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EXECUTIVE FUNCTIONS AS MODERATORS OF RESPONSE TO BEHAVIORAL  
INTERVENTIONS FOR ADOLESCENTS WITH ATTENTION-DEFICIT/HYPERACTIVITY  
DISORDER

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of  
Philosophy at Virginia Commonwealth University

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## Abstract

### EXECUTIVE FUNCTIONS AS MODERATORS OF RESPONSE TO BEHAVIORAL INTERVENTIONS FOR ADOLESCENTS WITH ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

Virginia Commonwealth University, 2019

Major Director: Joshua M. Langberg, Ph.D.  
Associate Professor  
Department of Psychology

Adolescents with Attention-Deficit/Hyperactivity Disorder (ADHD) experience significant academic impairment and multiple interventions have been developed to address common academic problems, such as difficulties with homework, organization, and planning skills. Given cost and resource constraints, research is needed on factors that mental health providers can use to select the most appropriate interventions. To date, there has been minimal research evaluating moderators of response to ADHD interventions. Further, many of the variables that have been studied do not have strong theoretical ties to the mechanisms of change invoked by the interventions. This study examined potential moderators of treatment response to two academic interventions for adolescents with ADHD: an organizational skills training intervention (HOPS) and a homework completion support intervention (CHIEF). Specifically, the study evaluated whether the cognitive skills known as executive functions (EF) moderate differential treatment response between the interventions. Results indicated that EF abilities were not consistently associated with differential treatment outcomes. Further, significant associations presented conflicting interpretations regarding which profiles of EF abilities were more responsive to HOPS in comparison to CHIEF.



## Executive Functions as Moderators of Response to Behavioral Interventions for Adolescents with Attention-Deficit/Hyperactivity Disorder

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by life impairment due to persistent difficulties along one or both of two symptom domains: inattention and hyperactivity/impulsivity (American Psychiatric Association, 2013; Biederman, 2005). Symptoms within the inattentive domain include trouble concentrating for extended periods of time, avoiding tasks that require sustained mental effort, and difficulties with organization and planning. Symptoms within the hyperactive/impulsive domain include excessive restlessness, impatience, and excessive talking and interrupting. ADHD is one of the most prevalent mental health disorders found during childhood, with recent estimates indicating that 7-9% of school-age children meet criteria for the disorder (Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014; Thomas, Sanders, Doust, Beller, & Giasziou, 2015). Although ADHD has a childhood onset, symptoms of ADHD frequently persist through adolescence and into adulthood, with 40% of individuals diagnosed in childhood still experiencing clinically significant symptoms and impairment (Holbrook et al., 2016; Sibley et al., 2017).

### **Etiology of ADHD**

Most theories regarding the etiology of ADHD suggest that it is the result of abnormal neural development, which is consistent with its classification as a neurodevelopmental disorder in the *DSM* (American Psychiatric Association, 2013). Most theories also posit that the behaviors and associated impairment exhibited by individuals with ADHD are attributable to underlying cognitive deficits and emphasize the role of the frontal lobe of the brain, particularly the prefrontal cortex (PFC), in the development of ADHD (Barkley, 1997; Halperin & Schulz, 2006; Rapport, Chung, Shore, & Isaacs, 2001; Sonuga-Barke, 2005). Researchers have theorized that

the PFCs of affected youth are chronically under-aroused, meaning that the neural circuits in this brain area do not fire as frequently for individuals with ADHD (Durstun et al., 2003; Quay, 1997). Indeed, neuroimaging studies have identified group-based differences in PFC neural activity between youth with ADHD and typically developing control subjects both in intensity of activity (Bush, Valera, & Seidman, 2005) and even in the rate of development of the PFC (Shaw et al., 2007). The PFC is one of the primary brain areas responsible for regulating a wide range of higher-order cognitive functions (Welsh, Pennington, & Groisser, 1991). Cognitive abilities commonly associated with the PFC include attention, working memory, inhibition, planning, and self-monitoring of behavior. Many of these abilities are considered to be part of a larger cognitive construct known as Executive Function (EF; Alvarez & Emory, 2006; Banich, 2009).

EF is broadly defined as the set of cognitive abilities responsible for engaging in goal-oriented behavior (Pennington & Ozonoff, 1996). Although significant debate exists regarding exactly which cognitive abilities are encompassed in the EF construct, the majority of theories include behavioral inhibition, working memory, task shifting, planning/organization skills, and self-monitoring of behavior (Anderson, 2002; Diamond, 2013). In what is now one of the most widely cited theories related to ADHD, Barkley (1997) proposed that the symptoms of ADHD are largely due to deficits in EF abilities. His theory posited an underlying deficit in a few particular abilities, including inhibition, working memory, planning, and initiation and self-monitoring of behavior. Other theories of ADHD propose that working memory is the core cognitive deficit within ADHD (Rapport et al., 2001). In general, however, these theories share a theme: deficits in cognitive abilities related to the broader construct of EF manifest in the negative behavioral outcomes that are exhibited by individuals with ADHD.

There is significant empirical evidence supporting the theory that ADHD is a manifestation of underlying deficits in EF abilities. For example, group comparison studies show that youth with ADHD exhibit poorer working memory, response inhibition, task shifting, and planning skills than typically developing youth (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002; Semrud-Clikeman, Walkowiak, Wilkinson, & Butcher, 2010). In typical development, the onset of adolescence brings a secondary exuberance of synaptic generation and subsequent pruning in the frontal lobe, including the PFC (Blakemore & Choudry, 2006; Bush, Valera, & Seidman, 2005; Selemon, 2013). Functionally, adolescents begin to exhibit adult-level performance on many of the cognitive abilities under the EF umbrella, although full maturation of all EF abilities does not generally occur until young adulthood (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Luna, Garver, Urban, Lazar, & Sweeney, 2004). However, despite this rapid development, adolescents with ADHD still exhibit poorer EF abilities than their peers (Martel, Nikolas, & Nigg, 2007; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997; Scheres et al., 2004).

### **Recent Advances in Understanding the ADHD-EF Connection**

Despite the popularity of the theory linking EF deficits to the presence of ADHD symptoms, and the wealth of evidence demonstrating group-level differences between individuals with ADHD and typically developing youth, the theory is not without its limitations. In particular, if EF deficits underlie ADHD this implies that they are universal within the disorder, but there is compelling evidence suggesting that this is not the case. Reported prevalence rates of EF deficits within ADHD samples vary widely, largely due to methodological differences in the measurement and definition of EF deficits. For example, Biederman and colleagues (2004) reported that 33% of their sample met criteria for EF deficits

based upon amalgamated performance across six neuropsychological tasks. In a separate sample of youth with ADHD, Lambek and colleagues (2010) reported that 54% exhibited EF deficits as defined by combined performance on eight neuropsychological tasks. Even when applying a low threshold of impaired performance on any one of seven neuropsychological tasks, EF deficits have not been found to be universal in youth with ADHD (79%; Nigg, Willcutt, Doyle, and Sonuga-Barke, 2005). Meta-analyses summarizing the empirical evidence on EF deficits in youth with ADHD conclude that although moderate-sized group differences in EF exist in comparing ADHD and non-ADHD samples, these deficits are not universal (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005).

A few theories have emerged that attempt to explain the observed heterogeneity of EF deficits within the ADHD population and offer alternative explanations for the relation between EF and ADHD symptoms. One theory, proposed by Halperin & Schulz (2006), argues that the onset of ADHD is not the direct result of atypical development only of the PFC, but rather multiple brain areas. They further posit that the overall development of the PFC may be a major compensatory mechanism that influences the impact of ADHD symptoms on daily functioning. A similar theory put forth by Sonuga-Barke (2005) emphasizes the role of neural pathways associated with reward and motivation, and proposes that EF deficits are one of several neurodevelopmental pathways that contribute to the manifestation of ADHD symptoms. Another theory, proposed by Coghill, Hayward, Rhodes, Grimmer, & Matthews (2014), suggests that EF deficits and ADHD symptoms share a common underlying biological mechanism but are influenced by different environmental factors. Coghill and colleagues' theory also proposes that EF deficits and ADHD symptoms both contribute to the impairments commonly exhibited by individuals with ADHD. Although these theories question the causal role of EF deficits in the

manifestation of ADHD symptoms, it is important to note that they all still imply a significant role for EF in the impairment exhibited by individuals with ADHD and suggest that EF abilities may be useful targets of intervention.

One additional consideration regarding the observed heterogeneity in EF abilities is the ambiguity surrounding the exact structure of the EF construct. Models of EF divide the specific cognitive processes contained within the broader construct in different ways. One popular classification system divides abilities into two domains: “hot” and “cool” EF processes (Zelazo & Carlson, 2012). “Hot” EF processes are those that manage in-the-moment behaviors, such as inhibition and emotion regulation. In contrast, “cool” EF processes are those oriented more towards future behaviors, such as planning, organization and self-monitoring of behavior. Other models use more narrowly-defined categories to organize the abilities encompassed by EF. For example, Anderson’s (2002) model of the development of EF contains four distinct subdomains: cognitive flexibility (e.g., shifting attention, working memory), behavioral regulation (e.g., inhibition, self-monitoring), information processing (e.g., fluency, processing speed), and goal setting (e.g., planning, organization). Still other models emphasize that EF abilities, while they contain several distinct cognitive processes, should be viewed as a unified construct (Miyake et al., 2000).

### **Impairment Associated with ADHD Symptoms and EF Deficits**

Although the underlying factors regarding the etiology of ADHD are still being debated, research has firmly linked the presence of clinically significant ADHD symptoms and EF deficits with an increased risk for impairment in a variety of life domains (e.g., academic, interpersonal, and employment) (Biederman & Faraone, 2006; DuPaul & Stoner, 2003; Wehmeier, Schacht, & Barkley, 2010). For youth with ADHD, impairment in school and academic functioning is

perhaps the most prevalent and persistent across time (for reviews, see DuPaul & Langberg, 2014; Loe & Feldman, 2007). On average, students with ADHD turn in fewer classwork and homework assignments and receive lower significantly lower grades in comparison to their peers (Frazier, Youngstrom, Glutting, & Watkins, 2007; Langberg et al., 2011; Power, Werba, Watkins, Angelucci, & Eiraldi, 2006). These academic impairments can have serious long-term consequences for educational success; individuals with ADHD are more likely to be retained a grade and are at greater risk of dropping out of school before earning their high school diploma (Bussing, Mason, Bell, Porter, & Garvan, 2010; Frazier et al., 2007).

Adolescence and the transition to middle school is a particularly important time for all students, and is a period of heightened vulnerability for students with ADHD (Langberg et al., 2008). In the United States, the middle school grades are associated with significantly increased expectations for students' to independently manage a variety of academic tasks. Middle school is often the first time that students interact with multiple teachers on a daily basis, with each teacher employing their own expectations and assignment workload. The transition to middle school is also associated with an increased number of long-term assignments, such as research projects and cumulative exams (Jacobson, Williford, Pianta, 2011; Taylor, Barker, Heavey, & McHale, 2013). Students must be able to keep track of assignments, develop a plan for completing work, gather the necessary materials and transition materials between school and home, and manage their time and extracurricular responsibilities effectively. In other words, the middle school environment requires that students are able to implement EF behaviors, such as setting short and long-term goals and self-monitoring and managing progress towards those goals.

Multiple studies have linked EF abilities with academic outcomes in students with ADHD, including academic achievement testing (Biederman et al., 2004; Rennie Beebe-Frankenberger, & Swanson, 2014), grade point average (Langberg, Dvorsky, & Evans, 2013), parent and teacher perceptions of academic functioning, (Kofler et al., 2016; Lambek et al., 2010; Langberg et al., 2013; Sjöwall & Thorell, 2014), grade retention (Biederman et al., 2004; Lambek et al., 2010), and the use of educational resources such as tutoring or special education classrooms (Lambek et al., 2010). Further, nearly all of the studies cited above found a significant relation between EF abilities and academic outcomes after controlling for the influence of general intelligence and ADHD symptoms. These associations have also been observed in longitudinal studies. For example, Miller, Nevado-Montenegro, and Hinshaw (2012) followed a sample of females with and without ADHD prospectively over 10 years to examine possible interaction effects between an ADHD diagnosis and EF abilities in predicting academic outcomes. They reported moderated associations, such that poorer EF abilities predicted poorer academic achievement and behavioral outcomes (i.e., school suspensions) for individuals with ADHD, but not for control participants.

### **EF and ADHD: Skills Deficit or Difficulties with Application?**

Although considerable evidence indicates a connection between EF abilities and academic impairment in youth with ADHD, it is unclear whether youth with ADHD truly have a deficit (lack the ability), or whether the problem is with application of EF abilities. This is an important distinction for intervention, and interestingly, is a debate the field had regarding social skills and ADHD almost 20 years ago which led to a paradigm shift for intervention efforts (Gresham, 1998). Several studies have observed that some groups of children with ADHD exhibit significant impairment in academic settings despite similar performance to their non-

disordered peers on neuropsychological tasks of attention and EF (Barry, Lyman, & Klinger, 2002; Swanson et al., 2000). Further, to date, interventions that have focused on remediating an EF deficit (e.g., cognitive or working memory training) have largely been ineffective (Chacko et al., 2013; Rapport, Orban, Kofler, & Friedman, 2013), whereas interventions focused on real world application of EF abilities are associated with significant improvement across a variety of academic outcomes (Abikoff et al., 2013; Langberg, Epstein, Becker, Girio-Herrera, & Vaughn, 2012). These empirical findings align with theories of ADHD emphasizing EF as a contributing factor, but not a unique one, to the development of symptoms and impairment associated with ADHD (Halperin & Schulz, 2006; Sonuga-Barke, 2005). Sonuga-Barke's (2005) multiple pathways model is particularly relevant, as it proposes that some youth with ADHD may experience difficulty with motivation or reward-sensitivity. In this framework, an adolescent with ADHD may have typically developed EF abilities, but still have difficulty applying their abilities in situations that are not immediately rewarding. In other words, this model suggests that although some individuals with ADHD may have an EF deficit, others may have the abilities but lack the motivation to apply them in real world settings. In summary, individuals with ADHD who exhibit EF related academic impairment may have: 1) a true underlying deficit in EF abilities, or 2) poor application of EF abilities to real-life tasks in an academic setting.

### **Interventions for ADHD Targeting Academic Impairment**

Given the high prevalence of ADHD and the variety of impairments these students encounter, it is not surprising that numerous interventions have been developed. Pharmacologic interventions – primarily psychostimulant medications – are one of the most common interventions for students with ADHD (Castle, Aubert, Verbrugge, Khalid, & Epstein, 2007). Stimulant medications' theorized mechanism of action is based on the chronic under-arousal of



the frontal lobe. Specifically, stimulants increase the rate of neural activity in the frontal lobe, which then leads to improved cognitive functioning (Arnsten, 2006; Volkow et al., 2003). Stimulant medication clearly reduces the frequency and intensity of some of the core symptoms of ADHD (for reviews, see Spencer, Biederman, & Wilens, 2000; Swanson et al., 1993). However, it is less clear that stimulant medication significantly reduces the academic impairment observed by youth diagnosed with the disorder (Evans et al., 2001; Langberg & Becker, 2012). Additionally, stimulant medication may be accompanied by adverse side effects, and as many as one in three youth do not exhibit a response to medication (Goldman, Genel, Bezman, & Slanetz, 1998; Graham & Coghill, 2008).

Several nonpharmacological interventions have also been developed. One group of interventions that has received a considerable amount of attention are EF training interventions. These interventions are designed to directly improve an individual's cognitive abilities, usually through the completion of computerized tasks. Theoretically, these interventions would lead to changes in the neural pathways associated with EF abilities, which would in turn allow an individual to use the abilities in the various settings of everyday life. Unfortunately, recent meta-analyses have called the efficacy of these interventions into question (Cortese et al., 2015; Rapport et al., 2013). Further, intervention studies that specifically examined academic outcomes have generally found small or nonsignificant effect sizes (Chacko et al., 2014; Elliot, Gathercole, Alloway, Holmes, & Kirkwood, 2010; Gray et al., 2012). In summary, these interventions do not yet appear to be a reasonable option for the treatment of ADHD.

Other nonpharmacological interventions utilize the principles of behavioral theory to address the academic impairments often associated with ADHD (for reviews, see Evans, Langberg, Egan, & Molitor, 2014; Raggi & Chronis, 2006). Some of these interventions, such as

daily behavior report cards, are designed to target disruptive classroom behaviors (e.g., leaving one's seat, blurting out) and are more commonly employed with younger children (McGoey, Eckert, & DuPaul, 2002; Raggi & Chronis, 2006). Interventions targeting adolescents with ADHD focus more on developing strategies and improving skills that are essential for completing classwork and homework in middle and high school. Most behavioral interventions include psychoeducation about the nature of ADHD, including its symptoms, its developmental course, and its relation to impaired daily functioning. Additionally, most behavioral interventions – especially those targeting academic impairment – include components that require collaboration of adults in the home (i.e., caregivers) and at school (i.e., teachers, counselors) in order to improve home-school communication and establish a unified approach to addressing a student's impairment.

Beyond these general components, academic interventions for adolescents with ADHD also typically include one or more skills training components. Given the large role that homework plays in most educational settings, the skills necessary for homework completion are frequently addressed. At least 94% of students in the United States report completing homework outside of school, and they spend an average of 9-11 hours per week on homework (Kalenkoski & Pabilonia, 2012; Wagner, Schober, & Spiel, 2008). Adolescents with ADHD often forget to record homework, procrastinate, lose assignments, and overall, turn in 15% fewer assignments on average in comparison to their peers (Langberg et al., 2011; Kent et al., 2011). Homework completion interventions for students with ADHD are designed to address these difficulties. Common strategies include the creation of a supportive, distraction-free physical environment for homework completion and establishment of clear expectations for homework completion behaviors (e.g., staying on-task, using effective studying methods). For example, the Family-

School Success program (Power et al., 2012) works with parents and teachers to ensure a reasonable amount of homework is assigned each day, establish a consistent location and time for completing homework, and develop a behavioral reward system that encourages students to set and achieve work completion goals each day. The Challenging Horizons Program (CHP; Evans et al., 2016) provides a structured homework completion time in an after-school program format, which reduces the homework burden that students face when they return home.

Although the actual completion of an assignment is a vital step, it is only a single point within the larger homework completion process. Adolescents with ADHD frequently show impairment in their ability to plan ahead and to organize their materials and behaviors, which negatively impacts their homework and academic performance (Langberg et al., 2011; Power et al., 2006). Therefore, several behavioral interventions, such as CHP, the Child Life and Attention Skills intervention (Pffner et al., 2014) and the Supporting Teens Academic Needs Daily intervention (Sibley et al., 2013) include organization and planning skills training as one component of their broader academic interventions. However, these skills are considered so vital to academic success, and are so frequently found to be impaired in youth with ADHD, that interventions have arisen that singularly focus on the development of these skills (see Bikic, Reichow, McCauley, Ibrahim, & Sukhodolsky, 2016 for a meta-analysis of organizational skills interventions). For example, Gallagher, Abikoff, & Spira's (2014) Organizational Skills Training (OST) intervention and the Homework, Organization, and Planning Skills (HOPS) intervention (Langberg, 2011) are interventions that specifically target these skills. Common organizational skills training components include the formalized use of a daily planner/agenda, the creation of a daily homework completion schedule, and the development of an organizational system for managing school materials.

It is important to note that homework interventions, and more specifically organizational skills training interventions, recognize the role of EF abilities in academic functioning. Planning and organization are two cognitive processes which are frequently considered as part of the broader EF construct (Anderson, 2002; Diamond, 2013). However, these interventions differ from cognitive training interventions because they place a greater emphasis on helping adolescents apply their underlying cognitive abilities in an everyday context. Behavioral reward systems are often employed to motivate students to apply the skills that they learn during instructional sessions, and the frequency of skills use is consistently tracked and reinforced. In other words, the presumed mechanism of change is through increased application of EF abilities to meaningful everyday tasks, rather than through the development of EF abilities.

### **Importance of Predicting Treatment Response**

Each of the behavioral interventions described above, as well as several other interventions that target adolescents with ADHD improve academic functioning (for a meta-analysis, see Daley et al., 2014). However, these behavioral interventions are not without their limitations. For example, interventions that attempt to address multiple aspects of academic functioning place a high training and resource burden on schools or community mental health providers that may make provision of the interventions less feasible (George, McDaniel, Michael, & Weist, 2014; Lever, Lindsey, O'Brennan, & Weist, 2014). In contrast, interventions that focus on a few distinct treatment components may be more feasible to implement. However, students risk missing out on skills or strategies that are targeted by other interventions and may be more effective in reducing their academic impairment. Mental health providers may offer multiple brief interventions, but administering multiple interventions to the same students leads to the same resource burden and feasibility concerns as the more intensive treatment. Therefore,

identifying students that are most likely to benefit from a particular intervention becomes critical to helping mental health providers efficiently use their intervention resources.

In response to this issue, clinical efficacy trials are often followed by studies examining factors that may help identify individuals who are most likely to benefit from a specific intervention. This line of research recognizes that although interventions are generally designed to be uniform and consistent, the individuals who receive interventions are heterogeneous and bring their own characteristics into the treatment process. Paul (1967, p. 111) offers a summary of the driving question in this field of research: “what treatment, by whom, is most effective for this individual with that specific problem, and under which set of circumstances?”

### **Approaches to Evaluating Treatment Response**

When testing variables that may be useful for predicting treatment response, researchers must choose from several analytic approaches. To a large extent, the analytic plan is guided by the design of the intervention study, and more specifically, how many treatments groups are used. In situations where a single group is used, analyses are confined to testing which variables predict more positive or negative treatment response within that treatment. Regression models offer the most straightforward analytic strategy. If a continuous treatment response variable (e.g., pre- to post-treatment change score) is used, then a linear regression model may suffice. If a dichotomous response (e.g., response vs. non-response) is used, then a logistic regression model would be a more appropriate choice.

If intervention study designs include more than one group, then more nuanced questions regarding treatment response can be asked. However, the usefulness of regression analyses in these study designs is limited, as they limit interpretation of results to the full sample. In practice, children and adolescents who receive mental health services are a heterogeneous population that

can be divided into multiple subgroups along a range of variables (e.g., sex, race/ethnicity, comorbid psychopathology, cognitive functioning). In recognition of this heterogeneity, researchers have called for an evaluation of *moderators* of treatment response (Kazdin & Kendall, 1998; March & Curry, 1998). A moderator refers to any variable that significantly influences the nature of the associations between an independent and dependent variable (Baron & Kenny, 1986). In treatment response research, moderator variables influence the relation between group assignment (e.g., active treatment vs. waitlist, treatment 1 vs. treatment 2) and intervention outcomes (Kraemer, Wilson, Fairburn, & Agras, 2002). Moderators of treatment response must also be measured before any group randomization occurs or intervention is provided (Hinshaw, 2007).

### **Moderators of Behavioral Treatment Response for Youth with ADHD**

To date, research on moderators of psychosocial treatment response for youth with ADHD has largely come from a single randomized control trial with young children (MTA Cooperative Group, 1999; 7 – 9 years old at baseline). ADHD symptom severity and ADHD diagnostic presentation are two intuitive moderator variables but findings have been mixed. Multiple studies have failed to find associations between symptom severity and treatment response (Langberg et al., 2016; Owens et al., 2003). Further, studies that have reported significant associations have indicated that more severe symptom levels are associated both with better (Tamm et al., 2014) and worse (Langberg et al., 2010) response to intervention. Comorbid psychopathology has also been examined as a moderator of treatment response. Rates of comorbidity, especially externalizing disorders such as Oppositional Defiant Disorder and Conduct Disorder, are high within the ADHD population (Larson, Russ, Kahn, & Halfon, 2011), and the presence of comorbid psychopathology in general has been associated with poorer

treatment response (Antshel & Remer, 2003; Jensen et al., 2001; van den Hoofdakker et al., 2010; Sibley, Smith, Evans, Pelham, & Gnagy, 2012). However, multiple studies have found that externalizing comorbidities do not moderate treatment response (Barkley, Guevremont, Anastopoulous, & Fletcher, 1992; Frankel, Myatt, Cantwell, & Feinberg, 1997; Pelham et al., 2000). Interestingly, presence of a comorbid anxiety disorder has been the most consistent moderator of treatment response, and it has generally been associated with more positive response to behavioral treatment when compared to individuals without comorbid anxiety (March et al., 2000; Swanson et al., 2007).

Demographic variables make up the remainder of commonly evaluated moderators of treatment response in the ADHD literature. For example, the impact of child sex has been evaluated in multiple studies. Males are more frequently diagnosed with ADHD than females (Willcutt, 2012), but females with ADHD tend to exhibit greater impairment than males with the disorder when compared to non-disordered peers (Elkins, Malone, Keyes, Iacono, & McGue, 2011). As with ADHD symptom severity and comorbid externalizing psychopathology, the moderating effects of sex have been quite variable and inconclusive. Multiple studies have found no significant associations between sex and treatment response (Mikami et al., 2010; Murray et al., 2008), and others have found that the moderating role of sex depends upon the treatment outcome of interest (Langberg et al., 2016; Mikami et al., 2012). Participant race has been minimally examined as a potential moderator of behavioral treatment, but one analysis using the MTA dataset noted that African American children demonstrated better treatment response to behavioral treatment than did White children and that Latino children exhibited better response to combined medication/behavioral intervention than to medication alone (Arnold et al., 2003). However, these associations were no longer significant after accounting for socioeconomic status

(SES). Other MTA analyses have examined SES as a treatment moderator, and reported both significant and nonsignificant associations with treatment response depending upon the measure of SES used (Owens et al., 2003; Rieppi et al., 2002).

### **Limitations of Current ADHD Treatment Response Literature**

Although some research suggests that psychopathology and demographic variables may moderate treatment response, the full body of evidence suggests that the relation between these variables and treatment response is inconsistent. Further, there is little data on moderators of response to behavioral intervention for adolescents with ADHD. This is partly due to the fact that the development of behavior interventions for adolescents is relatively new. A review of adolescent psychosocial interventions for ADHD identified only 22 new studies from 1999-2014, and only six of those studies were controlled trials (Sibley, Kuriyan, Evans, Waxmonsky, & Smith, 2014). Further, a review of evidence-based interventions for youth with ADHD presented by Evans, Owens, and Bunford (2013) noted that only 3 of 21 identified studies included analyses for moderators of treatment response. Therefore, it is not surprising that building the evidence base with high-quality treatment response studies has been repeatedly mentioned as a future direction for the field (Evans et al., 2013; Hinshaw, 2007).

As researchers seek to fill this gap in the literature, they must also be mindful of a significant conceptual limitation that has hampered the usefulness of treatment response studies. Specifically, studies examining treatment response in ADHD have lacked a theoretical approach to selecting potential moderator variables. Specifically, very few variables have been examined that are directly aligned with the proposed mechanisms of change embedded within a particular intervention. Kazdin (2000) noted that this was a problem throughout the psychosocial intervention literature, and multiple commentaries have noted this as a particular issue within the



ADHD behavior intervention literature (Hoza, Johnston, Pillow, and Ascough, 2006; Van der Oord et al., 2015). The lack of studies using intervention-specific theory to choose moderator variables likely contributes to the variable findings regarding ADHD symptom severity, comorbid psychopathology, and demographic variables.

Hoza and colleagues (2006) recognize and discuss the lack of a theoretical approach in the context of behavior parent training (BPT) interventions. They argue that the best candidate variables for treatment response studies should be directly linked to the theoretical mechanisms upon which an intervention is attempting to act. They then propose a model that outlines several theorized mechanisms targeted by BPT (e.g., parental cognitions, parenting efficacy) and propose that these should be the main focus of treatment response studies. Although the candidate moderator variables Hoza and colleagues proposed are not directly applicable to all interventions, the conceptual model provides a useful framework that can be adapted for other interventions.

### **Identifying Theoretical Moderators for Organizational Skills Interventions**

As discussed previously, academic interventions for adolescents with ADHD differ from one another mainly in the specific skills and strategies that they target. Organizational skills training programs such as the HOPS intervention seek to improve homework completion and academic outcomes by increasing the frequency of students' application of effective planning and organizational skills (Langberg et al., 2013). Based upon those hypothesized mechanisms, intervention-specific baseline moderators of treatment could include the underlying cognitive abilities that regulate planning and organization as well as students' application of those skills.

As noted previously, the cognitive processes that regulate planning and organizational abilities are included under the larger cognitive construct of EF. Therefore, measures of baseline

EF abilities could serve as useful moderator variables. Several methods for evaluating EF are available that may provide useful insights into an adolescent's functioning. Neuropsychological tasks were the first available measures of EF and are still the most commonly used measures of EF abilities in both research and clinical settings. Alternatively, rating scales of EF-related behaviors are also available. These rating scales, such as the Behavioral Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), ask respondents to rate how frequently an adolescent engages in a particular behavior that is thought to require some aspect of EF. Although these two methods were initially thought to measure the same aspects of EF, recent reviews have concluded that the two methods correlate only modestly with one another (Chan, Shum, Tuolopoulou, & Chen, 2008; Toplak, West, & Stanovich, 2013). Due to this discrepancy, researchers now view the methods as measuring complementary aspects of EF. They now propose that neuropsychological tasks provide a measure of an individual's underlying EF abilities in isolation, whereas ratings provide a measure of an individual's application of those abilities to real-world settings (Seidman, 2006; Toplak et al., 2013).

Given this conceptualization of EF measurement, both theoretical moderators of treatment response to organizational skills interventions (underlying cognitive abilities and baseline application of abilities) could be important. Relying solely on an EF rating scale raises a significant confound for studying treatment response. Specifically, a rating scale could indicate that an adolescent exhibits impairment in their use of EF abilities for two distinct reasons: 1) a true underlying deficit in the cognitive processes regulating EF, or 2) poor application of EF abilities despite otherwise normal EF abilities. In contrast, poor neuropsychological task performance can be more directly attributed to underlying deficits in the cognitive abilities that regulate EF.

As such, using EF data collected from both methods together as a single, holistic variable may provide the best information for understanding whether baseline EF abilities lead to differential treatment response. The combined assessment of EF abilities in a controlled context and the application of EF abilities in everyday behavior would allow for the most precise identification of adolescents who are hypothesized to benefit most from an organizational skills intervention. Specifically, adolescents who exhibit non-impaired EF abilities on neuropsychological tasks but demonstrate difficulty applying those abilities according to EF rating scales would be ideal candidates to benefit from organizational skills training.

### **Comparing Differential Treatment Response Across Interventions**

Given the increasing number of interventions available for the treatment of ADHD, it is important for intervention research to transition to a more direct comparison of interventions. Generally, early tests of interventions include comparison of an intervention group to a waitlist/control group; indeed many published ADHD intervention studies follow this format (Evans, Owens, & Bunford, 2014; Sonuga-Barke et al., 2013). Although waitlist/control studies are important first steps for determining the efficacy of an intervention, they provide limited insight regarding how the intervention performs in comparison to other treatment options. In practice, few families are choosing between whether they should seek intervention or whether they should wait to begin treatment. Rather, they are trying to choose the best treatment options. Similarly, mental health providers would benefit from information that could help them choose the most appropriate treatment for a patient from the available options. As waitlist/control studies only provide information about response to a single intervention, they cannot provide such information.

Additionally, studies examining treatment response based upon theoretically-based mechanisms of interventions may provide more meaningful information when comparing outcomes to another intervention rather than a waitlist/control group. Evaluating a potential moderator of treatment response by comparing an intervention group to a waitlist control contains a notable confound: any moderation could be related to the act of intervention itself, rather than the effects of the specific intervention studied. That is, the moderator could exhibit an affect if *any* intervention is applied, rather than the exact intervention provided in the study. In contrast, examining a potential moderator in the context of two active intervention groups eliminates this confound. Further, comparing two intervention groups provides a stronger test of a theory-based, intervention-specific moderator. For example, if a variable is found to moderate treatment response for one intervention but not the other, then one could argue that the intervention has a specific association with that variable. Conversely, if the variable is not found to moderate response to either intervention *or* if the variable is found to moderate response to both interventions, then it is less likely that the intervention of interest has a unique association with the potential moderator. Therefore, studying treatment response by comparing two intervention groups ultimately provides more nuanced information to help providers choose a specific intervention to maximize the likelihood a child will respond to treatment.

### **Statement of the Problem**

Researchers and clinicians have emphasized the need to identify factors that may inform the selection of one treatment over another when providing services. However, prior work examining treatment response in ADHD has largely neglected adolescent populations. Further, the studies that have examined moderators of intervention response have focused on factors such as symptom presentation and comorbid psychopathology which are often not linked to the

theorized intervention mechanisms of change. Many interventions for adolescents with ADHD are thought to improve academic functioning by training students to apply skills necessary to keep their academic materials organized and to generate plans for completing schoolwork. Based upon this mechanism of action, students' pre-intervention EF abilities and their ability to use those abilities in their everyday lives may be associated with differential response to intervention. To date, no studies have examined these associations. In summary, understanding the potential influence of individuals' pre-intervention EF abilities as well as their real-life application of those abilities may provide valuable insight regarding which specific interventions may be most efficacious for improving the academic functioning of adolescents with ADHD.

### **Current Study**

The current study was conducted using baseline assessment and outcome data collected from a clinical trial comparing an organizational skills training intervention (HOPS) to a homework completion intervention (the Completing Homework by Improving Efficiency and Focus; CHIEF). HOPS is an organization and planning skills training intervention designed for adolescents with ADHD that teaches students how to use an organization system for their physical school materials, accurately record their homework assignments, and develop daily and long-term plans for completing schoolwork. CHIEF is a homework completion support intervention where a clinician provides a quiet, structured environment for homework completion, helps the student set realistic work completion goals, and provides consistent monitoring and feedback of students' on-task behavior. Both interventions were recently shown to improve adolescents' academic functioning in comparison to a waitlist control sample (Langberg et al., 2017).

This study builds upon the existing literature in several meaningful ways. First, it uses data collected from a large clinical trial of an academic intervention for adolescents with ADHD. Second, it is one of the first studies in ADHD intervention research to evaluate whether variables chosen based upon the theorized mechanism of action for a specific intervention are associated with differential treatment response among two active interventions. Third, it compares two alternative methods of evaluating the full impact of EF abilities (i.e., task performance or ratings individually in comparison to the similarity/discrepancy between performance and ratings), either of which may be useful moderators of treatment response.

### **Aims and Hypotheses**

Based upon prior empirical evidence and the major theories regarding the relations between ADHD and EF, the current study had three main aims:

#### **Aim 1**

Evaluate whether pre-intervention EF abilities, as measured by neuropsychological task performance and/or ratings of EF-related behavior, moderate the association between the intervention an adolescent receives (HOPS vs. CHIEF) and treatment response.

**Hypothesis 1.** Given the broad associations between general academic functioning and EF, it was hypothesized that a main effect of baseline EF abilities (as measured by task performance) predicting post-intervention treatment outcomes regardless of intervention group would be observed. It was also hypothesized that a main effect of baseline application of EF abilities (as measured by ratings of EF behavior) predicting treatment outcomes across intervention groups would be observed.

**Hypothesis 2.** It was hypothesized that underlying EF abilities and application of EF abilities would exhibit a three-way interaction with one another to moderate the relation between

intervention status and post-intervention treatment outcomes. Specifically, it was expected that students with average or better baseline EF abilities (i.e., good task performance) would exhibit a greater response to HOPS than CHIEF only when they also exhibited poor application of their abilities (i.e., more impairment according to EF rating sales).

## **Aim 2**

Determine whether a subgroup of students exhibit a significant discrepancy between their underlying EF abilities (i.e., normal task performance) and the application of their abilities (i.e., impaired rating scores) before receiving any intervention. If such a subgroup exists, then examine whether exhibiting such a discrepancy moderates the relation between the intervention an adolescent receives and treatment response.

**Hypothesis 1.** It was hypothesized that latent profile analysis would result in the identification of at least three distinct subgroups in the sample. One group was expected to exhibit unimpaired performance on neuropsychological tasks measuring EF abilities and non-clinical scores on an EF rating scale. A second group was anticipated to exhibit unimpaired performance on neuropsychological tasks, but behavioral impairment based upon the EF rating scale scores (i.e., difficulties with application). A third group was expected to exhibit impaired performance on neuropsychological tasks and impaired EF rating scale scores.

**Hypothesis 2.** It was hypothesized that group membership would moderate the association between intervention status and treatment response. Specifically, the subgroup exhibiting unimpaired task performance but impaired rating scale scores was expected to exhibit better treatment response to HOPS than to CHIEF, whereas membership in any other subgroup was not expected to be associated with differential treatment outcomes by intervention.

## **Method**

## Participants and Recruitment

The current study used data collected from a total of 274 adolescents (age range 10-15 years,  $M$  age = 11.95,  $SD$  = 1.05) comprehensively diagnosed with ADHD. Participants were recruited from a total of six different middle schools within a single school district in the Eastern United States and were enrolled in grades 6 to 8. The full sample includes 52 participants who were assigned to a waitlist control group. Therefore, the current study used data from 222 participants who received either HOPS or CHIEF immediately after baseline evaluations (111 in each condition). Of those in the immediate treatment groups, approximately 72% of the participants were male ( $n$  = 160 males, 62 females), which is in line with the overall sex ratio observed in ADHD diagnoses (Willcutt, 2012). Caregivers of participants identified 55% ( $n$  = 122) of the youth as White, 30% ( $n$  = 66) as African-American, 10 % ( $n$  = 22) as multiracial, 2% ( $n$  = 4) as Asian, and 1% ( $n$  = 3) as Native American/Alaskan Native. Five participants declined to report race information. Based upon an evidence-based assessment protocol (described in Baseline Assessment Procedure), 61% of participants ( $n$  = 135) met diagnostic criteria for ADHD, Predominantly Inattentive Presentation (ADHD-IA) and 39% ( $n$  = 87) met criteria for ADHD, Combined Presentation (ADHD-C). Approximately 68% ( $n$  = 150) of participants had received a prior diagnosis of ADHD before study participation. Additionally, 55% ( $n$  = 121) were taking medication prescribed to manage ADHD symptoms. Importantly, no group differences on these variables are observed between these two intervention groups based upon independent-samples  $t$ -tests (all  $p$ -values > .05).

Participants were recruited to participate in a study examining the efficacy of two homework interventions for students with attention problems or with formally diagnosed ADHD. Participants were primarily referred to the study by school staff, specifically school counselors



and school psychologists, at each of the study sites. School staff were given basic descriptions of the homework interventions and were provided recruitment flyers to distribute to caregivers of students who could potentially benefit from study participation. Additionally, the staff within each school contacted parents of potential study participants directly to ask for permission to provide family contact information to the research team. If caregivers agreed to be contacted, the research staff reached out to them and provided a more in-depth explanation of the study and possible interventions. Caregivers were also allowed to initiate contact with the research team and inquire about participation, provided that their child was enrolled in one of the schools where interventions were provided. Once caregivers made contact with the research team and expressed interest in the study, they completed a brief telephone screen inquiring about the presence of the nine DSM symptoms within the Inattentive domain of ADHD. Participants were only scheduled for a full eligibility evaluation if caregivers endorsed that their child was currently exhibiting at least four of the nine inattentive symptoms.

### **Baseline Assessment Procedure**

If potential participants passed the telephone screen, a comprehensive ADHD evaluation was scheduled. The evaluation was based upon evidence-based recommendations (American Academy of Pediatrics, 2011; Pelham, Fabiano, & Massetti, 2005) and upon prior clinical trials of ADHD interventions, such as the Multimodal Treatment of ADHD study (MTA Cooperative Group, 1999). As part of the evaluation, data was collected from the adolescent, caregiver, and at least one of the adolescent's core course (i.e., English, math, science, or social studies) teachers. Parents and adolescents separately completed selected modules of the Children's Interview for Psychiatric Syndromes (ChIPS; Weller, Weller, Fristad, Rooney, & Schecter, 2000). Parents completed the ADHD, ODD, Conduct Disorder, Separation Anxiety, Social Phobia, Generalized

Anxiety, Obsessive-Compulsive Disorder, Major Depressive Disorder, and Mania modules. Adolescents completed the same modules as parents, except for the ADHD and ODD modules. Parents also completed the Behavior Assessment System for Children, Second Edition (BASC-2; Kamphaus & Reynolds, 2004) as a general screening tool for mental health difficulties, and they completed the Vanderbilt ADHD Rating Scale (VADRS; Wolraich et al., 2008) to collect additional information about the presence of ADHD, ODD, and Conduct Disorder symptoms. Adolescents completed a brief general intelligence screening through a two-subtest (Block Design and Vocabulary) administration of the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003) and a brief academic achievement screening through a four-subtest (Word Reading, Pseudoword Decoding, Math Problem Solving, and Numerical Operations) administration of the Wechsler Individual Achievement Test, Third Edition (WIAT-III; Wechsler, 2009). Data regarding the presence of ADHD symptoms in the school setting was collected from teachers through administration of the teacher-report version of the VADRS. All available assessment information was then interpreted by a team of licensed clinical psychologists and advanced clinical psychology doctoral students, who made formal mental health diagnoses and study inclusion decisions. Participants were included in the intervention study if three criteria were met: 1) the adolescent met full DSM-IV-TR (American Psychiatric Association, 2000) diagnostic criteria for ADHD, Predominately Inattentive or Combined presentations, 2) the adolescent's performance on the intelligence screening resulted in an estimated FSIQ of 80 or greater, and 3) the adolescent did not meet current diagnostic criteria for bipolar disorder or have a previous diagnosis of pervasive developmental disorder or psychosis.

It should be noted that additional information, including rating scales and neuropsychological task performance, was also collected during this baseline evaluation.

However, these measures were administered primarily for research purposes, and best-practice recommendations do not currently warrant their inclusion in diagnostic decisions (American Academy of Pediatrics, 2011; Pelham et al., 2005). Therefore, they did not contribute to the formal diagnostic decisions made by the research team.

### **Group Randomization and Description of Interventions**

If the baseline evaluation determined that an adolescent was eligible for inclusion in the intervention phase of the study, they were then randomly assigned into one of three groups. One group immediately received an organizational skills training intervention (i.e., HOPS), one group immediately received a homework completion intervention (i.e., CHIEF), and one group was placed on a one-semester waitlist for treatment. Group randomization was stratified by ADHD medication status at the baseline evaluation (i.e., currently taking any medication prescribed for ADHD vs. no current ADHD medication). Group assignment was randomized in a 2:2:1 ratio, with the immediate intervention groups containing more participants than the waitlist group. ANOVA testing indicated that the groups did not significantly differ from one another along several demographic characteristics, including age, sex, race, ADHD presentation, ADHD medication status, prevalence of comorbid ODD or anxiety or depressive disorders, estimated FSIQ, parental education, or family income (all  $p$ -values  $>.05$ ).

**Intervention delivery format.** Both interventions were administered by school mental health professionals who had earned a Masters-level degree in School Counseling. The school mental health professionals were provided with manuals for both interventions and administered each intervention to an approximately equal number of students. Interventions were administered in a one-on-one setting during the school day. Full completion of either intervention included 16 adolescent sessions and two-parent meetings. Parent meetings were completed to help parents

understand the specific intervention that their adolescent was receiving and to facilitate the transition of intervention skills into the home setting. Adolescents were briefly pulled from their regularly scheduled classes to complete the intervention; to reduce the potential negative impact on students' academic performance, sessions lasted no longer than 20 minutes. The first ten intervention sessions were administered twice-weekly, and the final six sessions were administered once-weekly. In total, the interventions took 11 weeks to complete. Both interventions also included a reward system for reinforcing the use of skills taught during the interventions. Adolescents in either intervention had the opportunity to earn a variety of small gift cards for demonstrating the skills taught in whichever intervention they received. Point systems were adjusted so that adolescents in either intervention had the opportunity to earn an equal number of gift cards over the full course of the interventions.

**HOPS intervention protocol.** The HOPS intervention was administered according to the procedures outline in the published manual (Langberg, 2011). The goal of the HOPS intervention was to train students on three main skills: organization and management of school materials, accurately recording assignments and projects, and developing daily and long-term plans to complete assignments and projects. These skills were introduced sequentially, beginning with materials organization and ending with planning skills, but all skills were introduced by the tenth session. When learning materials organization skills, students were introduced to a specific organizational system for their backpack, binder, and locker. Students also learned a system for transitioning all necessary school materials to and from school and developed a strategy for consistently monitoring their adherence to the organizational system. When learning assignment recording skills, students were introduced to the use of a daily planner for tracking all relevant school work (e.g., assignment due dates, upcoming exams). When planning skills were

introduced, adolescents learned how to break larger assignments, such as long-term projects or studying for an exam, into a series of smaller steps that could then be incorporated into their assignment recording system. They also learned how to develop a schedule for the completion of assignments in the context of their other after-school activities (e.g., extracurricular activities, family events). After all skills were introduced, the remainder of the intervention focused on helping students troubleshoot difficulties with their organizational and planning systems and developing a system to help the student maintain their skill use after the intervention concluded.

The HOPS behavioral reward system reinforced students' use of the newly learned organizational skills. School mental health professionals monitored each student's use of specific skills through operationalized definitions of the skills. For example, students may have been rewarded for keeping all homework assignments in a designated homework folder or for accurately recording their assignments from each class during the previous day. To monitor these skills, school mental health professionals completed a behavior checklist during each intervention session.

The first parent meeting in the HOPS intervention focused on introducing the parents to the skills being taught. Parents also learned about how their adolescent's skills were being monitored, and parents developed their own strategies to monitor their child's skill use at home. The second parent meeting focused on helping parents troubleshoot the behavior monitoring systems they developed during the first meeting, as well as helping the parent develop a strategy to continue rewarding their child for using their skills after the intervention ended.

**CHIEF intervention protocol.** The CHIEF intervention was also administered according to a manualized procedure that was developed by the research team. The goal of the CHIEF intervention was to train students to set work completion goals and to maintain on-task behavior

when completing assignments. Students either brought their own homework or assignments to each intervention session, or they were provided relevant academic work to complete if they did not bring any of their own materials. At the beginning of each session, the school mental health professional and student collaborated to set a specific work completion goal. Example completion goals may have included making a set number of vocabulary flashcards and completing a specific number of problems on a worksheet. Students were also taught to incorporate work accuracy checks into their completion goals, such as having a certain number of problems completed on a worksheet answered correctly. Students were encouraged to set work completion goals for subjects that they found more challenging or boring, but students were given the flexibility to choose the work they completed at each session. Additionally, students were taught an operational definition of “on-task” behavior, such as remaining in their seat and having their eye contact focused on school materials. During each session, school mental health providers monitored students’ on-task behavior on a regular time-interval schedule (every minute). If a student met the operational definition of on-task behavior during a particular monitoring period, they earned a point for their reward system. School mental health providers also offered periodic verbal praise of the student’s behavior. If a student was not on-task, they received a verbal prompt specifying how they could adjust their behavior to earn a reward system point during the next monitoring period. Reward points for on-task behavior were tracked by the school mental health professional and presented visually to the student for the duration of the session through the use of a clear jar and tokens. Students also earned reward points if they met their work completion goal by the end of the session.

The parent meetings in the CHIEF intervention were similar to the HOPS parent meetings. The primary goal of the first meeting was to introduce parents to the skills being

taught at school and developing strategies to monitor their adolescent's homework completion behaviors in the home. Parents and school mental health professionals problem-solved issues with the home monitoring system at the second meeting, and parents were taught how to maintain the reward system after the conclusion of the intervention.

### **Executive Function Measures**

**Delis-Kaplan Executive Function System (D-KEFS), Tower Test.** The D-KEFS (Delis, Kaplan & Kramer, 2001) is a neuropsychological assessment battery designed to tap multiple cognitive abilities that are usually considered components of the broad EF construct. The Tower Test subtest of the D-KEFS is conceptually similar to the Tower of London task (Shallice, 1982) and the Stockings of Cambridge task within the Cambridge Neuropsychological Test Automated Battery (Sahakian & Owen, 1992). In general, these tests are thought to measure an individual's planning abilities (Strauss, Sherman, & Spreen, 2006; Unterrainer et al., 2004). During the test, participants were asked to complete a series of puzzles that required the use of three to five disks varying in diameter and three equidistant wooden pegs of equal height. The disks are placed in a pre-determined starting position, and the participant is shown a picture of a specific arrangement of the disks on the pegs. Participants are then asked to move the disks so that they are identical to the picture. Participants are instructed to construct the tower in as few moves as possible, and they are required to follow two rules: (1) only one disk may be moved at a time, and (2) a disk with a larger diameter may never be placed on top of a disk with a smaller diameter. As the participant completes each puzzle, the test administrator records the total number of moves used to complete the puzzle and the total number of times the participant violated one of the two stated rules. Depending on the total number of moves needed to complete the tower, the adolescent's performance is then rated on a 1-4 scale. Alternatively, the adolescent

receives 0 points if they do not correctly reproduce the tower. This procedure is repeated for up to nine trials, or until the adolescent fails to reproduce two consecutive towers. At that point, a Total Achievement score (range 0-21) is calculated based upon their performance across items. Internal consistency for the Tower Test has been reported as marginal ( $\alpha=.68$ ), although the test developers note that many neuropsychological tests demonstrate lower internal consistency values in comparison to rating scales (Delis, Kramer, Kaplan, & Holdnack, 2004). The Tower Test has also been shown to discriminate between ADHD and non-ADHD participants with a correct classification rate of approximately 67% (Wodka et al., 2008). The Total Achievement score was used as the primary measure of performance on the Tower Test in the current study.

**Rey-Osterrieth Complex Figure (ROCF).** The ROCF (Osterrieth, 1944; Rey, 1941) is a neuropsychological task that requires participants to reproduce a novel figure in a paper-and-pencil format. Initially, participants are shown the figure template and asked to draw the figure as accurately as possible. During the first trial of the task, the template is fully visible to participants and they may reference it at any time, although they may not simply trace the figure. After the first trial is completed, participants may be asked to reproduce the figure from memory after a three-minute and/or a 30-minute delay.

Although originally designed as a test of visual-spatial abilities and visual memory, the ROCF has been recognized for its potential as a measure of planning and organizational abilities as well. Current recommendations for ROCF administration include evaluating the general organizational aspects of participants' figure reproductions, especially during the copy trial of the task (Strauss et al., 2006). Several ROCF scoring systems are available that now operationalize the planning and organizational aspects of the task. Scoring for the current study was completed with the Boston Qualitative Scoring System (BQSS; Stern et al., 1999). The



BQSS was developed on a normative adult population, but has been used in multiple studies with children and adolescents, including youth with ADHD (Cahn et al., 1996; Watanabe et al., 2005). The BQSS provides a Presence/Accuracy score, which focuses on individual components of the figure. It also generates several process scores based upon an individual's overall figure production. Examples of these scores include a Planning score that evaluates the logical quality of an individual's approach to drawing the figure, a Fragmentation score that indicates how frequently an individual switched between drawing different components of the figure, and Perseveration and Confabulation scores that indicate whether an individual incorporates components into their reproduction that are not part of the original figure. The BQSS has previously demonstrated good internal consistency ( $\alpha > .70$ ) and high interrater reliability ( $\alpha > .80$ ) for most summary and process scores (Folbrecht et al., 1999).

In the current study, ROCF figures were scored using the BQSS by two independent members of the research team under the supervision of a licensed clinical psychologist. Both members read the BQSS manual and scored the same ROCF performances until interrater reliability of .80 on the Planning/Accuracy scores, Fragmentation, Planning, Perseveration, and Confabulation scores of the copy condition was obtained. After reliability was achieved, raters scored the remaining figures independently. For analyses, the Planning/Accuracy score, the Organization score (a sum of the Fragmentation and Planning scores), and a Perseveration/Confabulation summed score were used as indicators of planning/organizational abilities based upon prior research indicating these scores were most strongly associated with other measures of EF (Somerville, Tremont, & Stern, 2000; Watanabe et al., 2005).

**Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000).** The BRIEF is an 86-item measure designed to assess an individual's behavioral application of EF

abilities. 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 their 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). For the current study, the Plan/Organize (12 items) and Organization of Materials (6 items) clinical scales measure behaviors that were particularly relevant. Example items on the Plan/Organize scale include "Becomes overwhelmed by large assignments" and "Underestimates time needed to finish tasks". Example items on the Organization of Materials scale include "Cannot find things in room or school desk" and "Keeps room messy". Internal consistency based upon the data collected from the clinical trial was and high for both scales ( $\alpha$ s = .81 - .85). In this study, the Plan/Organize and Organization of Materials scales were summed and used as the indicator of adolescents' application of planning and organizational abilities to everyday tasks.

### **Treatment Outcome Measures**

**Children's Organizational Skills Scale (COSS).** The COSS (Abikoff & Gallagher, 2008) is a parent and teacher report measure of organization, planning and time-management behaviors. The COSS generates three subscale scores: Task Planning, Organized Actions, and

Memory and Materials Management. The Task Planning subscale measures how often a student engages in planning behaviors, such as thinking out the steps needed to complete a large task. The Organized Actions subscale measures how frequently a student uses organizational tools or aids (e.g., planners, lists). The Memory and Materials Management subscale measures how frequently students lose important items and how well they organize their physical materials, such as backpacks and papers. Each of these scales was used as an outcome measure in the current study. Parent and teacher ratings were examined separately as treatment outcomes. Prior research with the COSS has demonstrated high internal consistencies for both parent and teacher forms across all subscales ( $\alpha > .80$ ; Abikoff & Gallagher, 2008). In the current study, a parent and at least one teacher rated each student's homework behaviors. Internal consistency was adequate across raters (parent  $\alpha = .84$ ; teacher  $\alpha = .88$ ). If more than one teacher provided ratings about a student, their scores were averaged together.

**Homework Performance Questionnaire (HPQ).** The HPQ (Power, Dombrowski, Watkins, Mautone, & Eagle, 2007) is a 13-item parent and teacher report questionnaire that provides a measure of how frequently a positive homework behavior occurs. The HPQ asks questions on a six-point scale, and each point on the scale represents a percentage of time that a particular behavior occurs (e.g., 0 = 0-50% of the time, 5 = 90-100% of the time). Example items include “writes down homework assignments independently” and “manages homework time well”. The HPQ has demonstrated high internal consistency across raters and convergent validity with other measures of homework (Power et al., 2007; 2015). For the current study, a parent and at least one teacher rated each student's homework behaviors. Internal consistency was high for parents ( $\alpha = .91$ ) and teachers ( $\alpha = .83$ ). If more than one teacher provided ratings about a

student, then their scores were averaged together. The total score was used as an indicator of treatment response, with parent and teacher scores examined separately.

### **Covariates**

#### **Vanderbilt ADHD Rating Scale, parent version (VARs; Wolraich et al., 2003).**

Although ADHD symptom severity has exhibited a mixed relation with EF abilities and treatment response, individuals with more severe ADHD symptoms tend to exhibit greater overall impairment in functioning (Biederman, 2005; Loe & Feldman, 2007). Therefore, overall ADHD symptom severity was controlled for in all analyses. The VARs asks respondents to rate the frequency of occurrence for each of the 18 DSM-IV symptoms of ADHD. Parents rate each symptom on a 4-point Likert scale (e.g., 0 = “never”, 3 = “very often”). The summed score of these 18 items collected at the baseline assessment was used as a covariate in all analyses.

Internal consistency for the total score was high in the present study ( $\alpha = .94$ ).

**ADHD medication status.** Prior research has indicated that children taking medication prescribed for ADHD may exhibit better performance on neuropsychological tasks than youth who do not take medication (Kempton et al., 1999; Semrud-Clikeman, Pliska, & Liotti, 2008). Therefore, ADHD medication use at baseline was included as a covariate in all analyses. Parents were asked if their child was currently taking medication prescribed for ADHD at the baseline assessment, and their responses was converted into a dichotomous variable (0 = not using medication, 1 = currently using medication) for analyses.

### **Analytic Plan**

#### **Missing Data Procedures**

Missing data from the baseline assessment time point was negligible, with only 3% of all data missing across baseline variables of interest. At post-intervention, approximately 15% of all

data were missing across the variables of interest for this study. Missing data from the post-intervention time point was managed using multiple imputation, which has been previously used in ADHD behavioral intervention studies (e.g., Abikoff et al., 2013; Langberg et al., 2017; Safren et al., 2010). Specifically, missing values for post-intervention variables were estimated using the Fully Conditional Specification method, which is a multivariate imputation algorithm that does not require an assumption of multivariate normality for all variables included in the algorithm (van Buuren, Brand, Groothuis-Oudshoorn, & Rubin, 2007). The algorithm included in SAS version 9.4 (SAS Institute, 2015) was used to conduct the imputations. Imputation was based upon observed values of post-intervention variables, pre-intervention variables, and other relevant baseline variables. Inclusion of additional variables in a multiple imputation model is recommended to improve the predictive capability of the model (Johnson & Young, 2011; Little & Rubin, 2002). In addition to pre-intervention ratings on outcome variables, participant age, sex, and treatment condition were included only for predictive purposes in the model (i.e., missing values were not imputed for these variables). Separate imputation models were run for each outcome variable, although teacher and parent ratings of the same outcome variable were imputed together; this imputation strategy improves prediction efficiency and reduces the risk of biased imputed values when compared to analyses conducted with only observed data (Spratt et al., 2010; Sterne et al., 2009). It should also be noted that previous analyses using this dataset and missing data management procedure found identical results when imputed data results were compared to observed-only data (Langberg et al., 2017).

### **Defining Treatment Response**

One of the most significant analytic challenges to any intervention study is to determine the optimal method for identifying individuals who have actually responded to the intervention.

One common strategy is the evaluation of pretest-posttest change through change scores, although numerous methods are present in the literature. The most basic type of change score is the raw difference score, which is simply the arithmetic difference between post-intervention values and pre-intervention values on an outcome measure (Rogosa, Brandt, & Zimowski, 1982). While this method is easy to implement in statistical analyses, intuitive to understand, and retains the continuous nature of the variable being measured, it has a major methodological drawback. Specifically, raw difference scores may be particularly unreliable measures of treatment change because they fail to account for measurement error at either the pre-test or post-test time points (Chronbach & Furby, 1970; Lord, 1956).

Alternatively, a residualized change score approach evaluates how much an individual's observed post-intervention score differs from their expected score based upon their pre-intervention score (Chronbach & Furby, 1970). This approach is most commonly implemented by building an analysis of variance model or multiple regression model with post-intervention scores used as the dependent variable and pre-intervention scores included as a covariate. Proponents of this method have argued that residualized change scores account for the variability in a measured construct that is related to the baseline value of the construct. However, residualized change scores are more complex to interpret as they no longer provide an absolute change value. Rather, they indicate how much an individual's observed score deviated from their expected score.

A more advanced method for observing change on a continuum is the implementation of a latent curve model (Meredith & Tisak, 1990; Curran & Muthén, 1999). This approach accounts for measurement unreliability because it separates the shared variance of indicators measuring an underlying construct from the residual variance of each indicator (i.e., error). However, latent

curve models are considered ideal for at least three time points of data, and more than three time points are recommended for unbiased estimation (Curran & Muthén, 1999). Many intervention studies, unfortunately, contain only 2 (i.e., pre-test/post-test) or 3 (pre-test/post-test/short-term follow-up) time points.

Other methods for measuring treatment response focus on whether or not a clinically significant change in an outcome measure has occurred. One of the more popular methods known as the Reliable Change Index (RCI) evaluates whether a significant change in a measure has occurred after accounting for the unreliability of psychological measurement (Jacobson, Follette, & Revenstorf, 1984; Jacobson & Truax, 1991). The RCI is somewhat similar to a raw difference score, as it requires the calculation of the difference between pre-intervention and post-intervention scores for each individual. However, the most commonly accepted formulation of the RCI makes a correction to the difference scores by dividing them by the standard error of difference ( $S_{diff}$ ) between the pre-test and post-test values (Jacobson & Truax, 1991), which incorporates a representation of measurement error (usually Chronbach's alpha; Hiller, Schindler, & Lambert, 2012; Wise, 2004). Once all calculations have been made, the RCI provides a standardized score, and these scores are generally dichotomized into two groups: responders, whose scores fall outside of a pre-specified confidence interval (e.g., RCI values > 1.96 for a 95% confidence interval), or non-responders, whose change in score is more likely due to chance measurement error. A different method for detecting a significant change is the use of clinical cutoff scores. These cutoffs are established thresholds that research suggests is indicative of significant impairment in the construct of interest. Clinical cutoffs have been established for many commonly used psychological measures and are easy for researchers and clinicians to interpret. However, clinical cutoff thresholds have not been reported for all psychological

measures, and those that have been reported were developed through a variety of methods and with varying degrees of empirical support (Jacobson, Roberts, Berns, & McGlinchey, 1999). It should also be noted that clinical cutoffs suffer from their own risk of measurement unreliability (i.e., identifying an individual as a responder due to measurement error), especially for individuals with pre-test or post-test scores near the cutoff value (Jacobson et al., 1999).

When considering the advantages and disadvantages of each of these change score approaches, residualized change scores were selected for use in the current study. This approach recognizes the limitations of psychological measurement, but still preserves the continuous nature of the variables being measured. Using a continuous measure of treatment response also provides more insight into the magnitude of difference in response.

### **Treatment of Neuropsychological Tasks**

When multiple neuropsychological tasks are used, as was the case in the current study, task performance is generally treated in one of two ways. The most straightforward method is to treat each task as a separate variable. This approach acknowledges that different tasks are generally designed to tap a narrow aspect of cognitive functioning. For tasks related to EF, tasks may measure planning/organization, inhibition, and working memory. However, some have argued that neuropsychological task performance, especially performance on tasks thought to tap EF abilities, is faced with the “task impurity” phenomenon (Miyake et al., 2000). Task impurity emphasizes the collaborative nature of EF abilities, meaning that although a certain behavior (i.e., task performance) may rely on one primary cognitive function, it also requires support from other EF abilities. Several available methods have been proposed to address the task impurity problem, although they share a general theme of condensing performance on multiple tasks into



a single score. The two most common methods used in the literature are principal component analyses or latent factor scores (Graziano et al., 2011; Loo et al., 2007; Miyake et al., 2000).

For the current study, principal component analysis was used via methods implemented in prior studies of EF abilities within ADHD populations (Graziano et al., 2011; Lambek et al., 2010; Loo et al., 2007). A principal component analysis with oblique rotation was performed using one indicator of performance from the Tower Test (Total Achievement) and three indicators from the BQSS scoring method of the ROCF task (Presence/Accuracy, Organization, Perseveration/Confabulation). These indicators were selected based upon prior work suggesting these measures are most commonly correlated with other measures of executive functioning (Cahn et al., 1996; Somerville et al., 2000; Unterrainer et al., 2004). A one-component solution was elicited. Factor scores along this component were then extracted and used as the independent variable representing an individual's underlying planning/organization abilities.

## Analyses

**Aim 1.** The first aim evaluated if either pre-intervention EF abilities or application of those abilities moderate the association between the intervention an adolescent receives and treatment response. To achieve this goal, a series of regression models were examined using PROCESS macro version 3.1 (Hayes, 2018). More specifically, moderation models with two proposed moderators (i.e., moderated moderation) were used to examine how EF abilities and/or application of abilities may affect the association between treatment condition and post-intervention values of treatment outcome measures, after controlling for pre-intervention values of treatment outcome measures. Each model also included ADHD symptom total scores from the VARS and ADHD medication use as covariates. All models included intervention group (HOPS or CHIEF) as a binary independent variable. Four total models were evaluated: two models

examining parent-reported outcomes and two models examining teacher-reported outcomes. Total scores from the COSS and HPQ were used as outcomes for both the parent and teacher reports. All models included EF task performance factor scores based upon the principal component analysis and the summed Plan/Organize and Organization of Materials scores of the BRIEF as moderators. Thus, the models contained two two-way interaction terms (i.e., intervention condition/task performance; intervention condition/BRIEF rating) and one three-way interaction term (i.e., intervention/task performance/BRIEF rating). Consistent with best-practice recommendations, the full model will be interpreted in the context of the highest-order significant interaction.

If a significant interaction term was observed for any model, then interaction effects were further probed by mapping the simple slope technique based upon the terms calculated by the PROCCESS macro. The effects of the moderators on the IV-DV relationship were calculated at the mean value of each moderator, as well as one standard deviation above and one standard deviation below the mean. These relationships were also visually graphed to further aid in the interpretation of interaction effects.

**Aim 2.** The second aim evaluated whether particular subgroups of adolescents with ADHD could be identified who exhibit distinct patterns of underlying EF abilities and everyday application of those abilities. It also examined whether membership in these subgroups moderated the relation between the intervention an adolescent receives and treatment response. These individual patterns were elicited via a latent profile analysis (LPA) in Mplus version 7.4 (Muthén & Muthén, 2012). LPA is a type of multivariate normal mixture model that allows for the identification of subgroups within a single population through a model built with indicator variables that are thought to distinguish the groups (Berlin, Williams, & Parra, 2013; Bauer &

Shanahan, 2007). In the current study, LPA provided a method to potentially identify the hypothesized subgroups of adolescents with ADHD that differ upon their underlying EF abilities as well as their application of those abilities. A model was built using six total indicators. The four neuropsychological task variables used in the principal component analysis served as indicators of an individual's EF abilities, whereas the Plan/Organize and Organization of Material subscales of the parent-report version of the BRIEF served as indicators of an individual's application of those abilities in everyday behavior.

Two-, three-, four-, and five-profile models were examined to determine the optimal number of profiles within the data. Three main criteria for determining the appropriate number of profiles were used. Two of the criteria are empirical indicators of model fit. Specifically, the Bayesian Information Criteria (BIC) and the bootstrapped parametric likelihood ratio test (BLRT) were used. A model is considered a better "fit" to the data if its BIC value is lower than other models, and a model with  $k$  profiles is considered better than a model with  $k-1$  profiles if the BLRT results in a significant  $p$ -value (Nylund, Asparouhov, & Muthén, 2007). The third criteria for evaluating model fit focused on signs of model instability. Specifically, the presence of a profile that contains less than 5% of the entire sample would likely be difficult to replicate in other samples and could be indicative of an outlying individual pattern. Therefore, models containing small-membership profiles were considered poorer than models with sufficient membership across all profiles.

After the optimal number of profiles were identified, a brief exploration of the groups was conducted to evaluate whether the groups demonstrated meaningful differences from one another based upon their mean indicator values. Individuals were grouped by their model class, which is the class an individual is most likely to have been associated with based upon the LPA

analysis. Group means for each task performance and BRIEF indicator were then calculated, and the magnitude of difference between the group means of each profile were compared with one another. Cohen's *d* values were calculated, and differences were considered small if values were greater than 0.2 less than 0.5, medium if values were greater than 0.5 but less than 0.8, and large if values were greater than 0.8 (Cohen, 1988).

Finally, moderation models using the best-fitting LPA model as a moderating variable were tested using Mplus. As with Aim 1, intervention condition was used as the independent variable. Baseline medication status, ADHD symptom severity, and baseline values of the dependent variable were included as covariates. Post-intervention values of the COSS total scores and HPQ total scores were treated as dependent variables, with parent ratings and teacher ratings examined separately for a total of 4 models. Latent profile membership served as the moderating variable for all models. Following best-practice recommendations, intervention group was designated as a predictor of both post-intervention measures and latent profile membership (Lamont, Vermunt, & van Horn, 2016). To account for the fact that LPA is a mixture model, and therefore individuals are rarely full members of a single profile group, Vermunt's 3-step approach (Vermunt, 2010) were used to estimate model parameters. The presence of potential moderation effects was tested using Wald tests of parameter constraints. A significant Wald test indicates that latent profile membership moderates the association between intervention group and treatment outcome. If a significant interaction was observed, the interaction effects were further examined through post-hoc testing. Since both the independent and moderator variables within this aim consist of inherently meaningful categories, the effect of latent profile membership on the independent variable-dependent variable association was

directly evaluated. Additionally, the estimated percentage of responders to HOPS and CHIEF was graphed, with response rates separated by latent profile membership.

## Results

### Descriptive Statistics

Before conducting the major analyses, descriptive statistics were calculated for all variables to screen for extreme non-normality. Means, standard deviations, and skewness/kurtosis values were calculated for all continuous variables. Descriptive statistics are presented in Table 1. All variables exhibited acceptable skewness and kurtosis values (all values between -2 and +2).

*Table 1*

*Descriptive Statistics for Executive Function Task Performance and BRIEF Ratings*

Variable	Mean	Standard Deviation	Range	Skewness	Kurtosis
<i>ROCF</i>	--	--	--	--	--
Presence/Accuracy	16.32	2.68	6 – 20	-1.26	1.51
Organization	4.68	1.74	0 – 8	-0.15	-0.48
Perseveration/Confabulation	5.68	1.83	0 – 8	-0.62	-0.33
<i>Tower Test</i>	--	--	--	--	--
Total Achievement	14.93	3.68	2 – 23	-0.36	0.16
<i>BRIEF</i>	--	--	--	--	--
Plan/Organize	29.53	4.27	17 – 36	-0.79	0.28
Organization of Materials	15.09	2.98	8 – 18	-0.78	-0.55

*Note.* All descriptive statistics represent raw score values. Range represents minimum and

maximum raw values observed within the full sample. BRIEF = Behavior Rating Inventory of

Executive Function; ROCF = Rey-Osterrieth Complex Figure.

### Aim 1

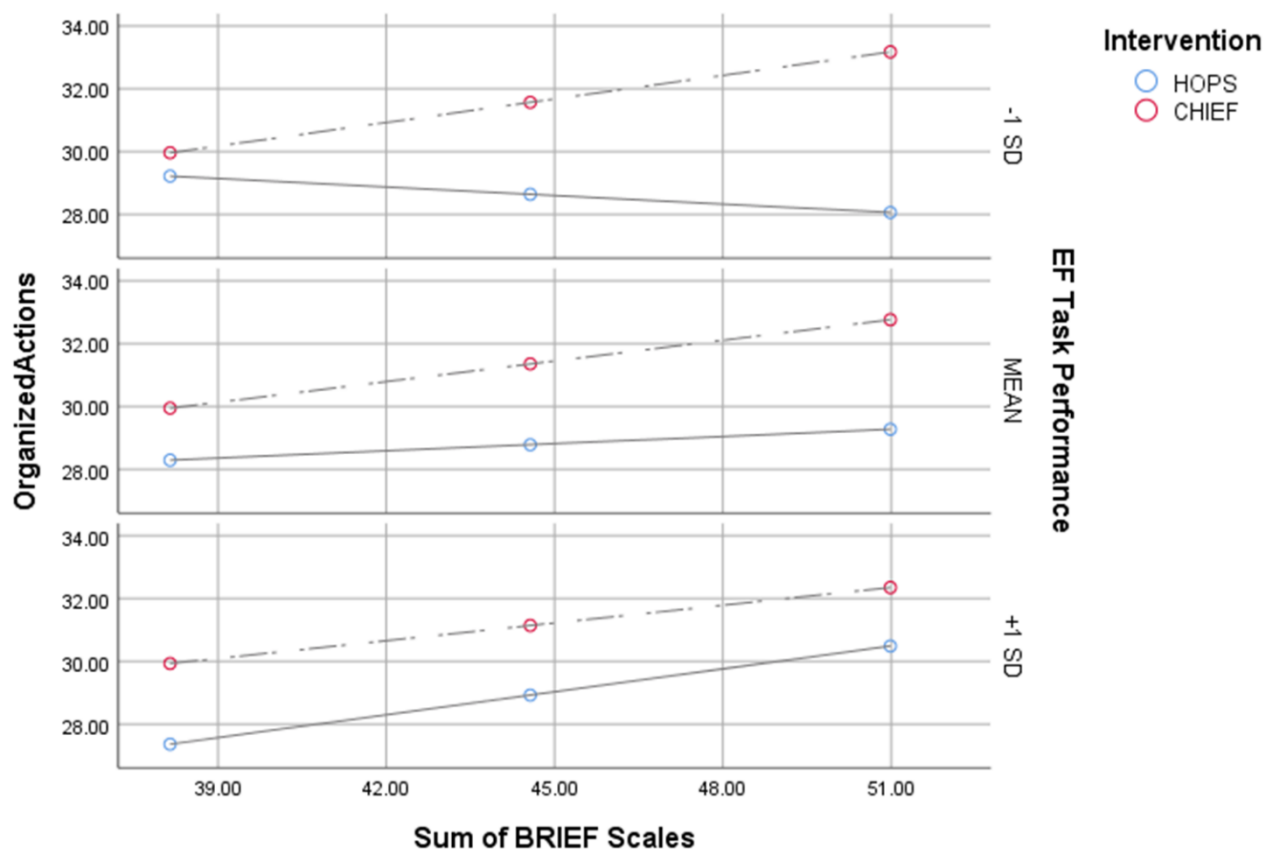
**Parent-report outcomes.** When examining the subscales of the COSS based upon parent report, all three models demonstrated overall significance. However, the model examining the Task Planning scale contained no significant predictors or interaction terms after controlling for

all covariates. Similarly, no significant predictors or interactions were identified within the model examining the Memory/Materials Management scale, after controlling for covariates.

In contrast, the model evaluating the Organized Actions scale contained several significant predictors and accounted for approximately 21% of the overall variance in post-intervention scores ( $F = 5.49, p < .001, R^2 = .21$ ). Consistent with the main outcomes study, treatment condition (HOPS vs. CHIEF) was a significant predictor, such that individuals who received HOPS demonstrated lower COSS scores (i.e., better organization skills;  $p < .001$ ). Neither EF task performance ( $p = .836$ ) nor EF ratings ( $p = .497$ ) were significant individual predictors of post-intervention ratings. However, evaluation of the interaction terms found a significant three-way interaction (i.e., intervention condition  $\times$  EF task performance  $\times$  EF ratings) on post-intervention scores ( $p = .037$ ). Simple slopes analysis of values at the mean and  $\pm 1$  standard deviation from the means (Figure 1) determined that individuals with higher EF ratings (i.e., more impairment) exhibited lower post-intervention COSS scores when they received HOPS, but only when they also demonstrated average task performance ( $p = .004$ ) or more impaired task performance ( $p < .001$ ). At mean values of EF ratings, individuals demonstrated better response to HOPS regardless of task performance ( $ps \leq .005$ ). Finally, individuals with lower EF ratings (i.e., less impairment) exhibited lower post-intervention COSS scores when they received HOPS, but only when they also demonstrated EF average impairment ( $p = .004$ ) or lower impairment ( $p = .031$ ) based upon task performance. Overall, results from this model indicate that individuals demonstrated a better response to HOPS in comparison to CHIEF when their EF task performance and ratings were congruent (i.e., both suggested more EF impairment or less EF impairment).

Figure 1

Visualized Three-way Interaction of Parent-Report Organized Actions Scale



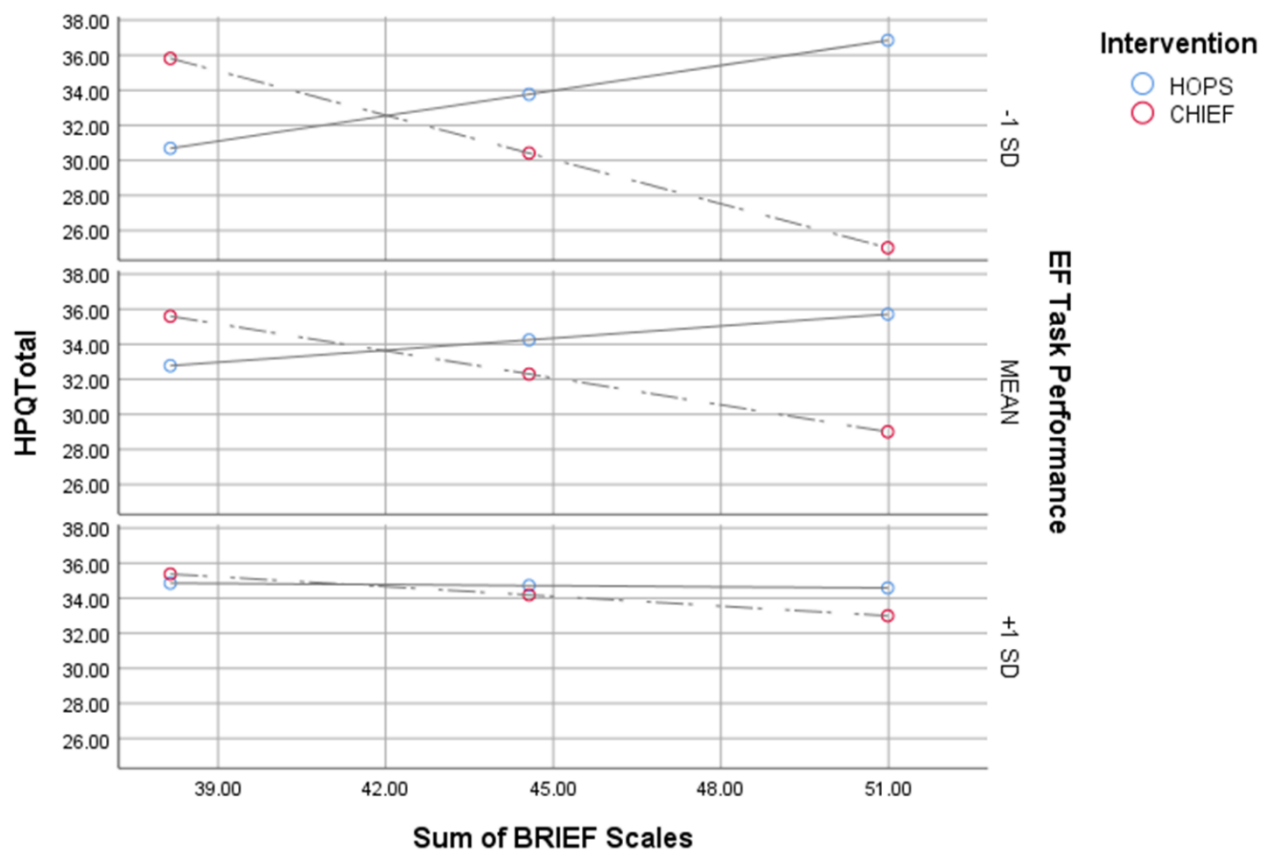
*Note.* The Organized Actions score is the raw summed score from relevant COSS items. The BRIEF scores are summed raw scores of the Plan/Organize and Organization of Materials scales. The Task performance score is the standardized factor score based upon ROCF and Tower Test performance variables.

When examining parent reported HPQ scores, the overall model accounted for approximately 20% of all variance in post-intervention ratings ( $F = 4.99, p < .001, R^2 = .20$ ). Consistent with the main outcomes study, treatment condition was not a significant predictor of post-intervention ratings ( $p = .286$ ) after accounting for pre-intervention HPQ scores, ADHD symptom severity, and ADHD medication status. Additionally, neither EF task performance ( $p = .774$ ) nor EF ratings ( $p = .286$ ) were significant individual predictors of post-intervention ratings. However, evaluation of the interaction terms found a significant three-way interaction on post-intervention HPQ scores ( $\beta = 2.84, p = .049$ ). Simple slopes analysis (Figure 2) determined that individuals with higher EF ratings (i.e., more impairment) exhibited lower post-intervention HPQ scores after receiving HOPS, but only when individuals also demonstrated average task performance ( $p = .002$ ) or more impaired task performance ( $p < .001$ ). At mean EF rating scores, individuals exhibited lower HPQ scores after HOPS intervention, but only when they demonstrated more impaired task performance ( $p = .027$ ). Individuals with lower EF ratings (i.e., less impairment) did not exhibit significantly different HPQ scores after receiving either intervention, regardless of EF task performance. Overall, results from this model indicate that individuals demonstrated a better response to HOPS in comparison to CHIEF when they exhibited more EF impairment at baseline according to both task performance and ratings.



Figure 2

Visualized Three-way Interaction of Parent-Report Homework Performance Questionnaire



Note. HPQ = Homework Performance Questionnaire. The HPQ Total score is the raw summed score from all HPQ items. The BRIEF scores are summed raw scores of the Plan/Organize and Organization of Materials scales. The Task performance score is the standardized factor score based upon ROCF and Tower Test performance variables.

**Teacher-report outcomes.** Similar to the parent report findings, all three models examining the subscales of the COSS based upon teacher report were significant overall. Also like the parent-report findings, the model containing teacher-report scores on the Task Planning scale demonstrated no significant individual predictors after accounting for the effects of covariates. For the model evaluating the Organized Action scale, individuals who received HOPS demonstrated lower post-intervention scores on average than those who received CHIEF, which was consistent with the main outcomes study ( $p = .006$ ). Neither EF task performance ( $p = .214$ ) nor EF ratings ( $p = .094$ ) were significant individual predictors of post-intervention COSS scores. However, pre-intervention EF ratings were a significant moderator, such that more impairment according to EF ratings were associated with lower post-intervention COSS scores ( $\beta = 1.36, p = .044$ ). EF task performance was not a significant moderator of post-intervention scores ( $p = .591$ ), and no three-way interaction was observed ( $p = .184$ ).

When evaluating the Memory/Materials Management scale, no individual predictors of post-intervention scores were observed after controlling for covariates. However, pre-intervention EF ratings were a significant moderator, such that more impairment according to EF ratings were associated with lower post-intervention Memory/Materials Management scores ( $\beta = 1.71, p = .022$ ). EF task performance was not a significant moderator of post-intervention scores ( $p = .088$ ), and no three-way interaction was observed ( $p = .768$ ).

When examining teacher reported HPQ scores, the overall model accounted for approximately 33% of all variance in post-intervention ratings ( $F = 10.11, p < .001, R^2 = .33$ ). However, no significant predictors or interaction terms were identified after accounting for the effect of all covariates.

## **Aim 2**

**Profile enumeration of EF task/rating LPA.** Profile enumeration results for the two-, three-, four-, and five-profile models are presented in Table 2. The empirical fit criteria indicated that the four-profile model provided the best fit for the data. The four-profile model had the lowest BIC value of all models tested. Additionally, BLRT results indicated that the four-profile model fit the data significantly better than the three-profile model. Notably, the BLRT test for the five-profile model indicated a significantly better fit than the four-profile solution. However, the five-profile solution contained a profile with a small membership (only 4% of all individuals). Further, the small-membership profile appeared to represent a modest split of a previously existing profile. Therefore, the four-profile model was chosen as the best fitting solution for the data.

*Table 2*

*Fit Indices for 2, 3, 4, and 5 Profile Solutions of Executive Functioning Task/Rating LPA*

<b>Number of Profiles</b>	<b>Number of Parameters</b>	<b>BIC</b>	<b>BLRT <i>p</i>-value</b>	<b>Class with &lt;5% Membership</b>
2	20	7683.11	<.001	No
3	28	7644.88	<.001	No
4	36	7624.22	<.001	No
5	44	7632.92	.001	Yes

*Note.* LPA = Latent Profile Analysis; BIC = Bayesian Information Criteria; BLRT = bootstrapped likelihood ration test.

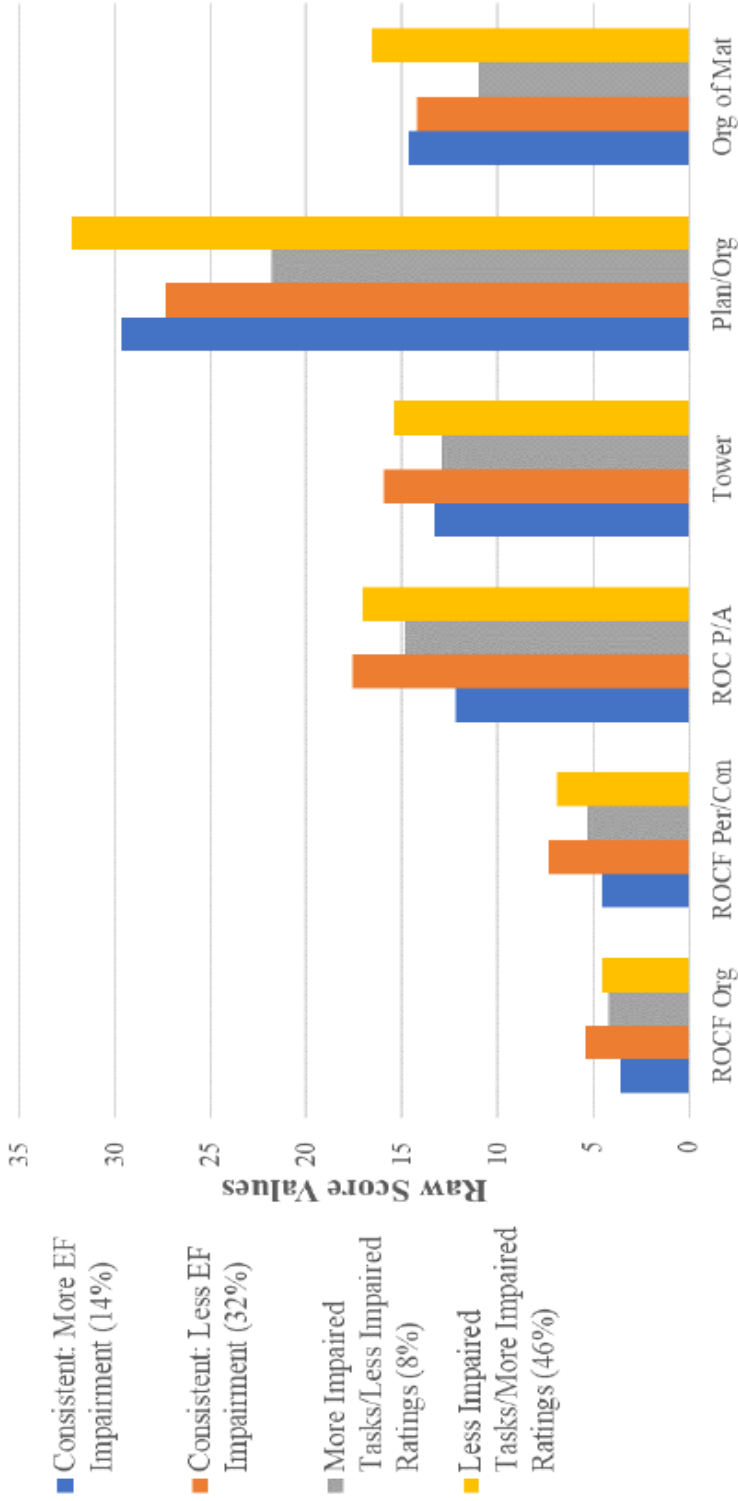
**Description of Four-Profile LPA.** The estimated means of the indicators (i.e., three ROCF scores, Tower Task score, two BRIEF scale scores) for each profile are presented in Figure 3. Two of the profiles demonstrated a consistent presentation of functioning between EF task performance and EF ratings. Specifically, one profile (“Consistent: More EF Impairment”; 14% of sample) exhibited the lowest mean performance across all profiles for the three ROCF scores and the second lowest mean performance on the Tower task. Additionally, the Consistent: More EF Impairment profile demonstrated the second highest mean scores for both BRIEF

scales, where higher scores are indicative of greater EF impairment. The second consistent profile (“Consistent: Less EF Impairment”; 32% of sample) exhibited the highest mean performance across all profiles for each task indicator, as well as the second lowest mean BRIEF scores.

In contrast, two profiles demonstrated a discrepancy between EF task performance and EF ratings. One profile (“More Impaired Tasks/Less Impaired Ratings”; 46% of sample) exhibited the second highest mean performance for all four task-related indicators. However, this profile also exhibited the highest mean ratings on both BRIEF scales; that is the profile showed the *most* EF impairment based on parent ratings. Of note, this profile closely resembles the EF ability/application profile that was hypothesized before the study, and the profile contained the most individuals from the full sample. The final profile (“Less Impaired Tasks/More Impaired Ratings”; 8% of sample) exhibited the second lowest mean performance for the three ROCF indicators and the lowest mean performance for the Tower Task, but the lowest mean ratings (i.e., the *least* EF impairment) for both BRIEF scales.

Figure 3

Mean Values of Four-Profile Model Using ROCF, Tower Test, and BRIEF Indicators



Profile Name	ROCF Org	ROCF Per/Con	ROC P/A	Tower	Plan/Org	Org of Mat
Consistent: More EF Impairment	3.57	4.52	12.19	13.29	29.68	14.60
Consistent: Less EF Impairment	5.38	7.35	17.61	15.95	27.32	14.21
More Impaired Tasks/Less Impaired Ratings	4.20	5.31	14.79	12.92	21.81	11.02
Less Impaired Tasks/More Impaired Ratings	4.51	6.87	17.05	15.43	32.25	16.60

Note. All mean values were derived from raw scores. BRIEF = Behavior Rating Inventory of Executive Function; ROCF = Rey-

Osterrieth Complex Figure; Org = Organization; Per/Con = Perseveration/Confabulation; P/A = Presence/Accuracy; Tower = Tower

Test Total Achievement; Org of Mat = Organization of Materials.

An exploration of the effect sizes between group means for each indicator suggested that the four profiles were meaningfully different from one another across indicators. The differences were most notable when comparing group means for the Presence/Accuracy score of the ROCF. Large-magnitude effect sizes were observed when comparing the mean Presence/Accuracy scores from either profile with less impaired task performance (i.e., “Consistent: Less EF Impairment” and “Less Impaired Tasks/More Impaired Ratings”) to the mean scores from either profile with more impaired task performance (i.e., “Consistent: More EF Impairment” and “More Impaired Tasks/Less Impaired Ratings”) (Cohen’s  $d$  values = 1.16 – 2.58). In contrast, smaller magnitude effect sizes were observed when comparing the two profiles with the least impaired task performance ( $d = 0.23$ ) or the two profiles with the most impaired task performance to one another ( $d = 0.97$ ). A similar pattern was observed when comparing mean Total Achievement scores from the Tower Test. Medium- to large-magnitude effect sizes were observed when comparing Total Achievement scores from the profiles with less impaired task performance to the profiles with more impaired task performance (Cohen’s  $d$  values = 0.54 – 1.07), whereas only a small-magnitude effect size was observed when comparing the profiles with the most impaired task performance to each other ( $d = 0.35$ ). The effect size was even smaller between the mean Tower Task scores for the profiles with the least impaired task performance ( $d = 0.18$ ). Finally, mean scores from the two BRIEF scales also showed notable differences between the profiles. For example, large effect sizes were observed when comparing the means of the BRIEF scale scores for the More Impaired Tasks/Less Impaired Ratings profile to the means of the two profiles with the most impaired ratings (Cohen’s  $d$  values = 1.16 – 4.02).

**Moderation of treatment response based upon LPA profile membership.** Moderation models using parent-report COSS scores resulted in nonsignificant Wald Statistics for all three

scales: Task Planning (Wald = 2.44,  $p = .487$ ), Organized Actions (Wald = 4.80,  $p = .187$ ), and Memory/Materials Management (Wald = 1.49,  $p = .685$ ). That is, profile membership based upon an individual's pattern of EF task performance and ratings did not significantly moderate the relationship between the intervention they received (HOPS vs. CHIEF) and their post-intervention COSS ratings. However, the moderation model using parent-report HPQ scores was significant (Wald = 23.08,  $p < .001$ ). Post-hoc group comparison analyses indicated that individuals classified in the Less Impaired Tasks/More Impaired Ratings profile had significantly higher post-intervention HPQ scores (i.e., better homework completion) after receiving HOPS than they did after receiving CHIEF ( $p < .001$ ). Further, individuals classified in the More Impaired Tasks/Less Impaired Ratings profile exhibited significantly higher post-intervention HPQ scores after receiving CHIEF than they did after receiving HOPS ( $p = .037$ ). Membership in the profile exhibiting consistent EF impairment or the consistent profile exhibiting less EF impairment was not associated with significant differences in post-intervention HPQ ratings depending upon the intervention administered.

When evaluating teacher-report outcomes, nonsignificant Wald Statistics were observed for two of the COSS subscales: Task Planning (Wald = 4.83,  $p = .185$ ) and Organized Actions (Wald = 1.92,  $p = .589$ ). However, the model using the Memory/Materials Management scale was significant (Wald = 8.52,  $p = .037$ ). Post-hoc analyses indicated that individuals classified in the Less Impaired Tasks/More Impaired Ratings profile had significantly lower post-intervention scores (i.e., better organizational skills) after receiving HOPS than they did after receiving CHIEF ( $p < .014$ ). Membership in the other three profiles was not associated with significant differences in post-intervention COSS ratings depending upon the intervention administered.

Additionally, the model examining the possible moderating effect of class membership using teacher-report HPQ scores resulted in a nonsignificant Wald statistic (Wald = 7.462,  $p = .059$ ).

### **Discussion**

As more evidence-based interventions for the treatment of ADHD become available, there is a growing need to help providers make informed decisions about treatment selection. The current study evaluated whether factors aligned with proposed intervention mechanisms of action moderated treatment response. Specifically, this study evaluated whether pre-intervention EF abilities were associated with significantly greater treatment response for participants who received an organizational skills intervention (i.e., HOPS) as compared to participants who received a homework completion intervention (i.e., CHIEF). A few distinct patterns of EF task performance and ratings were identified, including profiles that exhibited both consistency of EF abilities across the measures, as well as discrepant EF performance. The two profiles demonstrating congruence between EF tasks and rating scales, which contained 46% of all study participants, is contrary to prior research suggesting that tasks and ratings have low correspondence. Further, the Less Impaired Tasks/More Impaired Ratings profile was consistent with study hypotheses that a number of participants would specifically exhibit more impairment in their application of EF skills in daily life relative to their underlying cognitive abilities. Although the presences of these profiles are notable, membership in these profiles did not appear to consistently predict differential response to an organizational skills intervention in comparison to a homework completion intervention. Moreover, the studied measures of EF did not moderate differential response to these treatments when treated as continuous variables, either individually or through a three-way interaction of underlying EF abilities and daily application of EF.

### **Evaluation of Three-way Interaction Models**



First, the study aimed to evaluate whether pre-intervention EF abilities, as measured by neuropsychological task performance and/or ratings of EF-related behavior, moderate the association between the intervention an adolescent receives (HOPS vs. CHIEF) and treatment response. Contrary to initial hypotheses, neither EF task performance nor ratings were found to be significant predictors of post-intervention ratings, regardless of rater type or outcome measure. This was a somewhat surprising finding, given that extensive research has linked EF abilities to academic functioning (Biederman et al., 2004; Kofler et al., 2016; Lambek et al., 2010; Langberg et al., 2013). It is possible that given the adolescent nature of this sample, students' EF abilities had already exerted much of their influence on academic functioning.

Although neither EF-related variable was a significant predictor of outcomes on its own, multiple significant moderation effects were observed. For teacher-reported outcomes, students' underlying EF abilities (i.e., task performance) showed no significant moderation of the treatment condition – outcome association. However, students who exhibited more impairment in their ability to apply EF abilities to daily behavior did exhibit significantly lower post-intervention scores (i.e., better organization) for two of the three COSS scales after receiving HOPS when compared to the CHIEF intervention group. Evaluation of parent-reported outcomes revealed some evidence supporting a moderating role for EF abilities on the treatment-to-outcome relationship. Specifically, individuals who demonstrated more EF impairment according to both task performance and ratings appeared to have a better response to HOPS than to CHIEF for two of the four outcomes tested: the COSS Organized Actions scale and the HPQ total score. Of note, findings from these models did not support study hypotheses proposing that individuals with average or higher task performance would exhibit better response to HOPS if they also demonstrated more impaired rating scores at baseline.

### **Identification of Latent Profiles Combining EF Abilities and Application**

The second major aim of this study was to determine whether a subgroup of adolescents exhibited a discrepancy between their underlying EF abilities (i.e., normal task performance) and the application of their abilities (i.e., impaired rating scores), and further, whether exhibiting such a profile moderated the association between the intervention an adolescent received and their treatment response. Latent profile analysis (LPA) indicated the presence of four subgroups when using task performance and rating scales as indicators of EF abilities. Consistent with study hypotheses, one of these groups exhibited better task performance in comparison to the other participants in the sample, but more impairment in their ratings. Of note, the Less Impaired Tasks/More Impaired Ratings profile contained the most individuals within the full sample (46%), reducing the likelihood that this group was found by chance. The presence of this discrepant group highlights the importance of a multi-method assessment of EF abilities within the ADHD population. When compared to other children with ADHD, these individuals could be viewed as either more or less impaired if only one assessment method is used. This discrepant group also aligns with recent theories of ADHD emphasizing that underlying EF abilities may be a contributing factor, but not the sole factor, that affects the behavioral impairment of youth with the disorder (Halperin & Schulz, 2006, Sonuga-Barke, 2005).

Two additional groups also emerged as hypothesized with a consistent EF profile for both task performance and ratings: one group exhibiting good EF abilities based across measures (Consistent: Less EF Impairment) and one group exhibiting poor abilities (Consistent: More EF Impairment). However, a fourth group emerged with an unexpected profile. This group (More Impaired Tasks/Less Impaired Ratings) also exhibited a discrepancy in their EF profile, but it was the inverse of the originally hypothesized group of interest. This group had the smallest

membership (8%), which makes it the group least likely to be replicated in future studies. Nonetheless, it presents an interesting contrast to the Less Impaired Tasks/More Impaired Ratings group. Recent models emphasize the potential for multiple developmental pathways that could each lead to the manifestation of ADHD and its associated impairment, and the models propose an important yet heterogeneous role for EF abilities in the etiology of ADHD (Halperin & Schulz, 2006; Sonuga-Barke, 2005). Given that all individuals in this sample have been comprehensively diagnosed with ADHD, these profiles may represent two subgroups of individuals with distinctly different influences of EF abilities on the development of the disorder. Therefore, further exploration and comparison of these subgroups appears warranted.

### **Moderation of Treatment Response by EF Profile**

In contrast to the three-way interaction models containing EF task performance and ratings as separate variables, results from the models using LPA profile membership as a moderator of the intervention condition – outcome relationship were somewhat supportive of study hypotheses. Specifically, membership in the Less Impaired Tasks/More Impaired Ratings profile was associated with greater improvement in parent-report HPQ scores and teacher-report Memory/Materials Management scores from the COSS. Given that organizational skills training programs such as HOPS seek to teach students how to apply effective planning and organizational skills to academic tasks, it would be expected that individuals who exhibit a deficit in their application of EF abilities would benefit most from HOPS (Langberg et al., 2013).

Of note, the finding that membership in the Poor Task/Good Rating profile was associated with significantly better post-intervention parent-report HPQ scores after receiving CHIEF instead of HOPS was unexpected. The finding is in part surprising because the profile itself was unexpected. However, in light of this subgroup's overall profile, a few factors may be

contributing to the result. First, given that these individuals show the best application of EF abilities to their daily life (i.e., the lowest BRIEF scores), they would not be expected to benefit as much from an intervention that teaches application of EF skills. Second, prior work has indicated that impaired performance on tasks measuring EF is strongly associated with general intellectual abilities, such as processing speed (Mahone et al., 2002). The CHIEF intervention provides students with additional time to complete assignments in a highly structured setting, which would be beneficial for students with deficits in processing speed or related cognitive abilities. Therefore, the low task performance exhibited within this subgroup may be indicative of impairment not with EF abilities, but with other cognitive abilities that affect academic functioning.

### **Comparison and Synthesis of Model Findings**

When comparing the results of all moderation models, a contradiction arises between the models using two EF variables as simultaneous moderators – one representing task performance and one representing ratings – and the models using latent profile membership as a moderator. When task performance and ratings were treated as separate variables, individuals exhibited better post-intervention outcomes after receiving HOPS if they exhibited a congruent pattern of EF. For two outcome measures, individuals who showed *more impairment* across both task performance and ratings appeared to benefit more from HOPS. Further, individuals who showed *less impairment* across both measures of EF also appeared to benefit more from HOPS, based upon post-intervention scores from the Organized Actions scale of the COSS. In contrast, the significant models using LPA profiles as a moderator indicated that individuals exhibited better post-intervention outcomes after receiving HOPS if they exhibited a discrepant pattern of EF abilities. Several potential explanations for these seemingly discrepant findings are worth

consideration. First, it is possible that reducing four task performance scores and two rating scales into one variable each (i.e., 1 overall task performance variable, 1 overall rating variable) for the multiple moderator models resulted in the loss of variability that was preserved through the LPA methodology. For example, if performance on one of the four variables was a particularly strong indicator of treatment response, its influence may have been attenuated by its integration with the other three task-related variables into a single, standardized factor score. Although this is currently considered the best-practice method for reducing multiple task performance variables into a single measure of EF abilities, it is not without limitations (Loo et al., 2007).

It is also important to highlight the possibility that ratings may provide more useful information for predicting treatment response than tasks. The generally low correspondence between tasks and ratings that are both thought to measure EF has led to an on-going debate about the clinical utility of tasks, given that ratings appear to have a stronger association with measures of functional impairment than tasks (Toplak et al., 2013). Given that three-way interactions were only observed in two models (and no models evaluating teacher-report outcomes), one could argue that EF ratings on their own provide as much meaningful information about potential treatment response as a combined evaluation of task performance and ratings. However, it is important to note that the primary treatment outcomes in this study were ratings. Accordingly, ratings alone may best predict treatment response due to shared method variance. It is possible that if neuropsychological tasks were collected post-intervention and used to evaluate treatment outcome that task performance at baseline would have increased predictive value.

Perhaps the more important trend, however, is that most models tested indicated that EF abilities, regardless of the measurement source, did not significantly moderate the association between the intervention provided and treatment response. Ten of the sixteen total models tested were nonsignificant, and no single rater or outcome measure exhibited a consistent association with EF abilities. Additionally, although the model evaluating parent-report scores from the COSS Organized Action scale found a significant three-way interaction term, receiving HOPS treatment was associated better post-intervention outcomes on its own. Further post-hoc examination of the 3-way interaction found that HOPS resulted in better post-intervention outcomes for seven of the nine EF configurations, suggesting the most parsimonious interpretation of this model may be that completing HOPS was associated with better post-intervention Organized Action scores, regardless of students' EF abilities. When evaluating the results as a whole, the overarching hypothesis that EF abilities would moderate students' response to treatment was not supported in the current study.

### **Implications**

Despite the lack of consistent moderation findings, there are a number of important implications for clinical practice. For example, clinicians and researchers have debated for some time whether the assessment of comorbid EF deficits should be included as part of a comprehensive, evidence-based ADHD evaluation. Proponents have cited the possible role of EF in the etiology of ADHD and argued that comorbid EF deficits could have implications for treatment (Holmes et al., 2010; McCandless & O'Laughlin, 2007). Prior interventions attempting to directly train basic EF abilities have been minimally effective for reducing functional impairment or ADHD symptom severity (Chacko et al., 2013; Rapport et al., 2013). However, EF abilities have been predictive of treatment outcomes for other common ADHD interventions

when comparing the intervention group to a waitlist control (Molitor & Langberg, 2017; Van der Oord et al., 2015). Results from the current study suggest that EF abilities – whether measured through tasks, ratings, or a combination – are not associated with differential treatment response when comparing two active interventions, even though one of the interventions targeted EF-related behavior (i.e., OTMP skills). Although broad conclusions cannot be drawn from a single study, considering these findings in the context of prior research suggests that EF abilities may be a factor that influences response to ADHD treatments broadly, rather than having intervention-specific effects. For example, EF abilities could plausibly affect a student’s ability to learn new skills and strategies and/or to self-monitor whether their behavior is effectively helping them achieve treatment goals. Deficits in these specific facets of EF would likely affect treatment response to HOPS, CHIEF, or nearly any behavioral intervention for ADHD.

The current study findings may also have intervention specific implications related to the proposed mechanisms of change. Specifically, these findings may indicate that HOPS, although targeting organization and planning skills, may not exert its effect directly through EF abilities. For example, HOPS includes the regular use of rewards for meeting behavioral goals; therefore, the frequency of OTMP skill use could increase because adolescents experience increased motivation to engage in the behaviors, rather than increased EF abilities. Overall, these findings suggest that additional research is needed to evaluate the proposed mechanisms of change for HOPS and CHIEF and specifically, whether change in homework related organization and planning skills is significantly associated with change in EF abilities.

Finally, the variability in task performance/rating presentations elicited via the latent profile analysis has important implications for research and clinical practice. Assessment of EF abilities is a common component of many ADHD evaluations, and prior research has generally

led to the expectation that EF task performance and rating scales will have low correspondence (Seidman, 2006; Toplak et al., 2013). However, although studies to date have generally examined this relationship through correlation coefficients, the current study examines the task-rating relationship from an individual-level perspective. Indeed, discrepant task-rating profiles were more common (54%) than congruent profiles (48%) across the full sample, but not as drastically as would be expected based on prior studies. Rather, adolescents appear to be nearly equally likely to show either similar or discrepant EF abilities depending upon the measures used. Importantly, recent research has indicated that EF task performance and EF ratings may be associated with distinctly different outcomes of interest for patients, families, and providers. For example, task performance is frequently associated with standardized measures of academic achievement (Molitor & Langberg, 2017). In contrast, rating scales tend to be more strongly associated with general indicators of functional impairment (e.g., parent/teacher perceptions of homework problems or peer rejection) (Langberg et al., 2013; McAuley et al., 2010). If adolescents are truly heterogeneous in their holistic EF tasks/rating profiles, as the current study suggests, then clinicians may choose to include a specific EF measurement method depending on the forms of impairment for which they are most interested in evaluating a student's risk. Alternatively, clinicians could take a multi-method assessment approach to comprehensively evaluate which forms of impairment an individual may be at increased risk for.

### **Future Directions**

Given that the current study did not support the hypothesized variables as predictors of differential treatment response, it is important to reflect on whether future treatment response research should use a similar approach. Most ADHD treatment response studies to date have examined either mental health (e.g., symptom severity and comorbid diagnosis) or



sociodemographic variables as predictors. These variables often exhibit robust effects because they exert their effect on general treatment factors. For example, comorbid depression or low-income status negatively impact families' ability to actively engage in, and consistently attend, treatment (Antshel & Remer, 2003; Langberg et al., 2010; Owens et al., 2003; Swanson et al., 2007). In most cases, the findings from these studies suggest that more mental health problems and lower resources are associated with worse treatment response. The clinical utility of these findings is arguably limited as the findings do not point to or inform alternate treatment options. Therefore, it remains important to continue seeking to identify factors that may predict differential treatment response between existing evidence-based interventions. Currently for many problems students experience, such as ADHD, practitioners have multiple treatment options, but little to no information on how to choose which treatment to use. As related to the current study, there are certainly additional variables that may predict differential response between HOPS and CHIEF. For example, individuals with a comorbid learning disability (LD) may be hypothesized to exhibit a significantly better response to an intervention more similar to CHIEF than HOPS, given that evidence-based interventions for LD emphasize increased time for students to practice using academic skills (Swanson, Harris, and Graham, 2013).

In addition to the identification and evaluation of theoretically-linked variables of treatment response, newer and more efficient methodologies for evaluating these variables should also be incorporated into future research. One prominent method emerging in the field is machine learning, which involves the construction of an algorithm that a computer system can use data to iteratively "learn" about the associations between variables that may predict a certain outcome (Yarkoni & Westfall, 2017). Over time, the system improves its predictive reliability by learning which combination of variables provides the maximum predictive capacity. This data-

driven approach has been used in studies focused on the accurate diagnosis of mental health disorders (Galatzer-Levy, Karstoft, Statnikov, & Shalev, 2014; Bone et al., 2016), and a few studies have incorporated it as a method for identifying predictors of treatment response (Chekroud et al., 2016; Johnston, Coghill, Matthews, & Steele, 2015). However, this approach suffers from a notable drawback. Specifically, machine learning requires access to very large datasets (Bzdok & Meyer-Lindenberg, 2018). As the field continues transitioning toward the integration of data and the formation of large data repositories, machine learning will likely play a role in the identification of factors that can predict differential response to intervention.

One set of findings from the current study that warrants follow-up investigation is the EF task/rating presentations elicited via LPA. Despite their lack of association with differential treatment response to the tested interventions, the profiles themselves raise important questions. For example, the two profiles that exhibited congruent functioning across EF measures (i.e., the “Consistently More EF Impairment” and “Consistently Less EF Impairment” profiles) stand in contrast to the idea that EF tasks and ratings do not correlate strongly with one another (Toplak et al., 2013). Notably, this is the first study to date to evaluate EF tasks and ratings via LPA. Therefore, it is possible that the common associations between these measurement methods are more easily observed through a holistic, individual-oriented analysis such as LPA. It should also be noted that the current study focused on specifically measuring the aspects of EF associated with planning/organization, whereas prior work has generally focused on more global measures of EF (Seidman, 2006; Toplak et al., 2013). In other words, more consistent associations between tasks and ratings may be observed when comparing measures that assess the same specific components of EF rather than EF abilities broadly. Future research is needed to determine if the ratings/tasks consistent profiles can be replicated via LPA in other samples and

to explore predictors of congruent profiles. It will also be important to evaluate how these profiles relate to the functional impairment youth with ADHD exhibit. Although EF undergoes significant development in adolescence, these abilities grow over the full course of childhood and well into young adulthood (Anderson et al., 2001; Luna et al., 2004). Thus, future research should evaluate whether individuals within different task/ratings profiles exhibit a discrepancy chronically, or whether the discrepancy emerges over time. Understanding the developmental trajectory of both facets of EF is essential for understanding its potential effects on the functioning of youth with ADHD.

On a similar note, the emergence of the More Impaired Tasks/Less Impaired Ratings subgroup is also worthy of additional study. This group is striking because individuals exhibiting poor task performance (i.e., impaired underlying cognitive abilities) would not be expected to have EF ratings in the non-clinical range (i.e., normative daily EF-related behavior). In some ways, this could be viewed as a resilient group that is able to compensate for a cognitive deficit to engage in appropriate behavior. Given the small number of individuals who were classified under this profile (8% of full sample), the likelihood of replicating this profile is lower than the other elicited profiles. However, if the profile is replicated, then follow-up studies focusing on the group are certainly warranted to understand how these youth compensate for underlying cognitive challenges in daily life.

### **Limitations**

The results of the current study should be interpreted in the context of several key limitations. First, EF measures were analyzed using raw scores rather than scaled scores calculated from normative data. Thus, scores can only be considered relative to individuals within this sample. This decision was made because no normative data is available for the BQSS

scoring system, which was used to evaluate ROCF performance. Unfortunately, this approach means that the EF abilities of participants in this sample can only be understood in comparison to other participants in the study, rather than to the abilities of a normative sample. Additionally, other EF measures – especially neuropsychological tasks – could have been included as part of the baseline assessment. Although the measures most commonly associated with planning and organization abilities were included, multiple EF abilities are thought to operate in conjunction with one another in the service of a behavior (Miyake et al., 2000). Indeed, the selection of specific tasks is an issue common to EF and ADHD research; one recent review found that 52 different measures of EF or attentional abilities were used across 42 studies (Molitor & Langberg, 2017). Testing participants' underlying EF abilities more comprehensively may have led to a more accurate assessment of true abilities and improved predictive utility.

Another notable limitation is the lack of a long-term follow-up evaluation of participants' response to treatment. The maintenance of treatment gains is as important as the initial gains, and youth with ADHD tend to exhibit some regression after completing a behavioral intervention (Murray et al., 2008). In the context of the current study, it is possible that EF abilities and/or the application of abilities may have more of an effect on an individual's ability to maintain their improvements after learning skills through HOPS than on their ability to initially learn and apply the skills. However, it should be noted that the main outcome study comparing all three time points found minimal change between the immediate post-intervention and 6-month follow-up time point (Langberg et al., 2017), making it unlikely that examination of this additional data would lead to significantly different outcomes than current analyses.

### **Conclusions**

As more interventions are developed to address common academic impairments that youth with ADHD experience, mental health providers need strategies to help them select the most appropriate interventions. The current study sought to evaluate whether EF abilities would be associated with differential response to an organizational skills intervention in comparison to a homework completion support intervention. Results indicated that EF abilities were not consistently associated with differential treatment response, although a unique subgroup of adolescents was identified that exhibited a discrepancy in underlying EF abilities and the application of those abilities. Despite the nonsignificant findings, this study offers a framework for examining whether variables associated with intervention mechanisms of action may predict differential treatment response.

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