of the Society for Research in Child Development, Austin, TX.

Miller, M., & Hinshaw, S. P. (2010). Does childhood executive function predict adolescent functional outcomes in girls with ADHD? *Journal of Abnormal Child Psychology*, *38*(3), 315–326. https://doi.org/10.1007/s10802-009-9369-2

Miller, M., Nevado-Montenegro, A. J., & Hinshaw, S. P. (2012). Childhood executive function continues to predict outcomes in young adult females with and without childhood-diagnosed ADHD. *Journal of Abnormal Child Psychology*, *40*(5), 657–668. https://doi.org/10.1007/s10802-011-9599-y

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Monette, S., Bigras, M., & Guay, M. C. (2011). The role of the executive functions in school achievement at the end of Grade 1. *Journal of Experimental Child Psychology*, *109*(2), 158–173. https://doi.org/10.1016/j.jecp.2011.01.008

Narad, M. E., Garner, A. A., Peugh, J. L., Tamm, L., Antonini, T. N., Kingery, K. M., Simon, J. O., & Epstein, J. N. (2015). Parent-teacher agreement on ADHD symptoms across development. *Psychological Assessment*, *27*(1), 239–248. https://doi.org/10.1037/a0037864

Nigg, J. T., Willcutt, E. G., Doyle, A. E., & Sonuga-Barke, E. J. (2005). Causal heterogeneity in attention-deficit/hyperactivity disorder: Do we need neuropsychologically impaired subtypes? *Biological Psychiatry*, *57*(11), 1224–1230. https://doi.org/10.1016/j.biopsych.2004.08.025

Olsen, M. K., & Schafer, J. L. (2001). A two-part random-effects model for semicontinuous longitudinal data. *Journal of the American Statistical Association*, *96*(454), 730–745. https://doi.org/10.1198/016214501753168389

Paxton, P., Curran, P. J., Bollen, K. A., & Kirby, J. (2001). Monte Carlo experiments: Design and implementation. *Structural Equation Modeling*, *8*, 287–312. https://doi.org/10.1207/S15328007SEM0802_7

Pelham, W. E., Jr., Fabiano, G. A., & Massetti, G. M. (2005). Evidence-based assessment of attention deficit hyperactivity disorder in children and adolescents. *Journal of Clinical Child & Adolescent Psychology*, *34*(3), 449–476. https://doi.org/10.1207/s15374424jccp3403_5

Phan, K. L., Wager, T. D., Taylor, S. F., & Liberzon, I. (2004). Functional neuroimaging studies of human emotions. *CNS Spectrums*, *9*(4), 258–266. https://doi.org/10.1017/s1092852900009196

Polderman, T. J., Boomsma, D. I., Bartels, M., Verhulst, F. C., & Huizink, A. C. (2010). A systematic review of prospective studies on attention problems and academic achievement. *Acta Psychiatrica Scandinavica*, *122*(4), 271–284. https://doi.org/10.1111/j.1600-0447.2010.01568.x

Prager, E. O., Sera, M., & Carlson, S. M. (2016). Executive function and magnitude skills in preschool children. *Journal of Experimental Child Psychology*, *147*, 126–139. https://doi.org/10.1016/j.jecp.2016.01.00

Preston, A. S., Heaton, S. C., McCann, S. J., Watson, W. D., & Selke, G. (2009). The role of multidimensional attentional abilities in academic skills of children with ADHD. *Journal of Learning Disabilities*, *42*(3), 240–249. https://doi.org/10.1177/0022219408331042

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individuals difference, and cognitive approaches. *Learning and Individual Differences*, *20*, 110–122. https://doi.org/10.1016/j.lindif.2009.10.005

Reflection Sciences. (2014–2016). *Prediction of admissions measures to kindergarten reading level: Report to Marymount School*. https://reflectionsciences.com/wp-content/uploads/2020/03/MEFS-Tech-Report_January-2020.pdf

Reflection Sciences. (2017). *Minnesota Executive Function Scale technical report*. https://reflectionsciences.com/wp-content/uploads/2018/11/MEFS-Tech-Report-October-2017-v.12.pdf

Reid, A. M., Graziano, P. A., McNamara, J. P. H., Paneto, A., & Geffken, G. R. (2015). Functional impairment differences among youth with ADHD: The role of comorbid anxiety and

mood disorders. *Journal of Nature and Science*, *1*(1), Article e31.

Rinsky, J. R., & Hinshaw, S. P. (2011). Linkages between childhood executive functioning and adolescent social functioning and psychopathology in girls with ADHD. *Child Neuropsychology*, *17*(4), 368–390. https://doi.org/10.1080/09297049.2010.544649

Roberts, B. A., Martel, M. M., & Nigg, J. T. (2017). Are there executive dysfunction subtypes within ADHD? *Journal of Attention Disorders*, *21*(4), 284–293. https://doi.org/10.1177/1087054713510349

Rogers, M., Hwang, H., Toplak, M., Weiss, M., & Tannock, R. (2011). Inattention, working memory, and academic achievement in adolescents referred for Attention Deficit/Hyperactivity Disorder (ADHD). *Child Neuropsychology*, *17*(5), 444–458. https://doi.org/10.1080/09297049.2010.544648

Sayal, K. (2008). Attention deficit hyperactivity disorder is associated with poorer academic performance. *Evidence-based Mental Health*, *11*(2), 41–41. https://doi.org/10.1136/ebmh.11.2.41

Shanahan, M. A., Pennington, B. F., & Willcutt, E. W. (2008). Do motivational incentives reduce the inhibition deficit in ADHD? *Developmental Neuropsychology*, *33*(2), 137–159. https://doi.org/10.1080/87565640701884238

Shaw, P., Eckstrand, K., Sharp, W., Blumenthal, J., Lerch, J. P., Greenstein, D., Clasen, L., Evans, A., Giedd, J., & Rapoport, J. L. (2007). Attention-deficit/hyperactivity disorder is characterized by a delay in cortical maturation. *Proceedings of the National Academy of Sciences, United States of America*, *104*(49), 19649–19654. https://doi.org/10.1073/pnas.0707741104

Shaw, P., Kabani, N. J., Lerch, J. P., Eckstrand, K., Lenroot, R., Gogtay, N., Greenstein, D., Clasen, L., Evans, A., Rapoport, J. L., Giedd, J. N., & Wise, S. P. (2008). Neurodevelopmental trajectories of the human cerebral cortex. *Journal of Neuroscience*, *28*(14), 3586–3594. https://doi.org/10.1523/JNEUROSCI.5309-07.2008

Shaw, P., Lerch, J., Greenstein, D., Sharp, W., Clasen, L., Evans, A., Giedd, J., Castellanos, F. X., & Rapoport, J. (2006). Longitudinal mapping of cortical thickness and clinical outcome in children and adolescents with attention-deficit/hyperactivity disorder. *Archives of General Psychiatry*, *63*(5), 540–549. https://doi.org/10.1001/archpsyc.63.5.540

Spira, E. G., & Fischel, J. E. (2005). The impact of preschool inattention, hyperactivity, and impulsivity on social and academic development: A review. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *46*(7), 755–773. https://doi.org/10.1111/j.1469-7610.2005.01466.x

Talbott, E., Karabatsos, G., & Zurheide, J. L. (2018). Informant similarities, twin studies, and the assessment of externalizing behavior: A meta-analysis. *Journal of School Psychology*, *67*, 31–55. https://doi.org/10.1016/j.jsp.2017.09.004

Thorell, L. B. (2007). Do delay aversion and executive function deficits make distinct contributions to the functional impact of ADHD symptoms? A study of early academic skill deficits. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *48*(11), 1061–1070. https://doi.org/10.1111/j.1469-7610.2007.01777.x

Todd, R. D., Sitdhiraksa, N., Reich, W., Ji, T. H., Joyner, C. A., Heath, A. C., & Neuman, R. J. (2002). Discrimination of DSM-IV and latent class attention-deficit/hyperactivity disorder subtypes by educational and cognitive performance in a population-based sample of child and adolescent twins. *Journal of the American Academy of Child & Adolescent Psychiatry*, *41*(7), 820–828. https://doi.org/10.1097/00004583-200207000-00014

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *54*(2), 131–143. https://doi.org/10.1111/jcpp.12001

Tseng, W. L., & Gau, S. S. (2013). Executive function as a mediator in the link between attention-deficit/hyperactivity disorder and social problems. *Journal of Child Psychology & Psychiatry*, *54*(9), 996–1004. https://doi.org/10.1111/jcpp.12072

Vexelman, C., & Tannock, R. (2011). *Impact of working memory deficits on academic achievement in adolescents with attention-deficit/hyperactivity disorder (ADHD)* (Publication Number 18087). The University of Toronto. http://hdl.handle.net/1807/18087

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry*, *57*(11), 1336–1346. https://doi.org/10.1016/j.biopsych.2005.02.006

Wolraich, M. L., Bard, D. E., Neas, B., Doffing, M., & Beck, L. (2013). The psychometric properties of the Vanderbilt attention-deficit hyperactivity disorder diagnostic teacher rating scale in a community population. *Journal of Developmental and Behavioral Pediatrics*, *34*(2), 83–93. https://doi.org/10.1097/DBP.0b013e31827d55c3

Wolraich, M. L., Feurer, I. D., Hannah, J. N., Baumgaertel, A., & Pinnock, T. Y. (1998). Obtaining systematic teacher reports of disruptive behavior disorders utilizing DSM-IV. *Journal of Abnormal Child Psychology*, *26*, 141–152. https://doi.org/10.1023/a:1022673906401

Wolraich, M. L., Lambert, W., Doffing, M. A., Bickman, L., Simmons, T., & Worley, K. (2003). Psychometric properties of the Vanderbilt ADHD diagnostic parent rating scale in a referred population. *Journal of Pediatric Psychology*, *28*, 559–567. https://doi.org/10.1093/jpepsy/jsg046

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*, 297–301. https://doi.org/10.1038/nprot.2006.46

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives*, *6*(4), 354–360. https://doi.org/10.1111/j.1750-8606.2012.00246.x

Zelazo, P. D., & Muller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (pp. 445–469). Blackwell.