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Executive Function Deficits in Adolescents With ADHD: Untangling Possible Sources of Heterogeneity

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Abstract

Deficits in executive function (EFDs) are thought to be the mechanisms that underlie a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD). However, prior research has indicated that EFDs are not uniform throughout the ADHD population and it is not clear what factors lead to individual variability in EF abilities. The current study was conducted to (a) elucidate the possible presence of unique patterns in EFDs and (b) identify potential risk factors for clinically significant EFDs. A sample of 256 young adolescents were comprehensively assessed and diagnosed with ADHD, and parents completed the Behavior Rating Inventory of Executive Function (BRIEF). Latent profile analysis (LPA) was conducted to elicit individual-level patterns of ratings across the eight clinical scales of the BRIEF. Chi-square analyses and regression models were also conducted to determine whether ADHD presentation, gender, or comorbid psychopathology was associated with the profiles elicited in the LPA. LPA results demonstrated a consistent trend in relative EF strengths and weaknesses, with patterns differing primarily in the intensity of deficits. Females with ADHD and adolescents with ADHD Combined Presentation or comorbid Oppositional Defiant Disorder exhibited more severe patterns of EFDs based upon group comparisons and regression models. ADHD may be associated with a consistent pattern of relative strengths and weaknesses in EF, although several important factors appear associated with an increased risk of more severe EFDs. These findings carry important clinical implications for the assessment of ADHD in adolescence.

Keywords

attention-deficit/hyperactivity disorder, executive functioning, adolescence, latent profile analysis

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most prevalent childhood disorders and commonly persists into adolescence (Visser et al., 2014). Adolescents with ADHD frequently experience significant impairment in their academic and interpersonal functioning (DuPaul & Langberg, 2014; Hoza, 2007) and considerable research has documented the impact of ADHD symptoms on daily functioning. In addition, a rapidly growing body of research has focused on additional factors that contribute to the academic and social/emotional difficulties of youth with ADHD. One of the more commonly studied factors to date is executive functioning (EF). At the group level, youth with ADHD exhibit significant deficits in aspects of EF (i.e., EFDs), such as working memory, inhibition, and planning/organization abilities (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). These specific abilities have been repeatedly associated with the impairment experienced by youth with ADHD, even when accounting for the effect of ADHD symptoms. Meta-analyses show that moderate-sized group differences in EF abilities are commonly observed between ADHD and non-ADHD samples; however, EFDs are not universal within the ADHD population (Willcutt et al., 2005). Very little is known about the intraindividual patterns of EF abilities within ADHD. EF encompasses a range of distinct cognitive processes, and individuals tend to exhibit unique patterns of personal strengths and weaknesses. Accordingly, the present study evaluates how specific EF abilities vary within adolescents with ADHD using latent profile analysis (LPA) to elicit patterns. In addition, this study evaluates whether membership in identified subgroups of adolescents with ADHD (Combined presentation, females, and comorbid psychopathology) is associated with specific patterns of EFDs.

Executive Function and Adolescence

EF is an umbrella term that broadly refers to the cognitive processes necessary to complete goal-directed behavior (Pennington & Ozonoff, 1996). Included under the EF

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umbrella is an array of specific skills, and major theoretical models each provide slightly different approaches to organizing the skills into a cohesive model. For example, Miyake et al. (2000) proposed that EF abilities are best classified into three factors: mental shifting, response inhibition, and updating of information. P. Anderson (2002) proposed a four-factor solution: attentional control, cognitive flexibility, goal-setting, and information processing. Despite the different classification systems, the majority of theoretical models contain many of the same specific cognitive abilities, such as inhibition, planning, self-monitoring of behavior, and working memory. In addition, it is important to note that most theoretical models emphasize the integrative nature of EF; that is, goal-directed behavior is the result of *both* the functioning of specific abilities and the successful cooperation of these abilities.

Adolescence is considered a particularly vital period for the development of EF abilities. The onset of adolescence brings a secondary exuberance of synaptic generation and subsequent pruning in the frontal lobe, and particularly the prefrontal cortex, which is the primary brain area associated with EF (Blakemore & Choudhury, 2006). Functionally, adolescents begin to exhibit adult-level performance on tasks measuring working memory, inhibition, and planning skills (V. A. Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Luna, Garver, Urban, Lazar, & Sweeney, 2004). The maturation of EF in adolescence is paired with increased academic and social demands on these skills in adolescents' daily lives as they transition to middle school (Jacobson, Williford, & Pianta, 2011; Taylor, Barker, Heavey, & McHale, 2013).

Associations With EF and ADHD

Youth with ADHD have long been observed to exhibit EFDs throughout childhood and adolescence. A wealth of empirical evidence indicates broad group differences in EF between samples of youth with and without ADHD (for a review, see Seidman, 2006). Research within adolescent-specific populations is available, but scarce compared to research with younger children or youth in general (Martel, Nikolas, & Nigg, 2007; Scheres et al., 2004; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997). The most consistent EFDs observed in youth with ADHD are in working memory, inhibition, and planning/organization abilities (Willcutt et al., 2005). These specific abilities have been repeatedly associated with the impairment experienced by youth with ADHD, even when accounting for the effect of core ADHD symptoms (Kofler et al., 2017; Langberg, Dvorsky, & Evans, 2013; M. Rogers, Hwang, Toplak, Weiss, & Tannock, 2011). Further, both ADHD symptoms and EFDs frequently persist into adulthood (Halperin, Trampush, Miller, Marks, & Newcorn, 2008). These findings closely align with many of the prominent theories regarding the etiology of ADHD, which propose that the symptoms of ADHD are largely driven by deficits in EF abilities (Barkley, 1997; Pennington & Ozonoff, 1996; Sergeant, 2000).

Although group-level comparisons between adolescents with ADHD and typically developing adolescents are important, they may fail to fully capture heterogeneity of EF within ADHD and the complex relationship between ADHD and EFDs. For example, Willcutt and colleagues'(2005) meta-analysis found that although moderate-sized group differences in EF abilities are commonly observed between ADHD and non-ADHD samples, EFDs are not universal within the ADHD population. Overall, reported prevalence of EFDs within ADHD samples varies widely, depending on the nature of the sample and definition of EF (e.g., Biederman et al., 2004 = 33%; Lambek et al., 2010 = 54%). When Nigg, Willcutt, Doyle, and Sonuga-Barke (2005) used a low threshold of impaired performance on any one of seven neuropsychological tasks to define the presence of an EFD, they still found that only 79% of the sample met the EFD criteria. While this suggests that EFDs are prevalent in ADHD, a significant portion of youth with ADHD do not appear to have clinically significant deficits. These findings have led to alternative theories about the relationship between ADHD and EFDs which posit that although EFDs are related to ADHD symptoms, they are not the primary cause of the disorder (Coghill, Hayward, Rhodes, Grimmer, & Matthews, 2014; Halperin & Schulz, 2006). Importantly, they also suggest that the observed heterogeneity in EFDs may be attributable to biological or environmental factors other than the severity of core ADHD symptoms.

Limits in Current Understanding of EF Heterogeneity in ADHD

Although the current evidence base clearly indicates that youth with ADHD are more impaired in their EF abilities than youth without ADHD at the group level, very little is known about the intraindividual patterns of EF abilities within adolescents with ADHD. EF encompasses a range of distinct cognitive processes, and individuals tend to exhibit unique patterns of personal strengths and weaknesses that have been shaped by their individual biological and environmental factors. Theories positing that ADHD is a result of EFD would hypothesize that individuals with the disorder should demonstrate a relatively consistent pattern of personal strengths and weaknesses. Specifically, youth with ADHD would exhibit consistent deficits in the EF abilities that lead to the manifestation of ADHD symptoms. Therefore, although adolescents with ADHD may be expected to show differences in the *intensity* of their EFDs (just as they show varying severity of ADHD symptoms), they should show similar patterns of personal deficits (i.e., some EF abilities should be consistently weaker than others across all individuals with the disorder). Previous research with neuropsychological tasks points toward working memory, response inhibition, and planning/organization skills as the most frequently impaired in individuals with ADHD (Martel et al., 2007; Scheres et al., 2004; Willcutt et al., 2005). In contrast, if EFDs are not the primary cause of the disorder and are instead a distinct condition related to ADHD, individuals within the full ADHD population would be expected to show multiple patterns of EF abilities that could be distinguished from one another. These unique patterns would be the result of a variety of factors distinct from ADHD symptoms that have their own influences on the development of EF. In summary, understanding the individual patterns of cognitive abilities that adolescents with ADHD exhibit across the EF domain may provide valuable insights into the major theories regarding the nature of the EF–ADHD relationship.

In addition to identifying the common intraindividual patterns of EFDs in ADHD, it is also important to understand which youth are at an increased risk of exhibiting clinically significant EF deficits. Prior research has identified several factors related to ADHD and other relevant forms of psychopathology that may increase an individual's risk to exhibit EFDs. Further, previous group comparison data have indicated that these factors are associated with deficits in distinct subdomains of the broader EF construct. For example, individuals diagnosed with ADHD–Combined Presentation, but not youth diagnosed with Inattentive Presentation, tend to exhibit poorer response inhibition and planning skills in comparison with typically developing youth (Klorman et al., 1999; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002; O'Driscoll et al., 2005). In addition, two thirds of youth with ADHD have at least one comorbid mental health disorder, and some comorbid conditions are associated with unique patterns of EFDs (Larson, Russ, Kahn, & Halfon, 2011). Oppositional Defiant Disorder (ODD), for example, is associated with deficits in working memory and inhibition (Hobson, Scott, & Rubia, 2011; Rhodes, Park, Seth, & Coghill, 2012). Adolescents with ADHD are also at an increased risk for internalizing psychopathology (i.e., anxiety or depression), and individuals with internalizing disorders have demonstrated impaired working memory and cognitive flexibility compared with nondisordered youth (L. D. Evans, Kouros, Samanez-Larkin, & Garber, 2016; Han et al., 2016; M. A. Rogers et al., 2004).

Finally, gender differences may be a nonpsychopathology factor that warrants exploration. Arguments have been made that males and females exhibit different behavioral presentations of ADHD, which may include differences in EF abilities, although there is conflicting evidence suggesting which gender experiences greater impairment (Gaub & Carlson, 1997; Rucklidge, 2010). In typically developing samples, the available data suggest that females' EF abilities may begin to mature more rapidly than males' abilities in adolescence (V. A. Anderson et al., 2001). Therefore, one might expect to observe the same trends in adolescents with ADHD. However, females with ADHD tend to exhibit greater impairment than males with ADHD when both are compared with their nondisordered peers (Elkins, Malone, Keyes, Iacono, & McGue, 2011). This difference in impairment may be at least partly due to increased EFDs in females.

Current Study

The present study was designed to address some of the above noted limitations regarding the nature of EFDs in adolescents with ADHD. Specifically, this study sought to determine what patterns of specific EFDs are most commonly observed in adolescents with ADHD and to identify factors associated with particular patterns. Although the current literature contains many group-level comparisons of EF abilities between ADHD and non-ADHD samples, this study examined how specific abilities varied within individual participants with ADHD, and to our knowledge this is one of the first studies to examine EF abilities in adolescents with ADHD in this way. LPA was used to elicit the prevailing patterns of EF abilities in our sample. LPA is a technique that can identify subgroups of individuals that are similar to one another based upon a large set of related variables (e.g., specific cognitive abilities within the broad EF construct). A secondary study aim evaluated whether membership in identified subgroups of adolescents with ADHD (Combined presentation, females, and comorbid psychopathology) was associated with an increased risk for EFDs, and whether subgroup membership was associated with specific patterns of EFDs. It was hypothesized that individuals within the identified subgroups would be more likely to exhibit EFDs. Further, it was hypothesized that the factors associated with subgroup membership (e.g., ADHD symptoms, ODD symptoms, internalizing symptoms) would be significantly associated with EFDs beyond the influence of general intelligence and stimulant medication when included together in a regression model.

Method

Participants

The final sample included 256 adolescents (ages 11–15, *M* age = 12.0 years ± 1.07 years) in Grades 5 through 8 from seven middle schools in the eastern United States comprehensively diagnosed with ADHD. Participants were recruited over three consecutive years as part of a larger study focused on evaluating school-based interventions to improve the academic functioning of youth with ADHD; all data for the current study were collected during baseline (i.e., preintervention) evaluations. A total of 74% of the sample was male, and the distribution of participant sex did not significantly differ across ADHD presentations (χ^2 = .017, p = .89). Within this sample, 56% identified as Caucasian, whereas 32% identified as Black/African American, 11% identified as multiracial, and the remaining participants identified with another race or declined to report their race. The majority of participants (60%) met criteria for ADHD–Primarily Inattentive presentation (ADHD-I), with the remainder meeting criteria for Combined presentation (ADHD-C). As expected, both presentations exhibited high levels of inattentive symptoms according to parent report on a semistructured interview (ADHD-I: M symptoms = 7.9 ± 1.11, range = 4–9; ADHD-C: M symptoms = 8.34 ± 1.02, range = 4–9). The presentations did demonstrate differences in the presence of hyperactive/impulsive symptoms, which would be expected (ADHD-I: M symptoms = 2.08 ± 1.52, range = 0–5; ADHD-C: M symptoms = 6.80 ± 1.30, range = 4–9). Fifty-six percent of the sample was taking medication for ADHD at the time of the initial evaluation, with the majority taking stimulant medication (90.7% of medicated participants). In addition, 30% of the sample met *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*) criteria for ODD, 23% met criteria for Social Phobia, Generalized Anxiety Disorder, or Separation Anxiety Disorder, and 5% met criteria for Major Depressive Disorder or Dysthymic Disorder.

Procedure

All study procedures were approved by the research institution's Institutional Review Board prior to the start of the study. All participants were recruited from local middle schools using recruitment flyers describing ADHD symptoms generally. Caregivers who expressed interest were scheduled to complete an in-person evaluation. The evaluation consisted of a semistructured interview administered to parents and adolescents, brief cognitive and academic screening, and completion of several rating scales by adolescents, parents, and teachers. Information from the structured interview, behavior rating scales from parents and teachers, and the cognitive/academic screening were interpreted by a team of licensed clinical psychologists and advanced doctoral students in clinical psychology. The ADHD diagnostic procedure was based upon protocols used in previous studies of youth with ADHD (e.g., the Multimodal Treatment of ADHD study; MTA Cooperative Group, 1999). Specifically, a diagnosis required the endorsement of at least six symptoms within a single domain (i.e., inattention or hyperactivity/impulsivity), persistence of symptoms with an onset age of 7 or earlier, and presence of the impairment across multiple life domains (e.g., home, school, peer interactions). Although participants with comorbid diagnoses were included in the study, individuals were excluded if their symptoms of inattention and/or hyperactivity/impulsivity were better attributed to their comorbidities. In addition, participants were required to demonstrate an estimated full-scale intelligence quotient (FSIQ) of 80 or greater on a two-subtest administration (Block Design and Vocabulary) of the Wechsler Intelligence Scale for Children–Fourth Edition (Wechsler, 2003). All participants met full *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM-IV*-TR; American Psychiatric Association, 2000) diagnostic criteria for ADHD-Inattentive Presentation or Combined Presentation, and teacher report of symptoms on the Vanderbilt ADHD Questionnaire (Wolraich et al., 2003) were used to help determine presentation. Specifically, a teacher report could supplement a parent report if (a) both parent and teacher endorsed at least four symptoms within the same domain and (b) the combined parent and teacher report indicated the presence of at least six unique symptoms in that domain. Comorbid diagnoses were made using an either/or criterion; if either parent-report or self-report indicated the presence of a comorbid disorder, then the participant received the diagnosis. See (Smith et al., 2016) for further details regarding recruitment and evaluation of participants.

In addition, EF for each participant was assessed using the Behavior Rating Inventory of Executive Function (BRIEF), a widely used rating scale with normative data for adolescents (Gioia, Isquith, Guy, & Kenworthy, 2000). It is important to note that the BRIEF was not used by the diagnostic decision team for any diagnoses, which reduces the likelihood that particular patterns of scores from the BRIEF were confounded with formal clinical diagnoses. A total of 268 participants completed the BRIEF; however, additional screening of BRIEF ratings ensured internal validity of the data. Validity scales available on the BRIEF include an Inconsistency Scale and a Negativity Scale (Gioia et al., 2000). Data from 10 participants were excluded due to high Inconsistency scores, and data from two participants were excluded due to high Negativity scores. This resulted in a final sample of 258 participants for the current study.

Measures

Children's Interview for Psychiatric Syndromes–Parent Version (P-ChIPS). The P-ChIPS is a semistructured interview based on the *DSM-IV-TR* criteria of psychiatric conditions (Weller, Weller, Fristad, Rooney, & Schecter, 2000). The present study used the parent and child versions to assess whether participants met diagnostic criteria for a range of psychological disorders. Modules administered included ADHD, ODD, Conduct Disorder, Separation Anxiety, Social Phobia, Generalized Anxiety, Obsessive-Compulsive Disorder, Major Depressive Disorder, Dysthymic Disorder, and Mania. The P-ChIPS has previously demonstrated high convergent validity with other semistructured interviews and high interrater reliability (Fristad, Teare, Weller,

Weller, & Salmon, 1998). In addition to contributing to the formal diagnostic decisions made by the research team, individual symptom counts of inattention, hyperactivity/impulsivity, and ODD symptoms were used as continuous predictor variables in regression models.

BRIEF. The BRIEF is an 86-item measure designed to assess EF abilities (Gioia et al., 2000). Responses generate two index scores: the behavioral regulation index (BRI), which evaluates an individual's ability to appropriately inhibit and control behaviors and emotions and shift between tasks and environments, and the metacognition index (MI), which measures an individual's ability to self-manage and monitor one's own progress and performance. Further, these indices can be broken down into eight clinical scales. The Shift, Inhibit, and Emotion Control scales combine to make up the BRI, whereas the Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor scales generate the MI. For this study, the parent-report version was used to capture adolescent EFDs. Prior research has found good content and construct validity based upon expert review, as well as correlations between BRIEF scales and expected behavioral outcomes according to established behavior rating scales (e.g., Child Behavior Checklist, Teacher Report Form, and Conners' Rating Scale; Gioia et al., 2000). In addition, BRIEF ratings have shown statistically significant correlations with performance-based measures of executive functions, which offer additional support for the measure's construct validity (Roth, Isquith, & Gioia, 2014). However, these correlations are generally smaller in magnitude when compared with correlations of the BRIEF with behavior rating scales. The BRIEF also demonstrated good test–retest reliability (Roth et al., 2014). Internal consistency within the current study was adequate for the Initiate scale ($\alpha = .61$) and high across the remaining clinical scales (αs = .72–.92) and among the index scores (αs = .92–.95). Each clinical scale and index is represented by a *T*-score standardized by age and gender norms. Response patterns that result in *T*-scores at or above 65 have been suggested to indicate clinically significant impairment in that particular domain of EF abilities (Gioia et al., 2000).

Behavior Assessment System for Children, second edition (BASC-2). The BASC-2 is a broad-band measure of multiple positive and negative dimensions of adolescent behavior (Kamphaus & Reynolds, 2004). The present study used the self-report version to gain a measure of adolescent internalizing symptomatology. Two separate scales were used in the study: the 13-item Anxiety scale and the 12-item Depression scale. The BASC-2 calculates standardized *T*-scores for both of these scales. Prior work has demonstrated high test–retest and convergent validity, and the internal consistency was high within the current study (αs = .82–.88; Kamphaus & Reynolds, 2004). In the current study, data from the BASC were used to help determine formal clinical diagnoses, and the *T*-scores from the Anxiety and Depression scales were used as continuous predictor variables in regression models.

Analytic Plan

First, mean scores and standard deviations were calculated for the eight BRIEF clinical scales, the BRI, the MI, and Global Executive Composite (GEC). The proportion of participants with *T*-scores meeting or exceeding the clinical threshold of 65 as recommended by Gioia and colleagues (2000) was calculated for each of the scales. In addition, bivariate Pearson correlation coefficients were calculated for *T*-scores of each BRIEF subscale in comparison with the symptom severity in each ADHD symptom domain (16 total correlations). Second, an LPA was conducted using Mplus Version 7.1 to examine underlying patterns of EF deficits based upon BRIEF ratings. The eight clinical scales of the BRIEF were used as indicators to build the model. Adolescent estimated FSIQ and current ADHD medication status were included as covariates in the model. FSIQ was included due to evidence suggesting that FSIQ and EF abilities are significantly related constructs, meaning that some of the variance in EF profile membership could be accounted for by general intelligence (Mahone, Hagelthorn, et al., 2002). Similarly, medication status was included as a covariate given evidence suggesting that pharmacologic treatment of ADHD may result in improved EF abilities over time (Barnett et al., 2001; Mehta, Goodyer, & Sahakian, 2004). Given that neither of these constructs were of specific interest to this study, we elected to control for their influence on group membership status before making the group comparisons of interest for this study.

Five criteria were jointly used to determine the optimal number of profiles identified by the model: Akaike Information Criteria (AIC), sample size-adjusted Bayesian Information Criteria (saBIC), Entropy of the model, the Vuong-Lo-Mendell-Rubin Likelihood Ratio Test (VLRT), and the bootstrapped parametric likelihood ratio test (BLRT; Nylund, Asparouhov, & Muthén, 2007). A model is considered a better representation of the data if the AIC and saBIC values are smaller than the values for other models, and a model with k profiles is considered better fitting than a model with k-1 profiles if the likelihood ratio tests are significant. Entropy is a measure of how efficiently the elicited profiles classify participants, and values greater than 0.8 are considered acceptable. Each of these indicators has their own individual strengths and weaknesses, and rejecting a model based on a single criterion may be overly conservative. Therefore, a model was considered more representative of the data than a model with one fewer profiles if at least four of the five criteria indicated better model fit for that model.

Table 1. Descriptive Statistics for BRIEF–Parent Report, BASC-2, and Estimated FSIQ.

Scale	Range	*M* *T*-score or standard score (*SD*)	Percentage of sample with *T*-score ≥ 65
BRIEF			
Global executive composite	45–92	68.55 (9.04)	67.4
Indexes			
Behavior regulation index	37–94	61.84 (12.55)	38.8
Metacognition index	48–87	69.87 (8.21)	74.0
Clinical scales			
Inhibit	40–94	63.49 (13.94)	47.7
Shift	38–94	60.45 (12.85)	40.7
Emotion Control	36–91	56.86 (12.66)	24.0
Initiate	40–86	65.33 (8.68)	59.8
Working Memory	49–93	72.64 (8.90)	79.1
Plan/Organize	44–88	69.67 (8.62)	74.8
Organization of Materials	37–72	60.98 (8.61)	45.0
Monitor	40–91	65.67 (9.42)	54.3
BASC-2			
Depression	34–80	47.70 (10.44)	12.2
Anxiety	33–80	49.66 (11.09)	7.7
Estimated FSIQ	80–144	98.70 (13.07)	—

Note. BRIEF and BASC-2 mean scores are *T*-scores, FSIQ mean score is standard score. BRIEF = Behavior Rating Inventory of Executive Function; BASC-2 = Behavior Assessment System for Children, Second Edition; FSIQ = full-scale intelligence quotient.

Once the optimal model was identified, participants were classified into groups corresponding to the profiles based on their posterior probability values. After classification, the distribution of several subgroups of participants was evaluated using chi-square tests of independence. Specifically, the chi-square tests compared the distributions of females as well as participants with an ADHD-Combined diagnosis, comorbid ODD diagnosis, or comorbid internalizing diagnosis across the latent profiles. A significant chi-square test indicates that the distribution of participants in a particular subgroup (e.g., females) is not consistent with the distribution that would be expected by chance. Significant chi-square tests were followed up with post hoc analysis of the standardized residual values of each cell within the test. Standardized residual values greater than 2 suggest that more individuals than would be expected by chance were classified into a particular profile; values less than −2 suggest that fewer individuals than expected were classified into the profile.

Finally, two hierarchical multiple regressions were conducted to examine whether the variables assessed in the chi-square analyses predicted scores on either the MI or BRI of the BRIEF above and beyond estimated FSIQ and ADHD medication status. Continuous forms of the psychopathology variables (inattentive, hyperactive/impulsive, and ODD symptom counts from P-ChIPS, *T*-scores from the BASC-2 Depression and Anxiety scales) were used as independent variables in these models, with participant gender remaining dichotomous, and the bivariate correlations of the independent variables were examined to check for possible collinearity issues. The same two steps were used for building each hierarchical model. Estimated FSIQ and ADHD medication status were entered in the first step, and the psychopathology variables and participant gender were entered in the second step. In addition, the contribution of the individual predictor variables to the final model was examined. To safeguard against Type 1 error, the Bonferroni-Holm correction for multiple comparisons was used when determining statistical significance during examination of individual predictors (Holm, 1979).

Results

Descriptive Statistics and Bivariate Correlations

Descriptive statistics for the sample, including estimated FSIQ, BASC Anxiety/Depression *T*-scores, and BRIEF clinical scale and index *T*-scores are available in Table 1. Overall, the means and percentage of *T*-scores above the clinical cutoff indicate that EFDs were prevalent throughout the sample, but were not universal. At the broad index level, the sample exhibited greater deficits on the MI index than the BRI. This pattern is also reflected at the clinical scale level; the clinical scales comprising the BRI had three of the four lowest mean scores of all clinical scales, whereas clinical scales comprising the MI exhibited the four highest mean scores. It should also be noted that *T*-scores for the clinical scales comprising the BRI were more variable

Table 2. Bivariate Correlations Among ADHD Symptoms and BRIEF Clinical Scales.

BRIEF clinical scale	ADHD IA symptoms	ADHD HI symptoms
Inhibit	.225**	.685**
Shift	.109	.269**
Emotion Control	.149*	.294**
Initiate	.242**	.068
Working Memory	.370**	.146*
Plan/Organize	.420**	.064
Organization of Materials	.391**	.103
Monitor	.315**	.320**

Note. ADHD = Attention-Deficit/Hyperactivity Disorder; BRIEF = Behavior Rating Inventory of Executive Function; IA = Inattentive; HI = Hyperactive/Impulsive.
*$p < .05$. **$p < .001$. (for all correlations).

Table 3. Model Fit Statistics for Latent Profile Analysis Based on BRIEF Ratings.

Classes	AIC	ssaBIC	Entropy	VLMRT	BLRT
2	14,731	14,741	.869	.001	.001
3	14,612	14,626	.819	.216	.001
4	14,573	14,591	.794	.327	.001

Note. BRIEF = Behavior Rating Inventory of Executive Function; AIC = Akaike Information Criteria; ssaBIC = sample size-adjusted Bayesian Information Criteria; VLMRT = Vuong-Lo-Mendel Likelihood Ratio Test; BLRT = Bootstrapped Parametric Likelihood Ratio Test.

within this sample than for scales comprising the MI, as indicated by standard deviations 4 to 5 points higher across the scales.

The bivariate correlations between BRIEF subscales and ADHD symptom domains revealed modest to moderate correlations, and are presented in Table 2. For inattentive symptoms, Pearson correlation coefficients (r) demonstrated significant variability, ranging from .097 to .425. The correlation with Plan/Organize T-scores was strongest for inattentive symptoms. In the hyperactive/impulsive symptom domain, correlation coefficients were again variable, ranging from .073 to .686. T-scores from the Inhibit subscale were most strongly correlated with hyperactive impulsive symptoms. In summary, the bivariate correlations revealed that the BRIEF subscales were related to parent report of ADHD symptoms in both domains, but not strongly enough to consider that the BRIEF is simply a proximal measure of ADHD symptoms.

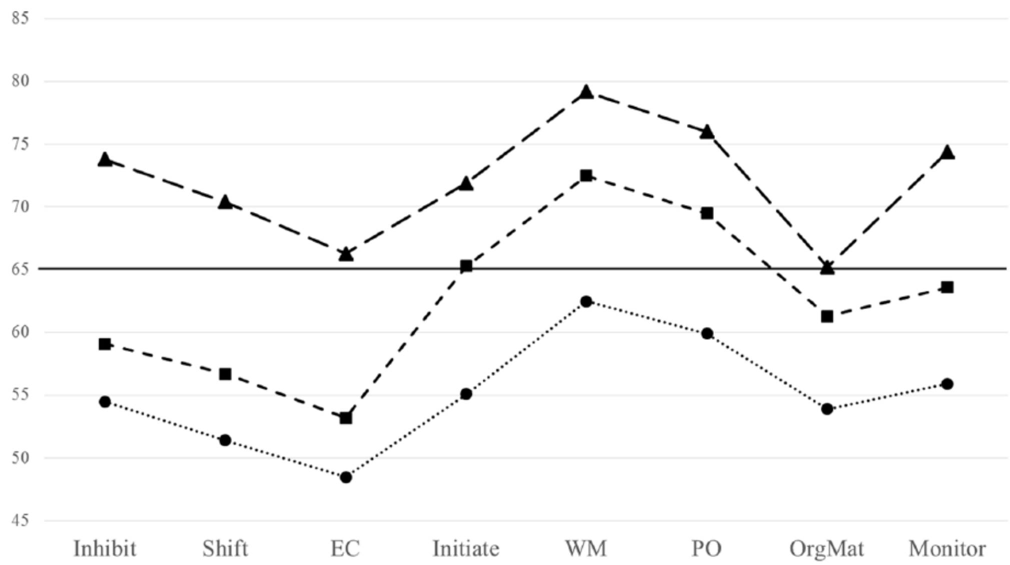
LPA

The model fit criteria for the two, three, and four-profile solutions are presented in Table 3. The three-profile solution was determined to be the optimal model due to two negative criteria for the four-class solution (VLRT and Entropy). The profiles are visually presented in Figure 1, along with the mean T-scores for the clinical scales for each profile. The profiles exhibited clear differences in the severity of overall EF deficits. The no-deficit profile (23% of sample) exhibited mean scores below the T-score clinical cutoff of 65 for all clinical scales. The MI-deficit profile (40% of sample) exhibited mean scores that were consistently higher for the five clinical scales contributing to the MI in comparison with the three clinical scales that make up the BRI. Further, several mean scores in the MI clinical scales were above the T-score clinical cutoff (Initiate, Working Memory, and Plan/Organize). The BRI/MI-deficit profile (37% of sample) exhibited mean scores that were above the recommended clinical cutoff for all clinical scales.

Although the profiles elicited in the model demonstrated clear differences in the intensity of EF deficits, they also exhibited very similar patterns of EF abilities in regard to the relative strengths and weaknesses within each profile. For example, the mean scores for the Working Memory and Plan/Organize scales were respectively the highest and second-highest mean scores for each profile. Similarly, the mean score for the Emotion Control scale was either the lowest or second-lowest mean score within each profile. Overall, these profiles suggest that the relative strengths and weaknesses in specific EF abilities are consistent across adolescents with ADHD, but that the intensity of the deficits can vary greatly.

Characteristics of Individuals Within Latent Profiles

The chi-square tests were statistically significant for all subgroup comparisons. More females than expected were classified in the BRI/MI-deficit profile ($\chi^2 = 21.31$, $p < .001$; standardized residual = 3.1) and fewer females than expected were classified in the no-deficit profile (standardized residual = −2.2). More adolescents with the Combined presentation were classified in the BRI/MI-deficit profile than expected by chance ($\chi^2 = 19.58$, $p < .001$; standardized residual = 2.7), whereas fewer adolescents than expected with a Primarily Inattentive presentation were classified in the same profile (standardized residual = −2.2). A similar pattern was found when comparing adolescents with or without a comorbid ODD diagnosis ($\chi^2 = 20.35$, $p < .001$), with more adolescents with ODD than expected classified in the BRI/MI-deficit profile (standardized residual = 2.9). The chi-square test was also significant when comparing individuals with or without a comorbid internalizing disorder ($\chi^2 = 6.16$, $p = .046$); however, the post hoc analysis of the standardized residuals revealed no classification patterns that were significantly abnormal in comparison with chance expectations.



	Inhibit	Shift	EC	Initiate	WM	PO	OrgMat	Monitor
No Deficit (23%)	54.5	51.4	48.5	55.1	62.5	59.9	53.9	55.9
MI Deficit (40%)	59.1	56.7	53.2	65.3	72.5	69.5	61.3	63.6
BRI/MI Deficit (37%)	73.8	70.4	66.3	71.9	79.2	76	65.2	74.4

Figure 1. Profiles elicited from optimal latent profile analysis model and sample means of clinical scales across profiles.
Note. Y-axis values and values within table are indicative of *T*-scores. X-axis labels correspond to one of eight clinical scales of the BRIEF. BRIEF = Behavior Rating Inventory of Executive Function; MI = metacognition index; BRI = behavior regulation index.

Predicting BRI and MI Scores

An examination of bivariate correlations revealed that no correlations exceeded r values of .7 (r values ranged = .017–.575), indicating no significant collinearity issues among the independent variables. For the hierarchical regression model predicting BRI scores, the full model accounted for a statistically significant portion of variance, $F(7, 250) = 48.48$, $R^2 = .58$, $p < .001$. Further, the variables added in the second step of the model accounted for a significant portion of the variance above and beyond FSIQ and ADHD medication status, $\Delta F(5, 250) = 59.77$, $\Delta R^2 = .51$, $p < .001$. When examining individual predictors, hyperactive/impulsive symptoms ($\beta = 0.45$, $p < .001$) and ODD symptoms ($\beta = 0.36$, $p < .001$) were the only individually significant predictors of BRI above and beyond FSIQ and current ADHD medication status. Specifically, higher levels of these symptoms predicted more EF deficits. For the model predicting MI scores, the full model again accounted for a statistically significant portion of variance, $F(7, 250) = 16.86$, $p < .001$, $R^2 = .25$, $p < .001$, and the second step of the model accounted for a significant portion of variance above and beyond the covariates, $\Delta F(5, 250) = 16.86$, $\Delta R^2 = .25$, $p < .001$. Hyperactive/impulsive symptoms ($\beta = 0.33$, $p < .001$) and gender ($\beta = 0.38$, $p < .001$) were the only individually significant predictors of MI in the final model, such that females were more likely to exhibit EF deficits than males.

Discussion

The current study sought to identify common patterns of EF deficits and to examine whether relevant subgroups of adolescents with ADHD were at an increased risk for EFDs. The results indicate that adolescents with ADHD exhibit a common pattern of EF abilities in regard to relative strengths and weaknesses, with differences mainly in intensity. Specifically, adolescents with ADHD were most likely to exhibit clinically significant deficits in the MI aspects of executive function (77% of the sample; see Figure 1). In contrast, only 37% of the sample exhibited clinically significant deficits in inhibition and emotional control. Further, females as well as adolescents with higher levels of hyperactive/impulsive symptoms and oppositional defiant behaviors were more likely to exhibit clinically significant patterns of EFDs.

The LPA was somewhat consistent with study hypotheses. Three profiles emerged, and different patterns of impairment were observed when considered in the context of recommended clinical cutoff scores for the BRIEF (no clinical deficits, clinical deficits along MI scales, and clinical deficits across all EF abilities). However, examining the three patterns together indicates a consistent pattern of personal strengths and weaknesses when comparing specific EF abilities within individuals. This finding carries theoretical significance, as it suggests that the heterogeneity of EF deficits often observed in general ADHD samples may be largely due to differences in the severity of the deficits overall, rather than due to unique patterns of EFDs. Theories of ADHD that emphasize the role of EFDs in the development of the disorder align most closely with these empirical findings (Barkley, 1997; Pennington & Ozonoff, 1996; Sergeant, 2000). Further, the specific skills exhibiting the most impairment across profiles in the LPA (i.e., working memory and planning/organization) are the same skills most consistently identified in group comparison studies focused on neuropsychological task performance (Gau, Chiu, Shang, Cheng, & Soong, 2009; Nigg et al., 2002; Willcutt et al., 2005). This strengthens the argument that the profiles elicited in the LPA are not spurious, but instead valid representations of EFDs within the sample. Taken together, the patterns elicited suggest that the manifestation of ADHD is characterized by comorbid personal weaknesses in working memory and planning skills in comparison with other EF abilities within an individual. However, it is important to distinguish that although the LPA findings highlight the consistency of personal weaknesses in specific EF abilities, they do not support the consistent presence of clinically significant impairment in these abilities. Consistent with previous findings (Willcutt et al., 2005), clinically significant EFDs were not universal in our sample, with 23% of participants captured by the latent profile exhibiting mean *T*-scores within the normal range on all subscales.

Findings from this study suggest that although ADHD is associated with a specific pattern of EFDs, certain factors contribute to the intensity with which this patterns manifests. Adolescents diagnosed with a Combined presentation appeared to be at a higher risk of deficits across the EF spectrum. These youth were more likely to be classified in the BRI/MI deficit profile, and the regression models indicated that adolescents with higher levels of hyperactivity/impulsivity symptoms exhibited increased deficits based upon both MI and BRI scores of the BRIEF. In contrast, higher levels of ODD symptoms demonstrated more specific associations with deficits in behavior regulation (i.e., inhibition, emotion control). In contrast, females were more likely to exhibit deficits in more abstract EF abilities, such as working memory and planning. Prior work with neuropsychological tasks has found similar differences in EFDs for individuals with the Combined presentation and comorbid ODD (Hobson et al., 2011; Nigg et al., 2002; O'Driscoll et al., 2005).

The EFDs associated with gender are more difficult to explain. Perhaps the best explanation, at least within the ADHD context, is that growing evidence indicates that females with ADHD tend to present a distinct clinical profile compared with males (Gaub & Carlson, 1997; Rucklidge, 2010). This profile includes exacerbated difficulties with working memory; and planning/organization abilities may be part of that unique clinical picture. Indeed, samples of females with ADHD have been consistently found to exhibit deficits in planning skills compared with typically developing females (Miller, Ho, & Hinshaw, 2012; Sami, Carte, Hinshaw, & Zupan, 2004). Alternatively, our findings could be an artifact of the "gender paradox" noted for many externalizing behavior disorders. This refers to the observation that although females are less frequently diagnosed with disruptive behavior disorders, such as ADHD, diagnosed females tend to exhibit greater functional impairment in comparison with their male counterparts (Elkins et al., 2011). Some have hypothesized that the impairment discrepancy is the result of diagnostic inaccuracy due to stereotyped expectations regarding psychopathology for each gender, leading to only the most severely impaired females receiving ADHD diagnoses (Loeber & Keenan, 1994). As such, it is possible that our sample is overrepresented by females with more impaired functioning overall.

The study findings also carry several implications for clinical practice and future research, especially in the assessment of ADHD. First, the differences between profiles in intensity—but not pattern of deficits—suggest that poor working memory and planning/organization abilities in relation to other domains of EF should be expected to accompany an ADHD diagnosis. Therefore, an individual who does not exhibit such a pattern may necessitate a stronger consideration for alternative diagnoses that may present with symptoms similar to ADHD (e.g., anxiety, learning disabilities). However, more variability exists in regard to deficits in other areas of EF, especially inhibition and emotion regulation. Further, higher levels of hyperactive/impulsive symptoms and ODD symptoms, which are common, were associated with more severe EFDs. Having an accurate accounting of an individual's possible EFDs has the potential to usefully inform treatment planning, as previous work has linked EFDs to impairment across academic and social domains for youth with ADHD (Kofler et al., 2017; Langberg et al., 2013; Tseng & Gau, 2013) and several behavioral interventions for ADHD target-specific facets of EF (e.g., planning/organization interventions; S. W. Evans et al., 2016; Langberg et al., 2018). In summary, an evidence-based evaluation of ADHD would potentially benefit from an EF screening—even a brief one—to guide both diagnostic and treatment decisions.

Another source of clinical and theoretical intrigue comes from the evidence that a significant portion of youth with ADHD may not exhibit clinically significant EFDs. Similar groups of youth with ADHD but without EFDs have been identified in studies using neuropsychological tasks, and a growing body of evidence suggests EFDs are not universally comorbid with the disorder (Biederman et al., 2004; Lambek et al., 2010; Willcutt et al., 2005). However, this group has received minimal attention in the literature. A greater understanding of these individuals may have a significant impact on the field's overall conceptualization of ADHD. Many fundamental theories of the disorder emphasize the role of a dysfunctional frontal lobe and EFDs in its manifestation, making it challenging for these theories to explain the presence of this profile. In a clinical context, this group may respond differently to intervention than youth with EFDs. For example, these individuals may experience less impairment in academic settings, where EF is especially important (Biederman et al., 2004; Langberg et al., 2013). Therefore, they may benefit from less-intensive interventions or accommodations at school than is often necessary for many students with ADHD. Conversely, a few studies have indicated that individuals with less-intense EFDs have weaker responses to pharmacological intervention, suggesting that it may not be a useful treatment option for these individuals (Hale, Fiorello, & Brown, 2005; Hale et al., 2011). Future work should seek to better understand how those without comorbid EFDs relate to the ADHD population overall.

Limitations

Some limitations should be considered in interpreting these findings. Importantly, the current study measured EF solely through the use of parent ratings and did not include the adolescent's perspective of their EF abilities or neuropsychological tasks that measure EF. This is important to note because rating scale measures of EF and EF task performance exhibit small to modest correlations (Toplak, West, & Stanovich, 2013). While neuropsychological tasks are often perceived as objective measures of cognitive abilities, they too have limitations in their methodology and clinical utility (Mahone, Cirino, et al., 2002; Miyake et al., 2000). Indeed, Toplak and colleagues (2013) argued that the two methods simply tap different aspects of EF and both are useful tools for assessing these abilities. Regardless, an important next step would be to attempt to replicate these profiles using task performance measures of EF. In addition, our finding that comorbid internalizing disorders did not significantly predict EFDs should be interpreted with caution in light of our use of the BASC, a broad screening measure that may not have been sufficiently sensitive to internalizing psychopathology. It is also important to note that all of these data were cross-sectional and as such, directionality of the associations between EFDs and the variables explored in the regression models cannot be inferred from these data. Finally, although we collected a sample of youth in the age range of early adolescence, we did not collect an explicit measure of individuals' pubertal development. Future work should examine whether the stage of pubertal development an adolescent is in is associated with their group membership status.

Conclusions

Findings from this study suggest that adolescents with ADHD exhibit a fairly consistent pattern of EFDs. Consistent with research using neuropsychological tasks, deficits in working memory and planning/organization were most common. Accordingly, the findings from this study suggest that the heterogeneity often cited as characteristic of EFDs in individuals with ADHD is primarily in the intensity of deficits, rather than in the overall pattern of strengths and weaknesses. Hypothesized risk factors for EFDs were significantly associated with EFDs in both LPA and regression models, such that females with ADHD, adolescents with a Combined presentation, and those with comorbid ODD might be especially vulnerable to high-intensity EFDs. Our findings contribute to and extend a growing body of research aimed at unpacking the heterogeneity in ADHD and EFDs. Finally, if replicated, our results may have important implications for the assessment of EFDs in youth with ADHD.

Authors' Note

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