2018

Early Adversity and Executive Dysfunction in Children with Attention Deficit Hyperactivity Disorder

Jennifer Amato
Antioch New England Graduate School, jamato1@antioch.edu

Early Adversity and Executive Dysfunction in Children with Attention Deficit Hyperactivity Disorder

by

Jennifer Amato

B.A., Keene State College, 2011
M.A., Union Institute and University, 2013
M.S., Antioch University New England, 2017

DISSERTATION

Submitted in partial fulfillment of the requirements for the degree of
Doctor of Psychology in the Department of Clinical Psychology
of Antioch University New England, 2018

Keene, New Hampshire

Department of Clinical Psychology

DISSERTATION COMMITTEE PAGE

The undersigned have examined the dissertation entitled:

EARLY ADVERSITY AND EXECUTIVE DYSFUNCTION IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

presented on October 4, 2018

by

Jennifer Amato

Candidate for the degree of Doctor of Psychology
and hereby certify that it is accepted*.

Dissertation Committee Chairperson:
Martha B. Straus, PhD

Dissertation Committee members:
Theodore Austin, PsyD
Jonathan Lichtenstein, PsyD

Accepted by the
Department of Clinical Psychology Chairperson
Lorraine Mangione, PhD

on **10/4/18**

Table of Contents

List of Tables

List of Figures

Abstract

This dissertation was designed to inform the existing literature gap regarding variability in Executive Dysfunction on neuropsychological assessment tasks in children with attention deficit/hyperactivity disorder (ADHD). The two primary objectives of the study included: (a) evaluation of the relationship between number of adverse childhood events (ACEs) and performance on neuropsychological tasks of executive functions (EF; as measured by neuropsychological test results on Color–Word Interference, Verbal Fluency, Trail Making Test, and Semantic Clustering) for children with ADHD; and (b) evaluation of the relationship between number of ACEs and behavioral impairment on parent ratings of EFs (as measured by the Inhibit, Task Completion, Shift, and Planning/Organization scales on the BRIEF) for children with ADHD. Archival data derived from neuropsychological and behavioral assessment were used to evaluate 107 children diagnosed with ADHD. Eight separate linear regressions for the two families of dependent variables (i.e., four cognitive variables and four behavioral variables) were conducted. Number of ACEs significantly predicted neurocognitive shifting performance, as well as parent-reported behavioral problems with inhibition, set shifting, and self-monitoring. Findings support the hypothesis that children with ADHD who have experienced higher levels of adversity can be expected to show greater deficits on some neuropsychological measures of executive functioning and to be rated by their parents as demonstrating a higher level of behavioral dysregulation when compared to same-age peers with ADHD and lower levels of adversity. Results suggest that the experience of early adversity is a potential developmental pathway to ADHD symptomology.

Keywords: ADHD, adverse childhood events, executive functions

Early Adversity and Executive Dysfunction in Children with Attention Deficit Hyperactivity Disorder

Statement of the Problem

In this dissertation, I describe a study designed to explore the variability in executive dysfunction on neuropsychological assessment tasks in children diagnosed with attention deficit hyperactivity disorder (ADHD). ADHD is the most commonly diagnosed neurodevelopmental disorder, affecting 5% to 11% of all school-aged children (Leung & Hon, 2016). Approximately 40% of children with ADHD experience debilitating symptoms into adulthood (Leung & Hon, 2016). Those with untreated symptoms are at an increased risk for a variety of psychological, functional, and social problems (Leung & Hon, 2016). In the effort to acknowledge the widespread variability among children with ADHD, researchers have proposed a developmental heterogeneity model suggesting multiple developmental pathways. According to this model, different etiological factors are responsible for the diverse behavioral and cognitive symptom constellations in children with ADHD (Fair, Bathula, Nikolas, & Nigg, 2012; Johnson, 2015; Songua-Barke, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Despite widespread prevalence, a great deal of information remains unknown regarding etiology, heterogeneity in cognitive and behavioral profiles, and discrepancies in long-term treatment outcome.

ADHD symptomology is associated with structural and neurobiological differences in the frontal lobes when comparing ADHD to non-ADHD children (Barkley, 1997). Functionally, deficits in executive functions (EFs), mediated by the prefrontal cortex (PFC), are often associated with ADHD. These abilities include flexible, goal-directed behavior, inhibition, self-regulation, and insight into the self and others (Arnsten, Raskind, Taylor, & Connor, 2015; Barkley, 1997). Although neuropsychological assessment is often used in the diagnosis of

ADHD, approximately 70% of diagnosed children do not demonstrate these executive deficits during neuropsychological assessment (Willcutt et al., 2005). The remaining 30% of children with ADHD have been identified as a subgroup within the ADHD population (Anderson, Jacobs, & Anderson, 2010; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2003; Sonuga-Barke, 2005).

This study examined the role of adverse childhood events (ACEs) known to interfere with EFs (independent of ADHD) as a possible explanation for this neuropsychological variability within the pediatric ADHD population. Findings can be used to inform conceptualization regarding potential neurodevelopmental pathways associated with ADHD, guide prevention strategies, and increase treatment efficacy.

Background

ADHD is both genetically and environmentally determined, with a 70–80% heritability rate (Freitag et al., 2012). Environmental risk factors are thought to account for 20–30% of the phenotypic variability in ADHD symptoms, although similar influences potentially impact rates of heritability (e.g., intergenerational trauma, socioeconomic status, mental health of caregivers; Faraone et al., 2005). Recently, a robust body of literature has established a strong correlation between childhood stress and ADHD. For example, the frequency of ADHD is higher in children who are adopted, have spent time in orphanages, have lived in foster care (Sonuga-Barke & Rubia, 2008), grew up in an impoverished community in the United States (Froehlich et al., 2007), live in families that have incomes below the poverty level, or live in a single parent household (U.S. Department of Health and Human Services, National Center for Health Statistics, 2011). Similarly, ADHD is more frequently diagnosed in children living in areas with high levels of community trauma (Ford, Goodman, & Meltzer, 2004; Heiervang et

al., 2007; Luna, 2006; Perry-Burney, Logan, Denby, & Gibson, 2007), and among survivors of interpersonal trauma (Briscoe-Smith & Hinshaw, 2006; Davids & Gastpar, 2005; Endo, Sugiyama, & Someya, 2006; Husain, Allwood, & Bell, 2008; Mulsow, O'Neal, & Murry, 2001; Weinstein, Staffelback, & Biaggio, 2000). Considering the relationship between psychological or environmental stressors and ADHD symptomology, it is recommended best practice to evaluate such exposure when considering a diagnosis of ADHD (American Psychiatric Association, 2013).

Further supporting this association, behavioral and cognitive symptomology of children who have experienced trauma and those with ADHD are quite similar. Both populations suffer from central deficits in limbic and prefrontal regions, likely causing impairment in inhibitory control and regulation (Arnsten et al., 2015). For example, the symptoms most frequently experienced after trauma exposure include problems with inhibition (e.g., symptoms of intrusion, recurring memories, avoidance of stimuli, intense hypervigilance, and inattention; Arnsten et al., 2015). Notably, these symptoms all involve the executive system, which is responsible for directing attention to important stimuli while screening out or inhibiting activation in response to irrelevant stimuli. Furthermore, traumatic stress, like ADHD, is associated with aggressive and irritable behavior, temper outbursts, reckless behavior, problems with concentration, and sleep disturbance. Each of these symptoms is a consequence of prefrontal dysfunction (Arnsten et al., 2015).

Despite the many similarities in patterns of impairment, there are several criteria that aid in the process of differential diagnosis between children with ADHD and those who have been traumatized. For instance, children who have experienced trauma are thought to engage in risky behaviors due to affective instability and attempts to self-soothe, whereas a child with ADHD

may be more likely to act out impulsively. Furthermore, although children in both groups struggle with self-regulation, children with ADHD typically do not suffer from underlying emotional distress (Reyes-Preez, Martinez-Taboas, & Ledesma-Amador, 2005). The traumatized child may have attentional, affective, interpersonal, or somatic dysregulation. Children with trauma histories tend to experience more extreme impulsivity, hyperactivity, and hyperarousal compared to their non-traumatized peers with ADHD (Reyes-Preez et al., 2005).

Additional differences in etiology become apparent when looking at response to treatment. Children contending with both ADHD and traumatic exposure are foremost among those in the ADHD population who respond poorly to disorder-specific treatments. Standard ADHD interventions insufficiently address the critical factors (e.g., neurocognitive deficits, family dysfunction, social struggles, and academic difficulties) occurring when ADHD is associated with a trauma history (Chacko, Kofler, & Jarret, 2014). These children experience improvement in functioning and symptom reduction only when provided with trauma-focused interventions addressing affect regulation, attention and consciousness, interpersonal skills, and attributions and schemas (D'Andrea, Ford, Stolback, Spinazzola, & Van der Kolk, 2012). Due to the significant comorbidity between ADHD and trauma-related diagnoses, recent reviews suggest that future researchers work to differentiate between regulatory dysfunction in children with ADHD and those with trauma histories (D'Andrea et al., 2012). Understanding and meeting the complex needs of children with both ADHD and a trauma history would improve treatment effectiveness for this high-risk group.

Objectives

Two primary objectives guided this study: (a) to evaluate the relationship between number of ACEs and performance on neuropsychological tasks of EFs (as measured by

neuropsychological test results on Color–Word Interference, Verbal Fluency, Trail Making Test, and Semantic Clustering) for children with ADHD; and (b) to evaluate the relationship between number of ACEs and behavioral impairment on parent ratings of EFs (as measured by the Inhibit, Task Completion, Shift, and Planning/Organization scales on the BRIEF) for children with ADHD. Research furthering our understanding of multiple etiological pathways to ADHD will help in the development of more accurate and incisive conceptualization and treatment strategies and aid in interpretation of assessment results of children with ADHD. Additionally, considering the overlap between the symptoms of children with ADHD and those with trauma, as well as the variability in ADHD symptomology, it is useful to determine strategies that aid in discriminating between children with ADHD alone and ADHD with trauma.

Conceptual Framework: The Executive Control Model

The theoretical underpinning of the proposed study is the executive control model (Anderson, 2002), a framework that is based in developmental neuropsychology research. This theory: (a) identifies the influence of development on the prefrontal cortex, making this area of the immature brain more susceptible to early childhood adversity; and (b) acknowledges specific neurodevelopmental stages which, if disrupted, might account for cognitive and behavioral differences among individuals with ADHD.

EFs are commonly referred to as higher order functions, representing advanced human cognition underpinning intellectual functioning, self-control, and social interaction. Together, these abilities constitute the central control processes that connect, prioritize, and integrate cognitive functioning. When working together, EFs generate the mental representations required for flexible, goal-directed behavior as well as the ability to inhibit inappropriate impulses,

regulate attention, and generate insight into the actions of the self and others (Arnsten et al., 2015; Barkley, 1997; Blakemore & Robbins, 2012; Goldman-Rakic, 1996). Researchers continue to expand the umbrella of functions related to EFs to include aspects of social functioning as well as organizing, directing, and determining emotional responses and behavior (Roth, Isquith, & Gioia, 2014). EFs are important across many different domains of functioning and are implicated in physical health, quality of life, school readiness, school success, job success, marital harmony, and public safety (Bailey, 2007; Borella, Carretti, & Pelegrina, 2010; Broidy et al., 2003; Brown & Landgraf, 2010; Crescioni et al., 2011; Eakin et al., 2004). Furthermore, executive dysfunction plays a role in a variety of mental health disorders including addiction (Baler & Volkow, 2006), ADHD (Diamond, 2005), conduct disorder (Fairchild et al., 2009), depression (Taveres et al., 2007), obsessive-compulsive disorder (Snyder, Kaiser, Warren, & Heller, 2015), and schizophrenia (Dirnberger, Fuller, Frith, & Jahanshahi, 2014).

Though the definition and range of skills that are related to EFs vary, factor analytic studies using outcome parameters from a variety of EF tests suggest EF variables load primarily onto four factors: (a) attentional control, (b) information processing, (c) cognitive flexibility, and (d) goal setting (Anderson, 2001). Each factor is assumed to be related to different prefrontal networks, though these networks are proposed to utilize bidirectional communication (Anderson, 2001). Level of input from each of the systems is determined by the task at hand. The four key elements of executive functioning as described by Anderson include several other components thought to fall under the umbrella term EF. These include anticipation and deployment of attention, impulse control and self-regulation, initiation of activity, working memory, mental flexibility, utilization of feedback, planning, organization, and selection of

efficient problem-solving strategies. Although these functions are defined and assessed separately, there is overlap in their intercommunication and functional use.

Several proposed theoretical models of ADHD describe executive dysfunction as a framework for understanding behavioral symptomology associated with the disorder (e.g., Anderson, 2002; Baddeley, 2000; Barkley, 2006; Stuss, Shallice, Alexander, & Picton, 1995). However, although multiple theories have been offered, none have been able to account for the widespread cognitive and behavioral variability found in children with ADHD. Furthermore, few of these theories take into consideration the impact of early environmental stress on the development of EFs. The executive control model addresses the shortcomings of other theoretical frameworks by attending to the potential impact of early adversity on the development of EF. The following section describes each of the four primary executive components included in the executive control model, along with the variety of functions each domain comprises.

Attentional control. Attentional control is crucial for proper functioning of other executive domains, as it involves the capacity to sustain attention and attend to specific stimuli while inhibiting more dominant responses. Common functions included in this domain are selective attention, self-regulation, self-monitoring, and inhibition. In the executive control model, attentional control involves regulation and monitoring of actions for goal-directed activity (e.g., ensuring steps are executed in the correct order and errors are identified). Children lacking this capacity tend to be impulsive, struggle with self-control, fail to complete tasks, make procedural mistakes, and are less likely to self-correct.

Attentional control is expected to increase over the course of development. Infants younger than nine months habitually fail to inhibit responses; however, after one year, infants

begin to both inhibit behaviors and show the ability to shift to a different response (Diamond & Doar, 1989). At the age of three years, children have the ability to inhibit the response of an instinctual behavior, although they make perseverative errors while doing so. Around six years of age, children can often incorporate attentional control with other cognitive abilities, developing speed and accuracy in behavioral response (Diamond & Taylor, 1996).

Information processing. Information processing involves fluency, efficiency, and speed of processing and output speed, reflecting a variety of neural connections and functional integration of frontal systems. This domain is composed of the capacity to access, retrieve, and vocalize information. Individuals struggling in this area tend to generate reduced output and delayed responses, be more hesitant, and have slower reaction times than their peers. Information processing is typically assessed through tasks of verbal fluency. Children between about three and five years of age tend to demonstrate verbal fluency with basic information. The ability to process more complex information quickly and with fluency continues to develop throughout childhood and into adolescence (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001).

Cognitive flexibility. Cognitive flexibility refers to the ability to switch from one thought to the next. Included in this domain is the capacity for divided attention, working memory, and utilization of feedback. Children with well-developed cognitive flexibility have the ability to shift between response sets, learn from mistakes, adapt to a situation or new rules, divide attention, and process a variety of pieces of information at the same time. Cognitive flexibility requires active working memory—the ability to hold and manipulate mental information. Children who are cognitively inflexible tend to be rigid and ritualistic, experience difficulty with change, and fail to adapt to new demands. These children tend to be

perseverative in their pattern of making mistakes (i.e., repeatedly making the same mistake despite external feedback). Cognitive flexibility, while absent in infancy, becomes well established by early- to middle-childhood. The capacity for set shifting (shifting attention between one task and another) develops between the ages of three and four years; however, abiding by more complex rules and switching behavior that is contingent on multiple dimensions develops more typically between the ages of seven and nine years (Anderson et al., 2001).

Goal setting. Goal setting refers to the ability to create new concepts and plan actions ahead of time. Skills included in this domain are conceptual reasoning, the ability to plan, strategic organization, and capacity for taking initiative. Such functions describe the capacity to plan actions in advance and engage in work with a strategic mindset. Children who have difficulty with goal setting show poor problem solving and inadequate planning, are not organized, struggle to create efficient strategies, and have poor conceptual reasoning. Children as young as four years of age may demonstrate the capacity to set goals and exhibit conceptual reasoning (Jacques & Zelazo, 2001; Welsh, Pennington, & Groisser, 1991). The ability to plan and organize information develops between the ages of seven and 10 years and continues into adolescence (Anderson, Anderson, & Lajoie, 1996; Krikorian & Bartok, 1998).

The executive control model and early adversity. Early childhood adversity may play a significant role in the development of EFs and might explain some of the variability seen in neuropsychological assessment of children with ADHD. Biological, psychological, and social factors interact over the course of childhood, leading to diverse developmental trajectories. According to Anderson's model, functional impairment can result from injury, causing these cerebral networks to be abnormal or never mature (Anderson et al., 2010). Developmentally,

children with ADHD show deficits beginning in early life when compared to their non-ADHD peers (Barkley, 2001; Willcutt et al., 2005). For children with traumatic exposure, the degree to which EF is impaired may be shaped by the interaction of biological, psychological, and social factors over the course of childhood and specifically the impact of stress on the developing brain.

Literature Review

Attention Deficit Hyperactivity Disorder

As defined by the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (*DSM-5*), ADHD is a disorder of age-inappropriate levels of inattention and/or impulsiveness and hyperactivity, occurring in approximately five million children and adolescents in the United States alone, and likely affecting as many as 26 million children worldwide (Leung & Hon, 2016). Though some studies suggest increasing prevalence (e.g., Pritchard, Nigro, Jacobson, & Mahone, 2012), other researchers argue that prevalence in the United States remains at about eight percent of youth (Froehlich et al., 2007). According to *DSM-5* diagnostic criteria, symptoms of ADHD must be present prior to age 12 and occur throughout childhood. The *DSM-5* describes three presentations of ADHD: (a) predominantly hyperactive-impulsive presentation, (b) predominantly inattentive presentation, and (c) a combined presentation of inattention and hyperactivity (American Psychiatric Association, 2013). Among children in the United States ages 8–15 years old, approximately twice as many are diagnosed with the predominantly inattentive subtype (4.3%) as compared to both the combined presentation (2.2%) and the predominantly hyperactive-impulsive type (2.0%). Children with the combined presentation make up the majority of referrals for mental health services (Aguiar, Eubig, & Schantz, 2015).

Guidelines for assessment and diagnosis of ADHD developed by the American Academy of Pediatrics include evidence of *DSM-5* criteria in multiple settings and evaluation of possible coexisting disorders (Conway, Oster, & Szymanski, 2011). Although not required, neuropsychological assessment is commonly considered in the diagnosis of ADHD. Data generated from the clinical interview combined with cognitive assessments provide a comprehensive biopsychosocial understanding of the child (Pritchard et al., 2012).

Neuroanatomical and functional differences have been found between boys and girls with ADHD (Seymour, Mostofsky, & Rosch, 2016). Further, symptom patterns differ depending on gender. For instance, girls display greater intellectual impairment, lower levels of hyperactivity, and lower rates of externalizing behaviors (Gaub & Carlson, 1997). Cultural differences have also been observed—namely social and behavioral expectations and norms vary within different racial and ethnic groups (Nigg, 2006). Racial disparities in health care and outcomes related to access to treatment and biopsychosocial stressors are also important to consider. However, there are few studies from which to generalize findings in regard to gender and cultural differences (Nigg, 2006).

Comorbidity. Adding to diagnostic complexity is the high rate of comorbidity between ADHD and other disorders. Approximately 60% of children with ADHD also meet criteria for oppositional defiant disorder, 50% for mood disorders, 33% for anxiety disorders, 30% for language or learning disorders, 26% for conduct disorders, and 20% for autism spectrum disorders (Leung & Hon, 2016).

Most notable for the current study, the comorbidity of ADHD and post-traumatic stress disorder (PTSD) has been found to be anywhere between 12% and 37% (Martinez, Prada, Satler, Tavares, & Tomaz, 2016). Furthermore, children with behavioral and cognitive

symptoms of ADHD often meet criteria for other disorders whether or not they are given more than one diagnosis. For example, symptoms such as difficulty concentrating, inattention, motor restlessness, and racing thoughts are common in a variety of emotional/behavioral disorders of childhood (Pritchard et al., 2012). To further complicate diagnostic clarity, a variety of medical conditions (e.g., thyroid dysfunction, eczema, and hearing loss) can both mimic and amplify many of these symptoms (Feagans, Kipp, & Blood, 1994; Hauser et al., 1993; Kooistra, van der Meere, Vulsma, & Kalverboer, 1996; Pritchard et al., 2012; Schmitt, Romanos, Schmitt, Meurer, & Kirch et al., 2009). Additionally, children with comorbid ADHD have more severe emotional problems associated with diagnoses of depression, anxiety, bipolar disorder, conduct disorder, and PTSD then those without ADHD (Leung & Hon, 2016).

Significance. ADHD is the most common reason for mental health referrals in children; however, the diagnosis is also increasingly common in adults (Antshel, Heir, & Barkley, 2014). The diagnosis and treatment of ADHD carries financial, developmental, and societal costs. ADHD is an expensive disorder, costing approximately $42 billion dollars annually, and placing significant burdens on medical and mental health services, schools, and families (Chacko et al., 2014). The educational costs for individuals, schools, and families include academic failure, school suspension, expulsion, peer rejection, bullying, adult disapproval, and decreased self-esteem (Antshel et al., 2014). Moreover, children diagnosed with ADHD are more likely to engage in risk-taking behaviors as teenagers (e.g., smoking cigarettes, using substances, and fast and distracted driving resulting in higher rates of motor vehicle accidents), leading to elevated social and medical costs (Leung & Hon, 2016). Symptoms of ADHD often persist into adulthood; adult ADHD is associated with poor workplace performance, pathological gambling, internet addiction, marital disharmony, and unemployment (Leung & Hon, 2016).

Despite numerous evidence-based strategies for symptom management, psychosocial interventions do not typically generalize to non-treatment settings and are rarely sustainable over a period of time. Further, pharmacological interventions insufficiently address impairment associated with deficits in EFs (Chacko et al., 2014).

ADHD and the brain. Evidence for structural abnormalities comes from functional neuroimaging in children with ADHD. These abnormalities include decreased total brain volume; delayed cortical maturation (particularly in the frontal and temporal regions); and abnormalities in the corpus callosum, prefrontal regions, temporal and parietal cortex, striatum, and basal ganglia (Filipek et al., 1997; Geidd, Castellanos, Casey, King, & Hamburger, 1994; Hill, Yeo, Campbell, Hart, Vigil, & Brooks, 2003; Pritchard et al., 2012; Sowell et al., 2003). Atypical development of the basal ganglia in combination with cerebellar and cortical developmental delays tends to be associated with difficulties in behavior inhibition and delay aversion, or the motivation to avoid delay (Sonuga-Barke & Halperin, 2010). Evidence suggests that cognitive, motor, and oculomotor deficits accompanying ADHD are associated with deficient basal ganglia development and widespread cerebellar and cortical delays (Pritchard et al., 2012). Children with ADHD also have decreased volume in the dorsolateral prefrontal cortex, an area associated with EF, in comparison with non-ADHD children (Seidman, Valera, & Makris, 2005).

The prefrontal cortex. The prefrontal cortex has been subdivided into numerous regions responsible for different functions, each utilizing distinct neural circuitry. The prefrontal cortex is divided into the anterior cingulate cortex, the prelimbic cortex, the infralimbic cortex, the dorsal peduncular cortex, the dorsolateral orbital cortex, the lateral orbital cortex, and the central orbital cortex. These domains are then grouped into two subregions: (a) the medial

prefrontal cortex (mPFC) and (b) the orbital prefrontal cortex (oPFC). The mPFC includes the anterior cingulate cortex, prelimbic cortex, infralimbic cortex, and the dorsal peduncular cortex. The oPFC includes the dorsolateral, lateral, medial, and ventral orbital cortices. All regions receive input from a variety of neurotransmitters including dopamine (DA), norepinephrine (NE), serotonin (5-HT), and acetylcholine (ACh; Logue & Gould, 2014).

Several of the structural regions implicated in the functional impairment of ADHD communicate through complex neural systems linking specific regions of the frontal lobes to subcortical structures. fMRI evidence has demonstrated altered cortical-striatal circuitry in individuals with ADHD (Aguiar et al., 2015), involving the dorsolateral prefrontal and dorso-anterior cingulate cortices, the dorsal striatum, the thalamus, and the cerebellum (Vaidya & Strollstorff, 2008). These systems are responsible for modulating and executing specific mechanisms and governing the way in which individuals interact with the environment. These neural networks include frontal projections to the basal ganglia and cerebellum, which form several frontal-striatal-thalamo-frontal and frontal-cerebellum-dentate-frontal circuits (Durston, 2010; Krause et al., 1990).

The frontal subcortical circuits, including the dorsolateral prefrontal circuit, are involved in organizing information to facilitate a response. Primarily, the orbitofrontal circuit communicates with the limbic system to determine the appropriate emotional and behavioral response to environmental information (Martinez et al., 2016). While the dorsal striatum is utilized in modulating and controlling responses, the cerebellum coordinates motor activities and timing and shifting of attention (Krain & Castellanos, 2006). The anterior cingulate cortex is involved in cognition and motor control underlying arousal (Makris, Biederman, Monuteaux, & Seidman, 2009). Together, these complex subcortical circuits and neuronal interactions play a

role in planning and organization of behavior, working memory, and response inhibition (Nigg et al., 2008).

Neuropsychological assessment of children with ADHD. Neuropsychological assessment of children with ADHD is typically used to evaluate EF capacity. Children with ADHD have been shown to have deficits in EF; however, many children without ADHD also display a similar constellation of neuropsychological symptoms. One meta-analytic study demonstrated significant impairment in executive functioning in children both with and without ADHD (Barkley, 2006); impairment is quite variable even within ADHD samples (Willcutt et al., 2005). Additionally, some children with ADHD do not show impairment in EFs (Willcutt et al., 2005). Inconsistencies found in the degree of executive impairment in ADHD-affected samples suggest that ADHD may not be a monolithic construct. However, some researchers attribute the variability in findings more to methodological problems and not accounting for potential confounding variables (e.g., small sample size, low statistical power, restrictive inclusion criteria, changing diagnostic criteria, not differentiating between subtypes of ADHD, inconsistency in tasks used to measure EF, age, sex, ethnicity, comorbidities, intelligence, and statistical methodology; Weyandt et al., 2016).

Across ADHD subtypes, a large meta-analysis found that among those who exhibit EF deficits, the most profound impairments in children with ADHD were found on measures of inhibition, vigilance, working memory, and planning (Willcutt et al., 2005). Across several studies, response inhibition has been shown to be consistently impaired in ADHD (Barkley, 2006; Mahone & Hoffman, 2007; Willcutt et al., 2005; Wu, Anderson, & Castiello, 2002). For example, in contrast with children without an ADHD diagnosis, children with ADHD demonstrate impairment on tasks requiring them to inhibit an automatic response and instead

engage in a less intuitive one (Fair et al., 2012; Willcutt et al., 2005). They also struggle to inhibit their responses on measures of visual motor integration and fine motor control (Alderson, Rapport, & Kofler, 2007; Barkley, DuPaul, & McMurray, 1990; Lijffijt, Kenemans, Verbaten, & van Engeland, 2005; Pitcher, Piek, & Hay, 2003), and show deficits in cognitive flexibility and planning (Barkley, 1997; Fair et al., 2012).

Additionally, when compared to their typically developing peers, children with ADHD tend to have greater difficulty on both verbal and visual measures of working memory including repetition of digit spans forward and backward (Willcutt et al., 2005), as well as speeded tasks of fluency involving a motor component (Barkley, 2006; Carte, Nigg, & Hinshaw, 1996; Willcut et al., 2005). Finally, children with ADHD repeatedly show deficits in verbal fluency (Barkley, 2006) and on non-automatized language tasks (Carte et al., 1996; Sergeant, Geurts, & Oosterlaan, 2002).

Childhood Trauma

Child maltreatment includes childhood sexual, physical, and emotional abuse (Teicher & Samson, 2013). By some estimates, child maltreatment accounts for approximately 45% of the variance in the development of early-onset psychiatric disorders (e.g., Teicher & Samson, 2016). One study suggests that somewhere between 13% to 42% of children on a year-to-year basis are exposed to one or more kinds of maltreatment, spanning across infancy to 18 years (Teicher & Samson, 2013). Children who have experienced maltreatment are more likely to develop psychiatric disorders with greater severity and more comorbidity; they are also less responsive to treatment than their non-maltreated peers (Nanni, Uher, & Danese, 2012). Children who have sustained early traumatic stress have been found to exhibit greater cognitive weaknesses in comparison with those who have not (Masson, Bussières, East-Richard, Mercier,

& Cellard, 2015), and are more likely to suffer compromised psychological and physical functioning. The effects associated with early maltreatment are pervasive across cognitive, emotional, physiological, behavioral, and social systems, causing impaired functioning throughout adolescence and into adulthood (Teicher & Samson, 2016).

Diagnostic challenges. Traumatized children are described diagnostically and conceptually in a variety of ways. Many researchers in the field of child trauma have argued the existing diagnostic nomenclature does not accurately represent the breadth and depth of symptom diversity seen in this population (De Bellis, 2001; Teicher & Samson, 2013; Van der Kolk, 2005). For example, different kinds of trauma, levels of exposure, and durations of trauma have been shown to result in different behavioral and cognitive presentations (Van der Kolk, 2005). In regard to the assessment of traumatized children, methods of categorizing trauma have included measuring trauma exposure without consideration of diagnosis, differentiating type of trauma, distinguishing acute vs. chronic PTSD, and categorizing based on the additional diagnoses comorbid with PTSD.

The term *developmental trauma* has been proposed as a more accurate description capturing the population of children exposed to interpersonal violence and disruptions in caregiving over time (Van der Kolk, 2005). Van der Kolk offered this term after recognizing the broad impairment and distress characterizing children and adolescents who have been abused and neglected. Research suggests that chronic child maltreatment at the hands of a primary caregiver has the most devastating effects. This type of maltreatment often entails sustained or repeated exposure to traumatic events, typically resulting in betrayal of trust (De Bellis, 2001) and deficits in attention, consciousness, and cognition (D'Andrea et al., 2012).

Developmental trauma involving repeated exposure to adverse events is associated with long-term effects, including a wide spectrum of psychological and medical disorders and shortened life expectancy (Teicher & Samson, 2013). Adult survivors tend to show a higher prevalence of emotional difficulties such as depression, anxiety, substance abuse, eating disorders, suicidality, psychosis, and personality disorders (Ball & Links, 2009; Teicher & Samson, 2016).

PTSD is defined as the exposure to a traumatic event, which results in re-experiencing phenomena (i.e., intrusive memories, flashbacks, and nightmares), avoidance of stimuli associated with the trauma, alterations in arousal and reactivity, negative alterations in cognitions and mood, and generalized hyperarousal (Sripada et al., 2013). Children with PTSD can be traumatized by an impersonal experience (e.g., bus accident, severe storm) or interpersonal experience (e.g., child abuse). Prevalence rates for pediatric PTSD suggest that five percent of children will develop PTSD by 18 years of age (Wolf & Herringa, 2016). Most children who have endured developmental trauma do not meet full criteria for PTSD. For example, they do not report the re-experiencing, avoidance, and hyperarousal consistent with PTSD; rather, they have extreme problems with affective and behavioral regulation and may have no specific memories of discrete traumatic events (Courtois, 2008; Straus, 2017). With the absence of a diagnosis for developmental trauma, the diagnosis of PTSD is frequently applicable to children who have a range of traumatic exposures (including children who have experienced a single traumatic event), as well as those children who have experienced chronic or pervasive events that result in cumulative traumatic exposure.

Chronic lower level adversity can be traumatic. Just as an established body of research has documented the detrimental biopsychosocial effects of single and repeated

episodes of trauma, studies evaluating chronic stress have yielded similar results. In an extensive study of the impact of stress on the brain, Lupien, Ouellet-Morin, Herba, Juster, and McEwen (2016) describe the brain's inability to discriminate between an absolute stressor (e.g., being attacked, being chased, experiencing natural disasters), and a relative or situational stressor (e.g., meeting deadlines, being stuck in traffic, doing homework, etc.). Therefore, similar physiological effects of stress occur regardless of the actual level of threat involved. Lupien et al. identified four conditions that activate the stress response system: situations of novelty, unpredictability, threat to one's sense of self, and decreased sense of control. Their research suggests that, from a historical perspective, modern-day individuals experience activation of the stress response system more often and to a greater degree compared to our ancestors. Consequently, it is probable that children living in environments of chronic stress (e.g., poverty, community violence, parents' mental health and substance abuse problems), may suffer many of the same neurodevelopmental consequences as their abused and neglected peers (Lupien et al., 2016).

Adverse Childhood Events (ACEs). ACEs are defined as traumatic occurrences experienced to be physically or emotionally harmful and occurring prior to the age of 18 (Felitti et al., 1998). This term encompasses the breadth of exposure to different adversities but does not capture the relative duration of adverse events. Measuring ACEs is now a widely-accepted means of classifying early adversity, used in hundreds of studies conducted across the United States. In the original 1995–1997 ACEs study conducted for Kaiser Permanente in California, using a largely white, middle-class sample (Felitti et al., 1998), ACEs were quantified by asking the following questions, yielding a sum total of zero to ten ACEs. Each endorsement of an item is classified as one ACE.

1. Did a parent or adult in the household often swear at you, insult you, put you down, or humiliate you? Or, act in a way that made you afraid that you might be physically hurt?
2. Did a parent or other adult in the household often push, grab, slap, or throw something at you? Or ever hit you so hard that you had marks or were injured?
3. Did an adult or person at least five years older than you ever touch or fondle you or have you touch their body in a sexual way? Or, try to or have oral, anal, or vaginal sex with you?
4. Did you often feel that no one in your family loved you or thought you were important or special? Or, that your family didn't look out for each other, feel close to each other, or support each other?
5. Did you often feel that you didn't have enough to eat, had to wear dirty clothes, and had no one to protect you? Or, that your parents were too drunk or high to take care of you or to take you to the doctor if you needed it?
6. Were your parents ever separated or divorced?
7. Was your mother or stepmother: Often pushed, grabbed, slapped, or had something thrown at her? Or sometimes or often kicked, bitten, hit with a fist, or hit with something hard? Or ever repeatedly hit over at least a few minutes or threatened with a gun or knife?
8. Did you live with anyone who was a problem drinker or alcoholic or who used street drugs?
9. Was a household member depressed or mentally ill or did a household member attempt suicide?
10. Did a household member go to prison?

Researchers followed 17,421 individuals separating them into two categories: (a) four or more or (b) three or fewer experiences of early adversity. Results from this study provided evidence for the ubiquity of significant traumatic stress, whether it might be classified as abuse or household dysfunction. Felitti et al. (1998) concluded that not only are ACEs commonplace, they are positively correlated with levels of social, emotional, and cognitive impairment, adoption of health-risk behaviors, disease, disability, and social problems, and they have been linked to premature mortality. When evaluating prevalence within the original sample—respondents were largely middle class, all with health insurance—researchers determined just 33% had endorsed no ACEs. By contrast, 26% had endorsed one, 16% had endorsed two, 10% had endorsed three, and 16% had endorsed four or more ACEs (Felitti et al., 1998).

Conclusions of the study are as follows: First, ACEs have a cumulative stressor effect and impact overall child and adolescent health, reproductive health, substance abuse, smoking behaviors, sexual behaviors, mental health, risk of re-victimization, stability of relationships, homelessness, and workplace performance. Second, individuals with more ACEs had higher rates of heart disease, chronic lung disease, liver disease, suicidality, injuries, and sexually transmitted diseases. Finally, researchers found that the more ACEs individuals reported, the more severe their mental health problems were (Anda, Butchart, Felitti, & Brown, 2010).

Neurobiological effects of early adversity. ACEs cause a variety of stress-mediated effects on different hormones and neurotransmitters, ultimately leading to impaired development of susceptible brain regions (Teicher & Samson, 2016). The most vulnerable brain regions include those having a high density of glucocorticoid receptors, a protracted postnatal developmental trajectory, and postnatal neurogenesis. Structures crucial for life including the

brain stem and diencephalon (e.g., the thalamus, hypothalamus, subthalamus, and epithalamiums) develop in utero, while those involved in higher order thinking, such as the limbic area and cerebral cortex, continue to develop throughout childhood and adolescence. Chronic stress affects processes such as neurogenesis, synaptic overproduction, pruning, and myelination in these areas, causing changes in brain structure and function (Malarbi, Abu-Rayya, Muscara, & Stargatt, 2017). Although recent literature suggests brain differences in traumatized children may actually occur in order to promote adaptation to adversity (e.g., enhanced threat detection, rapid recognition of fearful stimuli), continuous activation of the stress response system results in long-term impairment and maladaptive prefrontal functioning (Teicher & Samson, 2016).

Neurobiological effects of trauma include a variety of structural brain abnormalities. In studies examining the neurological effects of PTSD, behavioral correlates of the medial prefrontal cortex, hippocampus, and amygdala have been implicated in PTSD (Herringa, Phillips, Almeida, Insana, & Germain, 2012). Differences in cortical regions including the insular cortex, anterior cingulate cortex, thalamus, subcortical limbic abnormalities have also been found between those with and without PTSD (Herringa et al., 2012). Additional abnormalities associated with PTSD include a reduction of hippocampal volume, thought to be due to cell death associated with excessive stimulation (Pitman et al., 2012), and reduction of gray matter in the dorsolateral prefrontal cortex, parietal lobe, and cingulate cortex (Pitman et al., 2012). In children exposed to developmental trauma, differences have been found in brain structure including smaller total brain volume; decreased volume of the corpus callosum, prefrontal cortex, and cerebral areas; and larger lateral ventricles (Gabowitz, Zucker, & Cook, 2008).

Earlier onset of trauma and longer duration of abuse tend to be significantly associated with smaller intracranial volume (Gabowitz et al., 2008). Hanson et al. (2013) found that children who had experienced early adversity in the form of neglect had lower white matter directional organization in the prefrontal cortex. They also found lower directional organization in white matter tracts connecting the temporal lobe and prefrontal cortex (Hanson et al., 2013). Similarly, Ansell, Rando, Tuit, Guarnacci, and Sinha (2012) found that the reduction of gray matter in the prefrontal cortex correlates with the number of adverse events experienced.

In addition to structural and genetic abnormalities, stress hormone dysregulation causes further impairment in cognitive and physiological functioning. Traumatic exposure triggers a biological stress response system: an evolutionarily beneficial mechanism including both threat detection and reaction (Teicher & Samson, 2016). This system involves the autonomic nervous system, composed of both the sympathetic nervous system, responsible for the fight or flight response, and the parasympathetic nervous system, which acts as the "brake" of the sympathetic nervous system. When activated, the SNS causes increased heart rate, increased blood pressure, bronchodilation, increased pupil size, and inhibition of digestion (Teicher & Samson, 2016). The hypothalamic pituitary adrenal axis (HPA) is a key component to the stress response system, particularly in regard to the physiological reaction to stress. The primary function of the HPA axis is to assess stress, trigger a neurochemical response, and terminate the stress response when stress is no longer present (Teicher & Samson, 2016).

The prefrontal cortex is the area of the brain that first identifies a stressor and plays a critical role in inhibiting the stress response. In particular, monoamines (e.g., dopamine (DA), noradrenaline, and 5-HT) activate the goal-oriented executive center of the brain, modifying behavior to maximize survival (Joëls & Baram, 2009). Following threat detection, the prefrontal

cortex sends the appropriate stress mediators including monoamines, neuropeptides, and steroid hormones to the central nervous system (Joëls & Baram, 2009). Next, the HPA axis allocates resources for energy mobilization, activating the necessary autonomic and neuroendocrine systems. This process of energy mobilization leads to alteration of brain chemicals (McKlveen, Myers, & Herman, 2015).

In healthy circumstances, the prefrontal cortex will stop sending excitatory messages to the HPA axis when threat is no longer detected. However, the brain experiencing constant traumatic stress appears to function differently. Chronic activation of the HPA axis causes subsequent neuroanatomical, behavioral, and functional changes (McKlveen et al., 2015). Chronic stress has been shown to cause alterations in gene expression, neuroanatomical structures, individual neurons, and changes in patterns of neuronal firing. Children living in chronic adversity have a more sensitively activated amygdala that assigns an emotional value signifying threat even in situations that are not dangerous, thus triggering a stress response to nonthreatening stimuli. This process, termed *fear conditioning*, causes an overgeneralization of traumatic triggers. Hyperactivation of the amygdala results in repeated and unnecessary stimulation of the stress response system (Arnsten et al., 2015). Physiological problems associated with chronic stress and hyperactivation of the HPA axis include heart problems, gastrointestinal problems, asthma, cancer, and hypertension (Gabowitz et al., 2008).

Circuitry and the role of neurotransmitters in executive dysfunction. Neurotransmitter alterations have a role in prefrontal impairment resulting from chronic stress. Acute stress results in the release of catecholamine, norepinephrine (NE) and DA. High levels of NE and DA cause Ca2+-cAMP-signaling in the spines near network synapses, causing surrounding K+ channels to open. Ultimately this process weakens nearby synaptic connections

and reduces the rate of firing of the neurons responsible for executive control. High levels of catecholamine then strengthen the affective response generated by the amygdala and the striatum. Additionally, cortisol (a steroid hormone released during stress) accentuates the effects of catecholamine neurotransmitters in the prefrontal cortex and the amygdala, further amplifying this destructive and continuous fear response cycle. When stress is uncontrollable, high catecholamine levels in the brain thus weaken the functioning of the prefrontal cortex while simultaneously strengthening the amygdala's affective response (Arnsten et al., 2015).

Researchers evaluating the neural underpinnings of executive dysfunction have evaluated populations in which EFs are impacted, including individuals who suffer from schizophrenia, bipolar disorder, substance abuse, antisocial behavior, and obsessive-compulsive personality disorder (Logue & Gould, 2014). Moench and Wellman (2015) describe these disorders as stress sensitive in their research, highlighting the implications of chronic stress on the prefrontal cortex and the stress-related impact on neurochemicals and hormones involved in prefrontal cortical functioning.

Neuropsychological assessment of children with trauma. Children who have been exposed to trauma, similar to those with ADHD, show a variety of deficits on neuropsychological tasks. The negative cognitive impacts of trauma, such as the reduced inhibitory control, have been well documented. In their study of pathogenic care and the development of ADHD-like symptoms, Dahmen, Pütz, Herpertz-Dahlmann, and Konrad (2012) identified neurodevelopmental pathways resulting in similar symptomology between children exposed to trauma and children with ADHD. These two populations show deficits in visual and verbal memory (Brewin, 2011; Marx, Doron-Lamarca, Proctor, & Vasterling, 2009; McNally, 2006), attention (Aupperle, Melrose, Stein, & Paulus, 2012; Samuelson et al., 2006), sustained

attention (Vasterling et al., 2002), working memory (Aupperle et al., 2012), and learning and processing speed (Samuelson et al., 2006).

In a related study, De Bellis and Thomas (2003) compared maltreated youth to healthy controls, finding that those who had been maltreated showed lower intelligence, capacities for attention, language, and memory, and executive and academic functioning. Similarly, De Bellis, Woolley, and Hooper (2013) examined the neuropsychological profiles of children diagnosed with PTSD who had also experienced neglect, comparing them with a group of children who were neglected but did not have a PTSD diagnosis. Results indicated the neglected children with and without PTSD showed lower scores across measures of intelligence, academic achievement, visual-spatial abilities, learning/memory, language, attention, and executive functioning. Similarly, Beers and De Bellis (2002) found maltreated children with PTSD perform worse on measures of attention, problem solving, abstract reasoning, and learning and memory compared to non-maltreated children.

A recent meta-analysis conducted by Malarbi and colleagues examined a total of 27 studies, yielding a pooled sample of 1526 children (412 exposed to trauma but without diagnostic categorization, 300 children with PTSD and comorbid diagnoses, 323 children with PTSD, and 491 typically developing children). Results of the meta-analysis revealed that trauma-exposed children (regardless of diagnostic categorization or comorbidities) performed worse as compared to healthy controls in most cognitive domains. When comparing children diagnosed with PTSD to healthy controls, statistically significant results were found in regards to lower overall cognitive functioning, attention control, cognitive flexibility, language and verbal skills, perceptual/visual-spatial skills, information processing, verbal learning and

memory, visual learning and memory, overall learning and memory, and overall executive functioning (Malarbi et al., 2017).

Some researchers have concluded that interpersonal trauma occurring within the home is related to deficits in executive functioning, likely due to the chronic nature of family discord, the relational nature of the trauma, and exposure to trauma during critical periods for neurological functions (Malarbi et al., 2017). Furthermore, the impact of interpersonal trauma on EF seems to be more severe than the impact of impersonal trauma. In support of this argument, DePrince, Weinzierl, and Combs (2009) found a medium effect size for the relationship between familial trauma (classified as physical maltreatment at home, sexual maltreatment by an adult caregiver, or the witnessing of domestic violence) and poor performance on tasks of executive functioning, when compared to children who experienced non-familial trauma (natural disaster, motor vehicle accident). EF assessment included tasks measuring working memory, inhibition, auditory attention, and processing speed.

ADHD and trauma. Several studies suggest that children with a history of trauma commonly display symptoms consistent with ADHD. For example, Conway, Oster, and Szymanski evaluated the relationship between ADHD and developmental trauma in a sample of children in an urban inpatient psychiatric hospital. They found that some of the children with ADHD were more likely to have a history of chronic stress than those without ADHD, but still did not meet criteria for PTSD. The authors coined the term *environmental trauma* to describe the circumstances in which such individuals lived (Conway et al., 2011). These children also demonstrated greater disruptions in attachment relationships to primary caregivers than children without ADHD. Experience of chronic stress during childhood was determined to have a strong relationship with ADHD symptomology, particularly behavioral symptoms. Similarly, Pine et

al. (2005) discovered that the severity of physical abuse in a child's history was associated with that child's attentional biases—more so when a threatening stimulus was present. Finally, Nolin and Ethier (2007) found that children who had experienced physical abuse or neglect showed impairment in auditory attention, and visual-motor integration.

In some studies, ADHD has even been considered to be an outcome of early deprivation (Roskam et al., 2014). In a literature review, Oswald, Heil, and Goldbeck (2009) found that across several studies, a disproportionately high percentage of children in foster care were diagnosed with ADHD. In fact, the prevalence of ADHD in children who have been in foster care is four times higher than that of the general population (McMillen et al., 2005). Additionally, Kreppner et al. (2007) determined that the extent of inattention and hyperactivity in children with ADHD was positively correlated with the severity of deprivation in post-institutionalized adoptees; this relationship remained stable even after adoption.

In comparison to children with ADHD but without a history of adverse experiences, those exposed to traumatic stress lagged significantly in the development of EFs. Studies have shown that the longer children have spent in early deprivation, the worse they tend to perform on tasks of executive functioning (Chugani et al., 2001; Kreppner et al., 2007; Pollak et al., 2010). In one study, Ayoub et al. (2006) discovered deficits in problem solving abilities in children who were maltreated, and they determined that there was a direct relationship between interpersonal trauma severity and problem-solving capacity. Similarly, De Bellis, Woolley, & Hooper (2013) examined neuropsychological profiles of children with and without PTSD, finding that those diagnosed with PTSD performed significantly lower on tasks of both attention and executive functioning. Similarly, in another study comparing children with ADHD who had and had not experienced early adversity, researchers found significantly greater executive

impairment in the children with both ADHD and adverse early experiences (Sonuga-Barke & Rubia, 2008).

ADHD and ACEs. In a recent large-scale study, researchers specifically examined the association between ACEs and ADHD, utilizing a nationally representative sample of 76,227 children ranging in age from four to 17 years (Brown et al., 2017). Using a population-based cross-sectional telephone survey, researchers asked questions regarding ADHD diagnosis, severity, and medication. They inquired about the presence of nine ACEs, similar to those used in the original ACEs study: (a) poverty, (b) divorce, (c) death, (d) domestic violence, (e) neighborhood violence, (f) substance abuse, (g) incarceration, (h) mental illness in the family, and (i) discrimination. Questions included:

1. How often has it been very hard to get by on your family's income?
2. Did the child ever live with a parent or guardian who got divorced after the child was born?
3. Did the child ever live with a parent or guardian who died?
4. Did the child ever live with a parent or guardian who serviced time in jail or prison after the child was born?
5. Did the child ever see or hear any parent's guardians or other adults in his/her home slap, hit, kick, punch, or beat each other up?
6. Was the child ever a victim of violence or witness any violence in his/her neighborhood?
7. Did the child ever live with anyone who was mentally ill, suicidal, or severely depressed for more than a couple of weeks?
8. Did the child ever live with anyone who had a problem with alcohol or drugs?

9. Was the child ever treated or judged unfairly because of his/her race or ethnic group?

The researchers determined that children with ADHD have a higher prevalence of ACEs compared to children without ADHD. They also found that children who had experienced one or more ACEs were more likely to be diagnosed with ADHD than those without any ACEs; the presence of ACEs was also associated with ADHD symptoms reported to be moderate to severe. In particular, caregivers reporting ACEs related to socioeconomic hardship and parental mental illness were most likely to rate their children as having moderate to severe symptoms of ADHD. Overall, the relationship between ACEs and a diagnosis of ADHD was quite strong; notably, in this study, the presence of ACEs was also associated with more severe symptoms of ADHD.

Conclusion

In conclusion, there is much more to learn about etiological pathways leading to ADHD symptomology and executive dysfunction. Children contending with both traumatic exposure and attention problems represent a particularly vulnerable subset of children with ADHD, as they present with more debilitating symptoms and are less responsive to typical ADHD interventions (Spencer et al., 2013). Better understanding variability in EF on neuropsychological assessment in children with ADHD could help delineate potentially different pathways to executive dysfunction, which would then assist in conceptualization, prevention, and development of appropriate treatment strategies. Due to the strong association between early adversity and ADHD, early adversity as a neurodevelopmental pathway merits further investigation (Thorell, Rydell, & Bohlin, 2012).

Research Questions

This project expanded on the exploration of Brown et al. (2017) by focusing on the consequences of child maltreatment on executive functioning in children with ADHD. In this dissertation, I addressed two primary research questions:

Research Question 1: What is the relationship between number of ACEs and performance on neuropsychological tasks evaluating EF (as measured by neuropsychological test results on Color–Word Interference, Verbal Fluency, Trail Making Test, and Semantic Clustering) for children with ADHD?

Research Question 2: What is the relationship between number of ACEs and behavioral impairment on parent ratings of EF (as measured by the Inhibit, Task Completion, Shift, and Planning/Organization scales on the BRIEF) for children with ADHD?

Given the current literature, I hypothesized that (a) children with ADHD and fewer ACEs will perform better on neuropsychological tasks of EF when compared to children who have experienced a higher number of ACEs; and (b) both groups will show behavioral deficits related to impaired EF, although those with ADHD and more ACEs will show greater impairment than those with ADHD and fewer ACEs.

Children with ADHD and those with trauma histories may present with similar symptoms including inattention, hyperactivity, impulsivity, and executive dysfunction. The primary objective of the study was to evaluate the role of ACEs in the variability in cognitive and behavioral manifestations of executive dysfunction in children with ADHD. Failure to attend to etiological differences in the development of symptomatology may lead to misdiagnosis and misconceptualization, resulting in inadequate treatment and further health disparities in children who have experienced early adversity compared to those who have not.

To address the research questions, children's number of ACEs was used as a predictor variable to determine its relationship with their performance on neuropsychological assessment and behavioral measures along four continuous dimensions: (a) attentional control, (b) information processing, (c) cognitive flexibility, and (d) goal setting.

Methodology

Research Design

This quasi-experimental design consisted of retrospective archived data analysis of protocols collected during comprehensive neuropsychological evaluations conducted between 2012 and 2017 at an academic medical center. The number of ACEs was calculated for each child and used as the continuous independent variable, with a possible range of 0–9. Two sets of four continuous dependent outcome variables were grouped into corresponding behavioral and cognitive equivalents for each of the four executive functions of interest (i.e., attentional control, information processing, cognitive flexibility, and goal setting; see Table 1). Assessment of cognitive abilities included scores from neuropsychological assessment measures consisting of three tasks from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001) including the Color-Word Interference Test Condition 3 Total Time, the Trail Making Test Condition 4 Total Time, and the Verbal Fluency Test Condition 1 Total Correct Responses. Additionally, the Semantic Clustering Index from the California Verbal Learning Test — Children's Version (CVLT-C; Delis, Kaplan, Kramer, & Ober, 1994) was examined. Behavioral measures included scores taken from the following Behavior Rating Inventory of Executive Function (BRIEF) subscales: (a) Inhibit, (b) Shift, (c) Task Completion, and (d) Planning and Organization (Gioia, Isquith, Guy, & Kenworthy, 2000). Variables were chosen for this study based on frequency of use in research studies and in neuropsychological

assessment and well-established reliability and validity (Willcutt et al., 2005). Description of behavioral and neuropsychological measures including psychometric properties is provided in Table 1.

Neuropsychological Measures

The Delis-Kaplan Executive Function System (D-KEFS) consists of nine stand-alone subtests, each intended for use with children and adults ranging from 8–89 years of age (Delis, Kaplan, & Kramer, 2001). The D-KEFS is the first set of EF tests to be co-normed on a large representative national sample. Altogether, the tests measure flexibility of thinking, inhibition, problem solving, planning, impulse control, concept formation, abstract thinking, and creativity, both verbally and visuospatially. Test scores from three of the nine subtests will be used in this study: (a) the Trail Making Test, (b) Verbal Fluency, and (c) Color–Word Interference. Scores from each of the measures were converted to cumulative z-scores (t-scores for the BRIEF, scaled scores for the D-KEFS) for consistency and clarity. The CVLT- II and C computer software scoring program automatically converted raw scores to z-scores, therefore no conversion was necessary for the CVLT- II and C. All scores were converted first using a conversion formula in Microsoft Excel and then subsequently verified using the Apple PAR Assessment Toolkit application.

All subtests had evidence of good reliability and validity. Internal consistency values included split-half reliability estimates ranging from moderate to high for each of the subtests were used in the current study. Similarly, test–retest reliability estimates range from low (.20) to high (.90), reflect variable stability of the constructs being measured over time. Evidence demonstrating adequate convergent and discriminant validity is derived from correlations between the D-KEFS tests and other similar measures (Delis et al., 2001). Studies have

provided evidence for validity, indicating reasonable sensitivity in distinguishing different clinical groups such as those with ADHD, fetal alcohol exposure, schizophrenia, chronic alcoholism, Parkinson's disease, focal ventromedial prefrontal damage, dementia, mild cognitive impairment, subcortical ischemic disease, lateralized right hemisphere damage, multiple sclerosis, normal aging, autism, psychopathology, and stroke (Delis et al., 2001).

Attentional control (Inhibition). Attentional control was assessed using condition three total time from the Color–Word Interference Test on the D-KEFS. Initially, the task requires speeded color then word reading. The inhibition condition is the third component of the task; this page has words for colors printed in incongruent colors of ink (e.g., the word "green" is printed in red ink). The individual must inhibit the typical response of reading the word, and instead state the color of the ink. For each trial, the child must provide a response to all stimuli presented on each page. A time-to-completion score is then obtained. Total time is used as the raw score, which was then converted to a z-score for data analysis.

Studies of children with ADHD show performance variability on tasks of color–word interference; however, children with ADHD tend to perform worse than non-ADHD peers. Van Mourik et al., 2005) conducted a meta-analysis evaluating inhibitory control on tasks of interference using 17 independent studies (n= 1395) with individuals ranging in age from 6–27 years. Only a small effect size was found on the Color–Word Interference score (d = .35), though a heterogeneous distribution of effect sizes was found across studies. Eight studies found an effect size of zero. Wodka et al. (2007) compared children with ADHD (n = 54) versus controls (n = 69) and found worse performance in children with ADHD on the color–word interference task, although performance was still within the average range.

Information processing (Verbal fluency). Information processing was assessed using the Verbal Fluency Test on the D-KEFS. Specifically, the score for FAS Letter Fluency was used. For this measure the child is provided with certain rules and is then asked to generate as many words as possible for each of three letters (F, A, and S) throughout a one-minute duration per letter. The total number of words generated across three letters is the FAS score. This scaled score was then converted to a z-score.

Research suggests this measure may distinguish children with ADHD from those without the disorder. A large meta-analysis Sergeant and colleagues conducted evaluated performance on tasks of fluency with letters in children with ADHD. They found six studies showing worse performance in the ADHD group when compared to controls; three studies found no difference between groups (Sergeant et al., 2002).

Cognitive flexibility (Shift). Cognitive flexibility was assessed using respondents' total time (in seconds) on the Trail Making Test, condition four. The Trail Making Test consists of five conditions. In the first, examinees are asked to find all of the number threes on two pages, not marking any other numbers or letters. For the second condition, they are asked to connect the numbers in order by drawing a line; in the third condition, they are asked to connect the letters in order. Condition four, the variable used in the current study, requires that the child draw lines between letters and numbers alternately and in order ("1" to "A" to "2" to "B" and so forth). As such, the task involves cognitive switching and inhibitory capacity, though there is also a component of speed of visual search, attention, and visuo-motor functioning. The total time scaled score was then converted to a z-score for data analysis.

Meta-analyses of cognitive switching on the Trail Making Test have shown medium effect sizes (.59 and .55) when comparing children with ADHD to those without (Frazier,

Demaree, & Youngstrom, 2004; Willcutt et al., 2005). Bidwell, Willcutt, DeFries, and Pennington (2007) evaluated sets of twin children ages 8–18 years, one with ADHD and the other without, and found significant differences between children with and without ADHD on cognitive switching (d = .69). Barkley and Grodzinsky (1994) found a similar test of trail making (Trails A and B combined) to predict the presence of ADHD 69–70% of the time and to accurately predict absence of ADHD 51% of the time.

Goal setting (Semantic clustering). Goal setting was assessed using the semantic clustering index on the CVLT-C. Semantic clustering is a measure of the extent to which the child is able to utilize an effective categorical approach to recall information. This measure is associated with how well the child plans and organizes the information provided to them. Children who cluster words semantically tend to perform better overall on the CVLT-C and overall tend to recall more words (Delis, Kramer, Kaplan, & Ober, 2000). The CVLT-C consists of 15 items generated from three semantic categories: (a) fruit, (b) clothing, and (c) toys. Administration involves an extensive procedure as follows: This list of items, labeled List A, is read to the child five times. Following each exposure, the child is asked to recall as many items as possible. The sixth trial consists of a second 15-item distractor list with new words from the categories fruits, furniture, and sweets (referred to as List B). Following this exposure, the child is then asked to recall as many words as they can from List B. They are then asked to recite List A from recall. In the seventh trial, prompts are provided to the subject with the word category. Then, following a 20-minute delay, the child is again asked to repeat List A in an unstructured and then cued format. This global semantic clustering score is determined based on the amount of times, across trials, that the child consecutively reports two words in the same category regardless of whether they are correct words, perseverations, or intrusions (Delis et al., 2000).

On the CVLT-C, average values of internal consistency range from coefficient alphas of .72 to .85 (Donders, 1999). Test-retest reliability conducted over a median period of 28 days varied depending on age groups: .38 to .90 for 8-year-old children, .17 to .77 for 12-year old children, and .31 to .85 for 16-year-old children. Similar to the CVLT-II, a six-factor structure was found in the CVLT-C (Baron, 2003). Construct validity has been supported and a five-factor model has been found most predictive of performance validity (i.e., attention span, learning efficiency, free delayed recall, cued delayed recall, and inaccurate recall; Donders, 1999). Cognitive functions such as semantic clustering rely on the use of active organizational strategies and as such have been referred to as EFs. However, empirical support for convergent validity of the semantic clustering index (compared against other tasks of executive functioning) is inconsistent and this form of validity requires further evaluation (Beebe, Ris, & Dietrich, 2000).

Deficits in verbal learning and memory on the CVLT-C have been shown in children with ADHD (Delis et al., 2000). This impairment is not as prominent in initial learning but instead is associated with long-term retention of the verbal material (Loge, Staton, & Beatty, 1990). One reason for this phenomenon likely involves failure of a child to recognize the inherent organization within the CVLT-C, thus making long-term retention more difficult. Further supporting the involvement of EFs in performance on the Semantic Clustering Index is the developmental nature of when this ability tends to arise. For example, children between the ages of five and eight years typically do not organize the word list semantically upon free recall. Without prompting, this strategy does not ordinarily develop until the ages of nine to 12 years (Delis et al., 2000).

Behavioral Measures

The BRIEF is a standardized rating of everyday behavioral manifestations of executive functioning (Gioia et al., 2000). The parent-report measure was used in this study; however, there are also self-and-teacher report forms. The BRIEF is comprised of 86 questions falling into two general categories: (a) the Behavioral Regulation Index (BRI) and (b) the Metacognitive Index (MI). Items vary depending on age range. The BRI represents a child's ability to shift cognitive set and modulate emotions and behavior via appropriate inhibitory control. This index includes the Inhibit, Shift, and Emotional Control subscales. The skills on the BRI are required for appropriate metacognitive problem solving. The MI represents a child's ability to cognitively self-manage tasks and monitor self-performance. This index includes the Initiate, Working Memory, Planning and Organization, Organization of Materials, and Monitor subscales. The BRIEF is normed on a population characterized by nationally representative demographic variables including gender, socioeconomic status, ethnicity, age, and geographical population density. For scoring, raw scores are entered into a computer scoring software program. T-scores greater than or equal to 65 are in the clinically significant range relative to peers of the same age and sex (Gioia, Isquith, Kenworthy, & Barton, 2010). All scores were transformed from T-scores to z-scores. See Appendix E for BRIEF questions categorized by corresponding subscale.

In the development of the BRIEF, questions were selected for inclusion after evaluation of inter-rater reliability and item-total correlations. In standardization, a principal components analysis was used to identify the eight subdomains of EFs. T-scores were generated for each scale relative to the normative sample based on gender and one of three age groupings (5–7, 8–10, and 14–18 years; Gioia et al., 2000). T-scores over 65 represent clinically significant

ratings. The Cronbach alpha coefficient was used to measure internal consistency, ranging from .80 to .98 on both the parent and teacher forms in a clinical and normative sample (Gioia, Isquith, Retzlaff, & Espy, 2002). Test-retest reliability showed stability over a two- to three-week period suggesting that the BRIEF can be repeatedly administrated. Convergent and discriminant validity assessment results suggest index correlations with other ADHD measures evaluating attention and relevant behaviors. The manual cites these tests to be: the ADHD-Rating Scale-IV, (a) the Child Behavior Checklist, (b) the Behavior Assessment for Children, and (c) the Conner's Rating Scale. Predictive validity in regard to clinical ADHD diagnostic utility has also been established. Diagnostic group membership was evaluated using logistic regression analysis, which yielded results suggesting that children with ADHD score higher and lower on different scales depending on ADHD subtype. The ability of the measure to discriminate clinical subtypes of ADHD shows that the test has diagnostic sensitivity regarding the phenotypic variability seen in children with ADHD (Gioia et al., 2002).

The BRIEF includes two built-in validity scales, the Inconsistency index and the Negativity scale. The measure also quantifies missing items. The Inconsistency Index assesses whether similar questions were answered in an inconsistent manner when compared to clinical samples. The Negativity scale measures the degree to which answers were selected in an unusually negative manner when compared to a normative sample.

Attentional control (Inhibit). The Inhibit scale evaluates behaviors related to inhibitory control, defined as the ability to resist impulses and engage in self-stopping when appropriate. Children who score in the clinically significant range on this scale have difficulty resisting impulses and taking into consideration potential consequences prior to acting. These children demonstrate less self-control, have trouble staying in place, interrupt or call out in class, and

often need a greater level of adult supervision when compared to their peers. They may also be described as being verbally and socially intrusive. These children also likely display higher levels of physical activity, lack of boundary control, a tendency to disrupt group activities, and insufficient planning (Gioia et al., 2000).

Information processing (Self-Monitor). The Self-Monitor scale refers to the child's ability to produce work and assesses performance output. Task completion involves cognitive fluency, efficiency, speed of processing, and output speed. Individuals struggling in this area tend to generate reduced output and delayed responses, are more hesitant, and have a slower reaction times than their peers. Therefore, this measure reflects the child's ability to complete tasks appropriately and in a timely fashion. Children struggling in this domain often have difficulty finishing homework or other projects on time (Gioia et al., 2000).

Cognitive flexibility (Shift). The Shift scale assesses the child's ability to transition from one activity or situation to the next. It also assesses the ability of the child to adapt under the demand of new circumstances. This skill underpins abilities such as tolerance of change, problem-solving flexibility, capacity to switch attention, and the ability to change one's mindset. Deficits on this measure indicate problems with behavioral and cognitive flexibility. Individuals struggling in this domain are often rigid and inflexible, relying heavily on routines to be regulated; once dysregulated (due, for example, to frustration or disappointment), these children have great difficulty returning to baseline (Gioia et al., 2000).

Goal setting (Planning and organization). The Plan/Organize scale evaluates the way in which children manage current and future-oriented demands for task completion. The two components assessed on this subscale are the ability to plan and organize. Planning involves a child's ability to anticipate future events, set goals, and determine sequential steps prior to task

engagement. Children who struggle in this domain tend to underestimate the amount of time necessary for task completion and the amount of difficulty involved, procrastinate, and have trouble engaging in multiple steps necessary to achieve an end goal. Organization refers to the child's ability to systematize oral and written expression, understand main points during presentations or in written material, and scan visual information or keep track of an assignment. Children who struggle in this domain tend to miss the "big picture." They may have good ideas but struggle to express them on tests and assignments. They also often feel overwhelmed when presented with large amounts of information and generally have difficulty recalling material without cues (Gioia et al., 2000).

Children with ADHD frequently exhibit significant problems across all BRIEF scales compared to children without ADHD. Children with ADHD also show difficulties with flexibility. Gioia et al. (2000) found that children with the combined type of ADHD exhibited significant deficits in inhibitory control (89% showing a clinically elevated Inhibit scale) and working memory (89–92% showing a clinically elevated Working Memory scale).

Measurement of ACEs

Replicating the categories used by Brown et al. (2017), I included ACEs that could readily be extracted from the child's medical file in an effort to quantify level of early adversity (see adapted and current ACE criteria in Appendix C and D). ACEs were categorized into nine types of adversity: (a) socioeconomic hardship (established based on use of state insurance), (b) parental divorce, (c) death of a parent or guardian, (d) jail time served by parent or guardian, (e) exposure to domestic violence, (f) exposure to community violence (as evidenced by report from parent or child of violence due to race, ethnicity or culture and/or bullying), (g) unfair treatment (including abuse or neglect), (h) mental illness/suicidality in the home, and (i)

substance use in the home. The presence or absence of each ACE was determined based on information contained in the medical folder, which typically included a background history provided by a parent or guardian, collateral documentation gathered from schools, social services, mental health and/or medical providers, and information provided by the child over the course of the clinical interview and assessment as described in the neuropsychological report.

Data Collection

Data were extracted from a total of 515 archived neuropsychological evaluations completed in the general neuropsychology clinic within Dartmouth-Hitchcock Medical Center's Department of Psychiatry in Lebanon, New Hampshire. This study underwent IRB review through Dartmouth College (see Appendix A for the approval letter). As stated in the Antioch University New England IRB handbook, research involving the collection or study of existing data, documents, and records is exempt from IRB approval, as long as subjects are unidentifiable directly or through identifiers linked to the subjects. In efforts to address potential errors in the database, all data were cleaned by research assistants prior to this study. Prior to the original neuropsychological assessment, legal guardians of participants had given their informed consent for evaluation.

Inclusion and Exclusion Criteria

Neuropsychological assessment data from children aged 8–16 years, diagnosed with ADHD according to *Diagnostic and Statistical Manual for Mental Disorders, Fourth Edition, Text Revision* (*DSM-IV-TR*) or *DSM-5* criteria, and assessed between the years of 2012 to 2017 were reviewed for inclusion in the current study. Participants must have been administered at least a portion of the neuropsychological tests and their guardians need to have completed a BRIEF in order to be considered for inclusion in the study. These children also needed to have

the general interview form in their medical folders to allow for quantification of ACEs. Diagnostic subtype was documented when available; however, consistent with similar studies, the three ADHD subtypes (i.e., inattentive, hyperactive/impulsive, and combined presentations) were aggregated.

Both cognitive and behavioral dependent variables were based on degree of diversion from norms derived from an age-based standardization sample. Consequently, criteria defining clinically significant levels based on age were already established for all measures. For the cognitive variables, gender was documented but norms were not based on gender. The BRIEF has different norms for male and female, and thus the T-scores already reflect a score based on the norms of a specific gender. Considering both the reality of analyzing data collected in a medical setting where children are complex and often have multiple diagnoses, as well as the high levels of comorbidity between ADHD and many other disorders, the presence of comorbid diagnoses was not grounds for exclusion. Similarly, medication was documented when available but did not impact inclusion.

Full Scale IQ was documented for descriptive purposes if an IQ test had been administered. However, children with lower IQs were not excluded because of two factors. First, there is a well-documented body of literature on the relationship between lower IQ and early adversity. Secondly, there is a link between poor EF and deficits on academic and IQ measures. Thus, excluding cases on the basis of IQ would likely eliminate some of the variance I was attempting to identify (Barkley, 1997; Barkley et al., 2001; Nigg, 2001; Willcut et al., 2005). Consistent with related studies (Hauser, 1994), insurance status was a determining factor for low socioeconomic status (i.e., those with Medicaid received an ACE in the low

socioeconomic status domain). Where available, I noted race/ethnicity in order to describe the sample but did not exclude any cases based on race or ethnicity.

Procedure

Once selected, files were de-identified and assigned a research number. Names corresponding to numbers were kept on a password-protected data sheet. Necessary demographic information (e.g., age, gender, diagnoses, race/ethnicity, and type of insurance) was entered into SPSS with the converted z-scores from each of the four neuropsychological and behavioral measures (see demographic information in Appendix D). Participants' diagnostic interview form and folder containing medical information were then reviewed for details of developmental history and documentation of ACEs. Total ACE scores were then calculated and entered into the spreadsheet. Tallies of specific ACEs were documented.

Participants

Data from a total of 107 individuals were included in the study, including 70 boys, 33 girls, and four with unreported gender. Ages ranged from six years to 18 years with a mean age of 11.33 years. In terms of ethnic self-identification, ethnicity was not consistently recorded in the database. Ten of the children were reported to be adopted; two of the children's adoption status was unknown. Seventy-nine of the participants had been administered a measure of Full-Scale IQ as measured by either the Wechsler Intelligence Scale for Children — Fourth Edition (WISC-IV), Wechsler Intelligence Scale for Children — Fifth Edition (WISC-V), or Wechsler Adult Intelligence Scale — Fourth Edition (WAIS-IV). Out of the 79 children who had a reported Full-Scale IQ, 72 were in the broad average range (i.e., spanning from low average to high average). IQ varied from 68 to 128, with a mean IQ standard score of 93. Twenty-eight of the children were not administered a measure of Full-Scale IQ. ACES data were collected for all

107 children. No child had zero ACEs. Twenty-two of the participants had one ACE, 21 had two ACEs, 21 had three ACEs, 26 had four ACEs, 13 had five ACEs, and six had six or more ACEs.

Statistical Analysis

Data were analyzed in SPSS 16.0 statistical program with eight separate linear regressions, four for each of the two clusters of dependent variables (i.e., four cognitive variables and four behavioral variables). Preliminary data screening indicated that scores on behavioral and cognitive measures were normally distributed. Similar to the general population, ACEs were not evenly distributed. A scatterplot of each dependent variable (performance on cognitive and behavioral measures of EFs) against the independent variable (ACEs) indicated a horizontal relationship between the variables and therefore did not violate the assumption of linearity. To assure no outliers were present, scatter plots were evaluated, and SPSS was instructed to produce case-wise diagnostics for standardized residuals plus or minus three. Homoscedasticity was assessed by visual inspection of standardized residual plot versus standardized predicted values. Scatterplots showed random scatter; therefore, the assumption of homoscedasticity was met. Finally, residuals were normally distributed as assessed by visual inspection of a normal probability plot.

Literature on multiple comparisons utilizing the same independent variables suggests the necessity of correcting for type 1 error (i.e., finding statistically significant results by chance; Ludbrook, 1998). Although the Bonferroni method has typically been used for correcting alpha levels with multiple comparisons, this method is often criticized for being too stringent and ultimately too often producing a type 2 error (i.e., rejecting the null hypothesis when in fact a statistically significant difference exists; Abdi, 2010). As such, the Holm-Bonferroni method, an

adapted analysis from the Bonferroni correction designed to reduce the chance of type 2 error was used. The current research design separated the analyses into two groups to answer the two research questions. Therefore, both the Bonferroni and Holm-Bonferroni methods were used for the four behavioral regressions and the four cognitive regressions and can be found in Tables 3 and 4 (Abdi, 2010).

Results

Research Questions/Statistical Analyses

Research Question 1: What is the relationship between number of ACEs and performance on neuropsychological tasks of EF (Color–Word Interference, Verbal Fluency, Trail Making Test, and Semantic Clustering) for children with ADHD?

Attentional control (Inhibition). For the cognitive attentional control measure, out of the 107 individuals sampled, 48 had been administered DKEFS Color-Word, condition three. All 48 participants had data from which ACEs were derived. The minimum z-score achieved on this task was -3.00 and the maximum was 1.33. The mean z-score was -.884. Based on a simple linear regression, there was no significant correlation between degree of adversity and inhibition performance (r^2 = .017). Thus, number of ACEs did not predict performance on neurocognitive tasks of inhibition as measured by condition three total time on the Color-Word subtest, $F(1, 47) = .82$, $p = .368$ (see Table 2).

Information processing (Verbal Fluency). For the measure of information processing, out of the 107 individuals sampled, 71 had been administered FAS Letter Fluency from the DKEFS. All 71 participants had data from which ACEs were derived. The minimum z-score achieved on this task was -2.33 and the maximum was 3.00. The mean z-score was -.307. Based on a simple linear regression, there was no significant correlation between degree of

psychological adversity and information processing performance (R^2 = .001). Thus, number of ACEs did not predict performance on neurocognitive tasks of fluency as measured by FAS Letter Fluency on the DKEFS, $F(1, 69) = 1.068$, $p = .305$ (see Table 2)

Cognitive flexibility (Shift). For the cognitive flexibility task, out of the 107 individuals sampled, 71 had been administered condition four of DKEFS Trails. All 71 participants had data from which ACEs were derived. The minimum z-score achieved on this task was -3.00 and the maximum was 1.67. The mean z-score was -.732. A simple linear regression indicated that the independent variable (number of ACEs) significantly predicted neurocognitive shifting performance, $F(1, 69) = 6.69$, $p = .012$. Higher numbers of ACEs were associated with decreased performance in shifting (R^2 = .088). ACEs accounted for 7.5 % of the explained variability in performance, suggesting a small effect size (Adjusted R^2 = .075), according to Cohen's (1988) classification (see Table 2). The prediction equation was: set shifting performance = .056 - (.259 X number of ACEs). The 95% confidence interval for the slope to predict performance on set shifting based on number of ACEs ranged from (-1.330, -.632) for 4 ACEs, (-1.729, -.752) for 5 ACEs, and (-2.159, -.840) for 6 ACEs; thus, for every additional ACE, the predicted performance decreased with mean scores expected to fall between -.981 for 4 ACEs to -1.5 for 6 ACEs. A scatter plot of the data with a 95% CI around the fitted regression line appears in Figure 1.

Goal setting (Semantic Clustering). For the cognitive goal setting measure, out of the 107 individuals sampled, 76 had been administered the CVLT-II or CVLT–C. All 76 participants had data from which ACEs were derived. The minimum z-score achieved on this task was -2.00 and the maximum was 2.50. The mean z-score was -.157. Based on a simple linear regression, there was no significant correlation between degree of psychological adversity

and goal setting performance (r^2 = .001). Thus, number of ACEs did not predict performance on this neurocognitive task of planning, as measured by the Semantic Clustering score on the CVLT, $F(1,74) = .058$, $p = .810$ (see Table 2).

Research Question 2: What is the relationship between number of ACEs and behavioral impairment on parent ratings of EF (as measured by the Inhibit, Task Completion, Shift, and Planning/Organization scales on the BRIEF) in children with ADHD?

Attentional control (Inhibition). For the behavioral measure of attentional control, out of the 107 individuals sampled, 90 had scores entered for the BRIEF Inhibit Index. All 90 of these participants had data from which ACEs were derived. The minimum z-score achieved on this task was -1.00 and the maximum was 3.00. The mean z-score was 1.62. A simple linear regression indicated that the independent variable (number of ACEs) significantly predicted parent ratings of inhibition on the BRIEF, $F(1, 88) = 11.49$, $p < .001$. Thus, higher levels of psychological adversity were associated with lower parent ratings of capacity for inhibition (r^2 = .116). ACEs accounted for 10.6 % of the explained variability in performance, suggesting a small effect size (Adjusted R^2 = .106), according to Cohen's (1988) classification (see Table 3). The prediction equation was: parent ratings of inhibition on the BRIEF = .825 + (.267 X number of ACEs). The 95% CI for the slope to predict parent rated inhibition based on number of ACEs ranged from (1.618, 2.169) for 4 ACEs; (1.773, 2.547) for 5 ACEs, and (1.905, 2.950) for 6 ACEs; thus, for every additional ACE, predicted parent ratings increased with mean scores expected to rise between 1.893 for 4 ACEs to 2.427 for 6 ACEs. A scatter plot of the data with a 95% CI around the fitted regression line appears in Figure 2.

Information processing (Self-Monitoring). For the behavioral measure of information processing, out of the 107 individuals sampled, 87 had scores entered for the BRIEF

Self-Monitoring Index. All 87 participants had ACEs data. The minimum z-score achieved on this task was -1.60 and the maximum was 3.00. The mean z-score was 1.763. A simple linear regression indicated that the independent variable (number of ACEs) significantly predicted parent ratings of self-monitoring on the BRIEF, $F(1, 85) = 6.92$, $p = .010$. Thus, higher levels of psychological adversity were associated with lower parent ratings of capacity for self-monitoring ($R^2 = .075$). ACEs accounted for 6.4% of the variability in performance, suggesting a small effect size (Adjusted $R^2 = .064$) according to Cohen's (1988) classification (see Table 3). The prediction equation was: parent rated concerns for self-monitoring on the BRIEF = 1.137 + (.209 X number of ACEs). The 95% CI for the slope to predict parent ratings on self-monitoring abilities based on number of ACEs ranged from (1.695, 2.249) for 4 ACEs; (1.792, 2.570) for 5 ACEs; and (1.864, 2.915) for 6 ACEs; thus, for every additional ACE, the predicted performance decreased with mean scores expected to rise between -1.972 for 4 ACEs to 2.390 for 6 ACEs. A scatter plot of the data with a 95% CI around the fitted regression line appears in Figure 3.

Cognitive flexibility (Shift). For the behavioral measure of cognitive flexibility, out of the 107 individuals sampled, 90 had scores entered for the BRIEF Shifting index. All 90 participants had data from which ACEs were derived. The minimum z-score achieved on this task was -1.00 and the maximum was 3.00. The mean z-score was 1.614. A simple linear regression indicated that the independent variable (number of ACEs) significantly predicted parent ratings of shifting on the BRIEF, $F(1, 88) = 12.99$, $p < .001$. Thus, degree of psychological adversity was associated with lower parent ratings of capacities for shifting ($R^2 = .129$). ACEs accounted for 11.9% of the variability in performance, suggesting a small effect size (Adjusted R^2 .119) according to Cohen's (1988) classification (see Table 3). The prediction

equation was: parent rated concerns for shifting on the BRIEF = .752 + (.290 X number of ACEs). The 95% CI for the slope to predict parent rated set shifting abilities based on number of ACEs ranged from (1.628, 2.193) for 4 ACEs; (1.803, 2.597) for 5 ACEs; and (1.955, 3.024) for 6 ACEs; thus, for every additional ACE, the predicted ratings increased with mean scores expected to rise from 1.910 for 4 ACEs to 2.490 for 6 ACEs. A scatter plot of the data with a 95% CI around the fitted regression line appears in Figure 4.

Goal setting (Planning and organization). For the behavioral measure of planning and organization, out of the 107 individuals sampled, 92 had scores entered for the BRIEF Planning/Organization index. All 92 participants had data from which ACEs were derived. The minimum z-score achieved on this task was -1.00 and the maximum was 3.00. The mean z-score was 1.88. Based on a simple linear regression, there was no significant correlation between degree of psychological adversity and parent ratings of capacity for planning and organization (R^2 = .010). Thus, number of ACEs did not predict parent ratings of planning and organization as measured by the BRIEF, $F(1, 90) = .936$, $p = .336$ (see Table 3).

Correction for Multiple Comparisons

Both the Bonferroni and the Holm-Bonferroni methods were conducted for the four cognitive and four behavioral variables and are listed in Table 4 and Table 5 respectively. Using the Holm-Bonferroni method, all originally significant *p* values remain statistically significant after correction (Abdi, 2010).

Discussion

In this dissertation, I explored the relationship between early childhood adversity and cognitive and behavioral symptoms of executive dysfunction in children with ADHD. Higher numbers of ACEs predicted statistically significant differences on performance on a

neuropsychological task of cognitive flexibility and on parent ratings of behavior for attentional control, information processing, and cognitive flexibility. Overall, these results offer some support for the robust literature associating early childhood adversity with subsequent difficulty handling transitions, self-monitoring, and inhibiting responses.

More specifically, I hypothesized that there would be an association between number of ACEs and lower performance on both neuropsychological tasks of EF as well as behavioral deficits in skills related to EF for children with ADHD. Consistent with this hypothesis, the mean performance of children with ADHD was in the low average range on neuropsychological measures of attentional control, information processing, and cognitive flexibility, with higher levels of ACEs being predictive of greater deficits on tasks requiring cognitive flexibility. For every behavioral variable, average impairment (based on the mean) for all participants was in the clinically significant range as compared with a normative sample, with higher ACEs predicting more statistically significantly impaired performance on parent ratings of attentional control, information processing, and cognitive flexibility.

Notably, cognitive flexibility yielded statistically significant results on both cognitive and behavioral measures, suggesting that the number of ACEs for a child with ADHD is associated with significantly greater difficulty with set shifting. Therefore, in line with the concept of multiple developmental pathways leading to ADHD, early adversity should be further considered as a potential developmental pathway leading to the behavioral and cognitive inflexibility associated with executive dysfunction in children with ADHD.

Cognitive Findings

Within the executive functioning research, set shifting is one of the more well-established domains of executive dysfunction. For example factorial analyses examining

batteries of EF measures have identified response inhibition, working memory, set shifting, and interference control as core executive abilities (Barkley et al., 2001; Miyake et al., 2000; Robbins et al., 1998; Willcutt et al., 2005). Consistent with set shifting being a prominent functional impairment in the executive domain, deficits in cognitive set shifting are related to greater overall impairment in everyday life. Nigg (2017) found that children with set shifting deficits showed higher levels of impairment in additional domains of executive functioning when compared to other children with ADHD who did not show set shifting deficits. Similarly, within the ADHD population, cognitive set shifting has been associated with lower academic achievement, lower intelligence, and increased oppositional defiant disorder and hyperactive and impulsive ADHD symptoms (Nigg, 2017). Set shifting has also been associated with learning problems, which typically occur in children with ADHD (Bull, Espy, & Wiebe, 2008).

Set shifting is shaped by a complex interaction of biological, psychological, relational, systemic, and cultural factors. There are a variety of psychological, interpersonal and environmental reasons why children who have experienced early adversity may have more difficulty shifting. Biologically, set shifting deficits in children who have experienced early adversity could be explained, in part, by the implication of chronic stress on neurotransmitter systems (particularly monoamines, as discussed in the literature review). Neuroanatomically, set shifting is localized in the left inferior prefrontal cortex and the mPFC (McDonald et al., 2005). The cholinergic system is implicated in the modulation and release of DA and NE and thus is thought to be responsible for PFC and orbitofrontal cortex coordination associated with set shifting, attention, and response inhibition (Logue & Gould, 2014). Performance on tasks of set shifting is mediated by DA and NE. There is a relationship between low levels of DA and poor performance on set shifting activities, whereas an increase in DA is associated with improved

set shifting performance. Similarly, set shifting has been shown to be impaired when NE activity levels are low (Apud et al., 2007; Crofts et al., 2001; Floresco, Magyar, Ghods-Sharifi, Vexelman, & Maric 2006; Robbins & Roberts, 2007).

Childhood trauma has been associated with under and overcontrolled behavior patterns. Early caregiving environments that support children through transitions help these children become more flexible. Without such scaffolding in anticipating and predicting what comes next, the young child becomes overwhelmed and has greater difficulty coping. In the absence of safety and reassurance, children with histories of abuse or neglect may develop rigid behavior patterns due to perceived lack of control; previous research suggests that their inflexibility may be an attempt to stabilize and navigate what feels like a an unpredictably shifting and dangerous external environment (e.g., Cook et al., 2017; Crittenden & DiLalla, 1988). Similarly, Putnam (1997) described such executive deficits in maltreated children as dissociative adaptations. In efforts to protect themselves from the deleterious impact of chronic stress, children automatize their behavior, leading to deficits in higher order cognitive functioning—including the flexibility and regulation required for set shifting. Deficits on tasks of cognitive flexibility are positively correlated with stress severity in traumatized children (Harms, Shannon Bowen, Hanson, & Pollak, 2017). For example, lower cognitive flexibility has been measured in children who have been in foster care (Lewis-Morrarty, Dozier, Bernard, Terracciano, & Moore, 2012) or institutionalized (Hostinar, Stellern, Schaefer, Carlson, & Gunnar, 2012), as well as neglected adolescents (Bauer, Hanson, Pierson, Davidson, & Pollak, 2009). These observations are consistent with the findings of this dissertation study and support the link between childhood adversity and impairments in cognitive flexibility.

Notably, caregiver–child relationships likely impact the development of set shifting abilities, as greater maternal capability and support has been associated with increased cognitive flexibility in children (Fay-Stammbach, Hawes, & Meredith, 2014). As a corollary, the absence of maternal responsiveness is associated with cognitive rigidity—or what is sometimes referred to as black and white thinking (Guttmann-Steinmetz & Crowell, 2006).

Attentional control, information processing, and goal setting. Contrary to expectation, there was no statistically significant association between number of ACEs and the cognitive variables of attentional control (inhibition), information processing (fluency), or goal setting (semantic clustering). From a research design perspective, there are several possible explanations. First, dependent variables selected for the current study may not have adequately captured the EFs intended for study. For example, total time rather than number of errors on the DKEFS Color–Word Interference condition three was used as a measure of inhibition. Therefore, a child could have made a significant number of errors (suggesting poor inhibition) while still completing the task quickly. In addition, although verbal fluency is a task often used to evaluate self-monitoring (Delis et al., 2001), this measure requires the participant needing to express his or her response by stating words that begin with a provided letter. Category fluency may have been a better overall measure of fluency, as the child is asked to provide words for a less restrictive category (i.e., animals and boys' names), potentially better capturing the fluency construct. Thirdly, for the measure of planning and organization, there is limited research available on the use of the CVLT-C semantic clustering index as a measure of executive functioning or planning and organization, as it was in this sample (Beebe et al., 2000). Most individuals sampled were not administered tasks typically used in neuropsychological assessment to capture planning and organization. It is also possible that capacities for planning

and organization are more difficult to capture on neuropsychological assessment. Finally, neuropsychological measures tend to have poor ecological validity measures used for this study had variable test-retest reliability (Lezak, Howieson, Loring, & Fischer, 2004) It is not possible to offer a definitive explanation for non-significant findings. However, EF skills are interrelated and inextricable; it is notably difficult to isolate and determine deficits of a specific function (e.g., Chan, Shum, Toulopoulou, & Chen, 2008). Regarding the discrepancy between behavioral and cognitive deficits in this study, it may not be possible to measure cognitive manifestations of EF through neuropsychological assessment in a way that translates readily to behavioral ratings. Indeed, parent report ratings, including the BRIEF subscales used for this study, are not strongly correlated with neuropsychological measures of executive functioning (Toplak, West, & Stanovich, 2013). Also, it is important to consider that the normative samples against which the BRIEF scores were compared were gender-specific, while the cognitive measures had a mixed-gender normed sample, meaning that gender may have been a factor influencing the dependent variables. One final speculation involves the smaller neuropsychological data set that was available in the file review in comparison with the parent ratings of behavior. The sample sizes for behavioral variables generally consisted of about 20 more participants than the sample sizes for the cognitive variables. Lower sample size also reduced power, making statistically significant findings less likely.

Behavioral Findings

The behavioral finding in this study was that number of ACEs was associated with the degree of impairment on parents' ratings of their children's capacity for inhibition, self-monitoring, and set shifting. Consistent with my hypothesis, children with ADHD were rated as performing more poorly than the normative sample for the BRIEF in measures of

attentional control, information processing, cognitive flexibility, and planning as evidenced by mean performance falling in the low average range. Also consistent with predictions, higher levels of ACEs were associated with parent assessment of more impaired attentional control, information processing, and cognitive flexibility.

These findings are consistent with the research of Brown et al. (2017), which was foundational in shaping this dissertation study. In their large-scale epidemiological study, Brown and colleagues found a gradient relationship between ACE score and parent-reported ADHD symptoms. They noted that children with higher levels of parent-reported symptoms of ADHD had an increasingly higher incidence of each individual ACE compared to children without ADHD. Specifically, parent/guardian divorce, familial mental illness, neighborhood violence, and familial incarceration were all associated with significantly more parent-rated symptoms of ADHD (Brown et al., 2017). In my sample, parental divorce/separation (63 out of 107) and substance abuse in the home (68 out of 107) were the most common ACEs endorsed. Evaluating associations between specific ACEs and parent-reported ADHD symptoms, although potentially useful, was beyond the scope of this study.

Consistent with the behavioral findings in my study, higher expressions of hyperactivity, inattention and dysregulation have all been associated with each of the ACEs utilized in the current study. Adverse behavioral outcomes as manifested by higher parent ratings of ADHD symptoms have been found in children who have experienced psychopathology in family members (Ford et al., 1999) including anxiety and depression (Biederman, Faraone, Keenan, Steingard, & Tsuang, 1991). Further, this outcome is also associated with lower socioeconomic status (Hackman, Gallop, Evans, & Farah, 2015) and overall adversity (Biederman et al., 1991). Parental antisocial behavior and substance abuse are associated with child externalizing

behaviors (Connor, 2002). Children raised in a single-parent household are at higher risk for poor behavioral regulation (Carlson & Corcoran, 2001) and tend to display higher levels of impulsive and disinhibited behaviors (Astone & McLanahan, 1991; Covey & Tam, 1990; Dornbusch et al., 1985; Thornton & Camburn, 1987) than children in dual-parent households. Behavioral dysregulation and parent-child discord have also been found to occur more often in homes where domestic violence occurred (Maughan & Cicchetti, 2002).

The findings of this dissertation study are consistent with the well-established body of research that associates higher levels of ACEs with compromised parenting in children with ADHD (Brown et al., 2017). Given that many ACEs are markers of disruptions within the primary caregiving system, the connection between ACEs and behavioral regulation in children is indicative of the impact of the health of the caregiving system on children. Relationships between caregivers and children characterized by higher levels of hostility and lower levels of warmth and involvement have been shown to negatively impact the development of executive skills (Fay-Stammbach et al., 2014). Family systems burdened with factors contributing to early adversity in a child's life, including poverty, abuse, and neglect, are associated with maladaptive parenting practices (Fay-Stammbach et al., 2014) that also likely contribute to executive dysfunction in children.

Although the results of my research support the association between a child's cognitive inflexibility and both traumatic exposure and ADHD diagnosis, positive caregiving—in the form of a secure attachment relationship—likely provides the foundation for regulatory abilities. Children with a secure attachment show some distress when separated from their primary caregiver but are then easily comforted upon reunification. Interaction, attention, and stimulation facilitates the development of executive processes (Fay-Stammbach et al., 2014);

securely attached children tend to possess higher capacities for regulation and EF. Therefore, absence of secure attachment appears to be a common underlying factor related to problems seen in children with a high number of ACEs and emotional and behavioral dysregulation. Indeed, attachment theory has been viewed as a developmental theory of self-regulation, proposing that children learn to regulate themselves through the process of being regulated by another (e.g., when an infant cries and he or she is soothed, the infant can then begin to develop an internal process of self-regulation patterned on this caregiving interaction; Cozolino, 2014; Schore & Schore, 2008).

Behavioral impairments associated with insecure attachment styles include inflexibility along with impulsivity, self-destructive behavior, aggression, maladaptive coping, problems sleeping, eating disorders, substance abuse, oppositional behaviors, and trauma reenactment (Cook et al., 2017). Children with ADHD are already more vulnerable than their peers; at the very least they struggle with dysregulated attention. The compounding effects of developmental trauma may further compromise regulatory functions.

Children with ADHD may pose additional attachment challenges for an already-stressed parent. It thus may be useful in furthering our understanding of the link between ADHD and trauma to consider the relationship between ADHD and the development of a child's regulatory capacity. If secure attachment is instrumental in the attainment of capacity for self-regulation, then children with both ADHD and attachment insecurity with a primary caregiver are most likely to demonstrate the executive deficits measured in this dissertation study. Furthermore, attachment security would then likely represent a protective factor against the negative consequences of early adversity.

Goal setting (planning and organization). Contrary to expectation, number of ACEs was not significantly associated with the behavioral variable of goal setting (i.e., planning and organization as measured by the BRIEF). Planning and organization are higher order abilities dependent on core abilities including, for example, inhibition, working memory, and cognitive flexibility. A child who has not developed these foundational skills is less likely to be able to goal set. The children in this sample on average had significant goal setting deficits regardless of the number of ACEs. In fact, on average, parent ratings were most clinically significant (i.e., low) on this measure when compared to the other behavioral outcomes used in this study. As suggested by other researchers, it is also quite possible that the higher-level cognitive processes associated with executive dysfunction—such as planning—are not accurately measured by parent report measures (Pennington, 1997).

Finally, one unexpected outcome of this study was that no statistically significant relationships were found for the relationship between number of ACEs and either the cognitive or the behavioral measure of planning and organization in this sample. Regardless, the mean score of the children in the planning and organization sample was in the clinically significant range, which bears acknowledgement given the importance of this higher order skill for academic and social functioning. It is possible that planning and organization is an EF skill that develops later than other capacities such as inhibition, information processing, and set shifting. There is some research suggesting that, untreated, traumatized children will have enduring difficulties in planning and organization into adulthood because adaptation to traumatic circumstance shapes a survival- and present-oriented form of interacting with the environment (e.g., van der Kolk, 2005).

Clinical Implications

Traumatized children present with multiple biopsychosocial risk factors affecting executive functioning and significantly influencing development. The relationship between chronic stress and multiple ACEs is well documented and constitutes a significant public health concern. For traumatized children with ADHD and difficulties with EF, cognitive interventions are insufficient if the role of traumatic stress on functioning is not considered. Indeed, standard ADHD interventions inadequately address the critical factors (e.g., neurocognitive deficits, family dysfunction, social struggles, and academic difficulties) occurring when ADHD is associated with a trauma history (Chacko et al., 2014). These children experience improvement and symptom reduction only when provided with trauma-focused interventions that address affect regulation, attention and consciousness, interpersonal skills, and attributions and schemas (D'Andrea et al., 2012). A more nuanced understanding of the multiple etiological pathways to ADHD will help in the development of more accurate and incisive conceptualizations and treatment strategies and aid in interpretation of assessment results. Dyadic, systemic, and parenting interventions are all important elements to consider when addressing deficits in EF given that ACEs and developmental trauma occur in the context of the caregiving system.

It is well-established that supportive parent-child relationships and predictability within the home has a positive impact on the development of executive functions (Bowers et al., 2000; Lewin-Bizan, Bowers, & Lerner, 2010; McClelland et al., 2018). Responsive early caregiving, including parental sensitivity, frequently coordinated social attention, and behaviors fostering secure attachment, are associated with increased self-regulation and executive skills (Stams, Juffer, & van IJzendoorn, 2002; Wellman, Phillips, Dunphy-Lelii, & LaLonde, 2004). There is also evidence to suggest that interventions implemented with the caregiving system positively

impact executive functioning (McDermott, Westerlund, Zeanah, Nelson, & Fox, 2012). Studies evaluating the trajectory of executive dysfunction in children who experienced early life deprivation and were then adopted into nurturing homes later exhibited better performance on tasks of EF then children who were not adopted (McDermott, et al., 2012). Additionally, McDermott et al. suggest a combined approach of interventions designed to improve caregiving and others targeting aspects of executive functioning in order to maximize likelihood for academic success.

Children with ADHD who have experienced early adversity require a multimodal treatment methodology, with intervention occurring at the individual level as well as on the system level (i.e., within the child–caregiver dyad). A variety of evidence-based treatments for traumatized and/or maltreated children focus on increasing self-regulation/executive skills. Outcome results from studies evaluating such interventions suggest they lead to more efficient higher-order thinking and problem-solving skills (e.g., Diamond, Barnett, Thomas, & Munro, 2007; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005). These treatment models specifically target executive functions and self-regulation through working with the caregiver, the child, and the family system. For example, the Attachment, Self-Regulation, and Competency (ARC) model was developed in coordination with the National Child Traumatic Stress Network (NCTSN) and is based on a three-pronged approach. Specifically, ARC addresses attachment through caregiver affect management, attunement, consistency in parenting, and establishment of routines and rituals; self-regulation, addressing affect identification, modulation, and expression; and competency, including EFs and self-development (Arvidson et al., 2011). Other similarly promising trauma-informed, evidence-based models known to improve ADHD symptoms (including executive dysfunction)

and designed to intervene at the individual, family, and systems level include Assessment-Based Treatment for Traumatized Children, Trauma Assessment Pathway, Attachment and Biobehavioral Catch-up, Child Adult Relationship Enhancement, Child and Family Traumatic Stress Intervention, Child-Parent Psychotherapy, Combined Parent Child Cognitive-Behavioral Approach for Children and Families At-Risk for Child Psychical Abuse, Integrative Treatment of Complex Trauma for Children and Adolescents, Trauma Affect Regulation, Trauma Systems Therapy, and Parent-Child Interaction Therapy.

While medication management for children with ADHD has been a popular treatment choice over the past 10–15 years, results have been variable (Chacko et al., 2014). Pharmacological treatment is an evidence-based treatment for ADHD and are most effective when accompanied by psychosocial treatments. Stimulant medications including methylphenidate and amphetamines have been shown to be more effective than non-stimulant medication and are generally used as a first choice for reducing behavioral symptoms associated with ADHD (e.g., attention regulation, response speed; Chacko, et al., 2014). Research suggests that stimulant medication, however, does not improve executive functioning (Bedard, Jain, Hogg-Johnson, & Tannock, 2007; Epstein et al., 2006; Kobel et al., 2009; Rhodes, Coghill, & Matthews, 2006).

When considering medication management, it is imperative to take into consideration the high rates of comorbidity between ADHD and other disorders. This is particularly true in cases with children who have experienced trauma, as some studies suggest stimulant medication may make the symptoms of trauma exposure worse. Relevantly for children with comorbid ADHD and PTSD, stimulant medication increases NE, DA, and 5-HT, in turn impacting consolidation and recollection of memory (Herbst et al., 2017). During emotionally charged

events, the brain experiences a surge of NE. This neurotransmitter, in conjunction with others, helps to create detailed and vivid memories. The more emotionally based a memory is, the more likely one is to remember that memory and recall it based on sensory experiences. Models of PTSD conceptualize the disorder as a learning deficit related to dysfunctional fear conditioning (Herbst et al., 2017). The brain continues to identify threat when threat is not present. This creates a cycle of continuous nervous system activation and unnecessary arousal of the fight or flight response.

Some research suggests stimulant medication could increase the perpetuation of this pathological learning cycle due to the surge in neurotransmitters and subsequent engagement of the amygdala, leading to an exaggerated fear response or heightened level of arousal (Debeic, Bush, & LeDoux, 2011; Herbst et al., 2017). This response could result in two possible consequences of interest: (a) children with ADHD who are prescribed stimulant medication could potentially be more likely to develop PTSD symptoms, and/or (b) children with comorbid ADHD and PTSD could experience an exacerbation of the sympathetic nervous system response (Friedman, 2012). In either case, pharmacological treatment of children with ADHD and a high number of ACEs requires more nuanced consideration than is often provided.

In summary, findings from the current study suggest a higher prevalence of certain executive deficits and corresponding behavioral manifestations in children with ADHD who have experienced higher levels of early adversity than those with lower levels of adversity. Considering a great deal of early adversity tends to occur throughout development and in the context of the caregiver–child dyad and/or the larger system, trauma-informed models utilizing a three-pronged approach including interventions implemented individually, within the caregiver child dyad, and systemically seem most beneficial. Trauma-focused interventions

improve executive dysfunction in children who have experienced early adversity and should therefore be considered in the treatment of children with ADHD (Arvidson et al., 2011; Diamond et al., 2007; Rueda et al., 2005). Because children who have experienced a high number of ACEs are at risk for developing trauma-related disorders, medication management of traumatized children with ADHD symptomology should be sensitively conducted due to the potential for exacerbation of and/or increased risk of developing PTSD symptoms.

Limitations

It is important to consider the several limitations of this study. Regarding the study design, use of archived data presents problems in terms of potential scoring errors after administration of the test as well as during data entry. I attempted to address this problem by using data that had been cleaned by research assistants; however, potential for error is always heightened when scores are transferred from one location to another.

Additionally, number of ACEs was determined based on information provided in the general interview form, along with clinically relevant information the neuropsychologist incorporated into the report. These limited sources restricted my access to information about participants' exposure to the whole list of potential early adversities. Families did not complete ACEs questionnaires and were not interviewed specifically about the children's exposure to ACEs. Given the epidemiological research associating ADHD and ACEs, it is likely that my data set would have included higher numbers of ACEs had there been more direct sources of data about ACEs.

Due to the research design and the use of individual linear regressions to maximize the sample size, I was not able to control for additional variables. For example, I did not control for gender in the analysis of the cognitive data even though gender has been shown to influence

ADHD symptomology and treatment (Gaub & Carlson, 1997). As previously mentioned, neuroanatomical structural and functional differences have been found in boys and girls with ADHD (Seymour et al., 2016). Further, symptom presentations differ depending on gender (e.g., girls display greater intellectual impairment, lower levels of hyperactivity, and lower rates of externalizing behaviors; Gaub & Carlson, 1997). Additionally, traumatic exposure may affect boys and girls differently. Age was also not controlled for. Considering EFs are developmental and acquired throughout childhood, not controlling for age could have impacted findings.

In addition to gender and age, I did not take into account the potential impact of medication on differential test performance and do not know how many children sampled were taking stimulant medication. Although medication does not directly improve EFs, pharmacological treatment of ADHD can help children sustain attention and aid in behavioral inhibition. Medication management could have also impacted parent ratings, potentially allowing the child to be viewed as less hyperactive and distractible.

Additionally, this study did not account for type of ADHD (i.e., predominantly hyperactive, inattentive, or combined presentation), although some research has identified a different pattern of executive deficit depending on subtype (Hashemi & Abbasi, 2013; Roberts, Martel, & Nigg, 2017). Though a possible limitation of the research, there are two reasons why this level of diagnostic selectivity was not feasible. First, diagnostic criteria changed for ADHD during the transition from the *DSM-IV* to *DSM-5*, which occurred in the time period during which the records were reviewed. Second, as documented by other researchers, obtaining this level of information was not possible due to lack of documentation. Children with different subtypes would have presented with different cognitive and behavioral symptoms. Subtype may also impact differential presentation of particular EF deficits; for example, while some

researchers have found no differences in performance on tasks of executive functioning between subtypes (Houghton et al., 1999; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002), Klorman et al. (1999) found children with ADHD either combined or predominately hyperactive presentation showed greater deficits on tasks of planning and problem solving than those with predominately inattentive presentation. Using ACEs as a marker of childhood adversity or trauma has limitations even beyond the difficulties in accruing numbers of ACEs through the available documentation. ACEs are typically scored as equivalent, with no weight given to duration, severity, level of disruption, or measurable impact on the child. For example, it is likely that divorce resulting in ongoing relationships with caregivers causes a different kind of developmental disruption than the incarceration or death of a primary caretaker, yet all of these events are scored the same. Being bullied in school is surely terrible, but likely less life-shattering than experiencing parent–child incest over many years—yet these are not differentiated on the ACEs checklist. Finally, the ACEs checklist is by no means a comprehensive record of all the traumatic events a young child could potentially endure. Children may have been affected by experiences not included on the ACEs checklist, including, for example, natural disasters, medical trauma, sibling trauma (i.e., either trauma happening to a sibling or a sibling perpetrating abuse as a potential trauma), vehicle accidents, or homelessness.

Lastly, the research questions and study design focused entirely on deficits. It is a limitation of the project that it was so entirely problem-focused. More information about the multiple pathways to ADHD and development of executive functioning may have been gleaned had I also explored protective factors that may have contributed to resiliency and post-traumatic growth in the children studied. Additionally, it is possible that the level of safety and support children had at the time of testing may have had decreased the severity of ADHD symptoms and

EF deficits. The effects of early adversity can be mitigated by resources at all levels; appropriate interventions can have an impact on both cognitive functioning and behavior.

Directions for Future Research

Future researchers might investigate the connection between EF and the stress response system, as some theorists have proposed the idea that certain executive functions are related to emotional processes while others are related to cognitive functioning. Although these processes are interrelated, *hot* functions refer to executive skills used for regulation in highly emotional times, whereas *cold* functions are utilized when emotions are not heightened (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Kerr & Zelazo, 2004; Rubia, 2011; Zelazo & Mueller, 2002). For example, traumatized children may differ in performance on tasks of executive functioning depending on their emotional state. Considering the dysfunction in the executive system that occurs as a result of chronic stress or trauma (i.e., emotionally heightened events), exploring a child's utilization of hot and cold EFs based on the situation may help elucidate the link between stress or trauma and executive functioning. This could provide further evidence for executive dysfunction in children who have experienced early adversity as being both behaviorally and neurologically based (Petrovic & Castellanos, 2016).

Specific to the population studied, the term medical trauma has been suggested in the field of pediatric psychology to account for the repeated traumatic experiences associated with acute and chronic medical conditions sustained in children. There is a substantial body of research indicating the psychosocial and cognitive impact of medical trauma (Marsac, Kassam-Adams, Delahanty, Widaman, & Barakat, 2014). Considering the sample of this dissertation study came from an academic medical center and tertiary care facility, many of the individuals sampled were receiving a neuropsychological assessment secondary to medical

conditions. Future research that includes medical trauma as an ACE or focuses exclusively on the presentation of ADHD and EF deficits in children with chronic medical conditions would further inform our understanding of the relationships between ADHD, executive functioning, and early trauma.

Executive dysfunction does not occur in all children with ADHD and children who have executive deficits do not necessarily demonstrate them in one specific executive domain (Willcutt et al., 2005). Considering the variability of executive dysfunction among children with ADHD, as well as variability in response to treatment for the ADHD population, future researchers should continue to explore the possibility of an executive-impaired subtype of children with ADHD (i.e., differentiating between those who demonstrate executive dysfunction and those who do not). This distinction could then inform treatment and possibly reduce variability in treatment response. Furthermore, although ADHD is thought to be a neurological disorder, diagnostic criteria are based on behavioral symptomology, which has contributed to confusion in the field of neuropsychological assessment. Considering that diagnostic evaluation of ADHD is a common referral question for neuropsychological assessments, distinguishing between executively-impaired children with ADHD versus those who are not would provide neuropsychologists with direction for assessment and treatment recommendations.

Conclusions

In conclusion, the prefrontal cortex, which mediates executive functioning, represents a vulnerable area of the brain with latent developmental periods and heightened susceptibility to environment factors. The role EFs play in survival of a person and the relationship to and mediation of the HPA axis make this part of the brain an integral component of threat detection, maintaining attention to relevant information, response inhibition, planning, and decision

making. Furthermore, these functions do not develop intrinsically but instead are reliant on, and influenced by, behavioral and environmental factors such as stress, adversity, learning, modeling, and attachment to others. Without taking a biopsychosocial conceptualization and treatment approach, the vulnerable population of traumatized children will continue to be marginalized, disproportionately represented, and inappropriately treated as children with disorders of behavioral regulation. Results from this research provide a platform to further explore the complex relationship among early brain development, adversity in childhood, and executive dysfunction in children with ADHD.

Clinically, consideration of trauma and early adversity when assessing and treating ADHD is essential for both neuropsychological assessment and clinical practice. The results of this dissertation indicate that children diagnosed with ADHD need to be assessed for exposure to psychological and physiological stressors. Appropriate screening could then contribute to more accurate and useful conceptualization, diagnosis, and treatment. The short- and long-term cognitive, emotional, behavioral, and social challenges for children with high ACEs and ADHD is well documented; better understanding and appropriate intervention will improve their prognosis.

References

Abdi, H. (2010). Holm's sequential Bonferroni procedure. *Encyclopedia of Research Design*, *1*(8), 1–8.

Aguiar, A., Eubig, P., & Schantz, S. L. (2015). Attention deficit/hyperactivity disorder: A focused overview for children's environmental health researchers. *Environmental Hazards and Neurodevelopment: Where Ecology and Well-Being Connect*, 223(12)

Alderson, R. M., Rapport, M. D., & Kofler, M. J. (2007). Attention-deficit/hyperactivity disorder and behavioral inhibition: A meta-analytic review of the stop-signal paradigm. *Journal of Abnormal Child Psychology*, *35*(5), 745–758.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Anda, R. F., Butchart, A., Felitti, V. J., & Brown, D. W. (2010). Building a framework for global surveillance of the public health implications of adverse childhood experiences. *American Journal of Preventive Medicine*, *39*(1), 93–98.

Anderson, P. (2001). *Measurement and development of executive function* (Unpublished doctoral dissertation). The University of Melbourne, Victoria, Australia.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, *8*(2), 71–82.

Anderson, P., Anderson, V., & Lajoie, G. (1996). The Tower of London Test: Validation and standardization for pediatric populations. *The Clinical Neuropsychologist, 10*, 54–65.

Anderson, V., Anderson, P., Northam, E., Jacobs, R., & Catroppa, C. (2001). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental Neuropsychology, 20*, 385–406.

Anderson, V., Jacobs, R., & Anderson, P. J. (2010). *Executive functions and the frontal lobes: A lifespan perspective*. Psychology Press.

Ansell, E.B., Rando, K., Tuit, K., Guarnaccia, J., & Sinha, R. (2012). Cumulative adversity and smaller gray matter volume in medial prefrontal, anterior cingulate, and insula regions. *Biological Psychiatry, 72,* 57-64.

Antshel, K. M., Hier, B. O., & Barkley, R. A. (2014). Executive functioning theory and ADHD. In *Handbook of executive functioning* (pp. 107–120). New York, NY: Springer.

Apud, J. A., Mattay, V., Chen, J., Kolachana, B. S., Callicott, J. H., Rasetti, R., ... & Goldberg, T. E. (2007). Tolcapone improves cognition and cortical information processing in normal human subjects. *Neuropsychopharmacology*, *32*(5), 1011.

Arffa, S. (2007). The relationship of intelligence to executive function and non-executive function measures in a sample of average, above average, and gifted youth. *Archives of Clinical Neuropsychology*, *22*(8), 969–978.

Arnsten, A. F. T., Raskind, M. A., Taylor, F. B., & Connor, D. F. (2015). The effects of stress exposure on prefrontal cortex: Translating basic research into successful treatments for post-traumatic stress disorder. *Neurobiology of Stress*, *1*, 89–99.

Arvidson, J., Kinniburgh, K., Howard, K., Spinazzola, J., Strothers, H., Evans, M., ... & Blaustein, M. E. (2011). Treatment of complex trauma in young children: Developmental and cultural considerations in application of the ARC intervention model. *Journal of Child & Adolescent Trauma*, *4*(1), 34–51.

Astone, N. M., & McLanahan, S. (1991). Family structure, parental practices and high school completion. *American Sociological Review, 6,* 309–320.

Aupperle, R. L., Melrose, A. J., Stein, M. B., & Paulus, M. P. (2012). Executive function and PTSD: Disengaging from trauma. *Neuropharmacology*, *62*(2), 686–694.

Ayoub, C. C., O'Connor, E., Rappolt-Schlichtmann, G., Fischer, K. W., Rogosch, F. A., Toth, S. L., & Cicchetti, D. (2006). Cognitive and emotional differences in young maltreated children: A translational application of dynamic skill theory. *Development and Psychopathology, 18*, 679–706.

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*(11), 417–423.

Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Annals of the New York Academy of Sciences*, *1118*(1), 122–141.

Baler, R. D., & Volkow, N. D. (2006). Drug addiction: The neurobiology of disrupted self-control. *Trends in Molecular Medicine*, *12*(12), 559–566.

Ball, J. S., & Links, P. S. (2009). Borderline personality disorder and childhood trauma: Evidence for a causal relationship. *Current Psychiatry Reports, 11,* 63–68.

Barkley, R. A. (1997). *ADHD and the nature of self-control.* New York, NY : Guilford Press.

Barkley, R. A. (2001). The executive functions and self-regulation: An evolutionary neuropsychological perspective. *Neuropsychology Review*, *11*(1), 1–29.

Barkley, R. A. (2006). *A handbook for diagnosis and treatment*. New York, NY: Guilford Press.

Barkley, R. A., DuPaul, G. J., & McMurray, M. B. (1990). Comprehensive evaluation of attention deficit disorder with and without hyperactivity as defined by research criteria. *Journal of Consulting and Clinical Psychology*, *58*(6), 775.

Barkley R. A., Edwards, G., Laneri, M., Fletcher, K., & Metevia, L. (2001). Executive functioning, temporal discounting, and sense of time in adolescents with attention deficit

hyperactivity disorder (ADHD) and oppositional defiant disorder (ODD). *Journal of Abnormal Child Psychology, 29,* 541–556.

Barkley, R. A., & Grodzinsky, G. M. (1994). Are tests of frontal lobe functions useful in the diagnosis of attention deficit disorders? *The Clinical Neuropsychologist*, *8*(2), 121–139.

Baron, I. S. (2003). *Neuropsychological evaluation of the child*. New York, NY: Oxford University Press.

Bauer, P. M., Hanson, J. L., Pierson, R. K., Davidson, R. J., & Pollak, S. D. (2009). Cerebellar volume and cognitive functioning in children who experienced early deprivation. *Biological Psychiatry, 66*, 1100–1106.

Bedard, A. C., Jain, U., Hogg-Johnson, S., & Tannock, R. (2007). Effects of methylphenidate on working memory components: Influence of measurement. *Journal of Child Psychology and Psychiatry, 48*, 872–880.

Beebe, D. W., Ris, D. M., & Dietrich, K. N. (2000). The relationship between CVLT-C process scores and measures of executive functioning: Lack of support among community-dwelling adolescents. *Journal of Clinical and Experimental Neuropsychology*, *22*(6), 779–792.

Beers, S. R., & De Bellis, M. D. (2002). Neuropsychological function in children with maltreatment-related posttraumatic stress disorder. *American Journal of Psychiatry*, *159*(3), 483–486.

Bidwell, L. C., Willcutt, E. G., DeFries, J. C., & Pennington, B. F. (2007). Testing for neuropsychological endophenotypes in siblings discordant for attention-deficit/hyperactivity disorder. *Biological psychiatry*, *62*(9), 991-998.

Biederman, J., Faraone, S. V., Keenan, K., Steingard, R., & Tsuang, M. T. (1991). Familial association between attention deficit disorder and anxiety disorders. *American Journal of Psychiatry, 148,* 251–256

Blakemore, S. J. & Robbins, T. W. (2012). Decision-making in the adolescent brain. *National Neuroscience, 15*, 1184-1191.

Borella, E., Carretti, B., & Pelegrina, S. (2010). The specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of Learning Disabilities*, *43*(6), 541–552.

Bowers, E. P., Gestsdottir, S., Geldhof, G. J., Nikitin, J., von Eye, A., & Lerner, R. M. (2011). Developmental trajectories of intentional self-regulation in adolescence: The role of parenting and implications for positive and problematic outcomes among diverse youth. *Journal of Adolescence*, *34*(6), 1193–1206.

Brewin, C. R. (2011). The nature and significance of memory disturbance in posttraumatic stress disorder. *Annual Review of Clinical Psychology*, *7*, 203–227.

Briscoe-Smith, A. M., & Hinshaw, S. P. (2006). Linkages between child abuse and attention-deficit/hyperactivity disorder in girls: Behavioral and social correlates. *Child Abuse & Neglect, 30*, 1239–1255.

Broidy, L. M., Nagin, D. S., Tremblay, R. E., Bates, J. E., Brame, B., Dodge, K. A., ... & Lynam, D. R. (2003). Developmental trajectories of childhood disruptive behaviors and adolescent delinquency: A six-site, cross-national study. *Developmental Psychology*, *39*(2), 222.

Brown, N. M., Brown, S. N., Briggs, R. D., Germán, M., Belamarich, P. F., & Oyeku, S. O. (2017). Associations between adverse childhood experiences and ADHD diagnosis and severity. *Academic Pediatrics*, *17*(4), 349–355.

Brown, T. E., & Landgraf, J. M. (2010). Improvements in executive function correlate with enhanced performance and functioning and health-related quality of life: Evidence from 2 large, double-blind, randomized, placebo-controlled trials in ADHD. *Postgraduate Medicine*, *122*(5), 42–51.

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

Carlson, M. J., & Corcoran, M. E. (2001). Family structure and children's behavioral and cognitive outcomes. *Journal of Marriage and Family*, *63*(3), 779–792.

Carte, E. T., Nigg, J. T., & Hinshaw, S. P. (1996). Neuropsychological functioning, motor speed, and language processing in boys with and without ADHD. *Journal of Abnormal Child Psychology*, *24*(4), 481–498.

Castellanos, F. X., Sonuga-Barke, E. J., Milham, M. P., & Tannock, R. (2006). Characterizing cognition in ADHD: beyond executive dysfunction. *Trends in cognitive sciences*, *10*(3), 117-123.

Chacko, A., Kofler, M., & Jarrett, M. (2014). Improving outcomes for youth with ADHD: A conceptual framework for combined neurocognitive and skill-based treatment approaches. *Clinical Child and Family Psychology Review*, *17*(4), 368–384.

Chan, R. C., Shum, D., Toulopoulou, T., & Chen, E. Y. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of Clinical Neuropsychology*, *23*(2), 201–216.

Chugani, H. T., Behen, M. E., Muzik, O., Juhasz, C., Nagy, R., & Chugani, D.C. (2001). Local brain functional activity following early deprivation: A study of post-institutionalized Romanian orphans. *Neuroimage, 14*, 1290–1301.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences. 2nd. New York, NY: Academic Press Inc.

Connor, D. F. (2002). *Aggression and antisocial behavior in children and adolescents: Research and treatment.* New York, NY: Guilford Press.

Conway, F., Oster, M., & Szymanski, K. (2011). ADHD and complex trauma: A descriptive study of hospitalized children in an urban psychiatric hospital. *Journal of Infant, Child & Adolescent Psychotherapy*, *10*(1), 60–72.

Cook, A., Spinazzola, J., Ford, J., Lanktree, C., Blaustein, M., Cloitre, M., ... & Mallah, K. (2017). Complex trauma in children and adolescents. *Psychiatric annals*, *35*(5), 390–398.

Cools, R., Roberts, A. C., & Robbins, T. W. (2008). Serotoninergic regulation of emotional and behavioral control processes. *Trends in Cognitive Sciences*, *12*(1), 31–40.

Courtois, C. (2008). Complex trauma, complex reactions: Assessment and treatment. *Psychological Trauma: Theory, Research, Practice, and Policy, S*(1), 86–100.

Covey, L. S., & Tam, D. (1990). Depressive mood, the single-parent home, and adolescent cigarette smoking. *American Journal of Public Health, 80*, 1330–1333.

Cozolino, L. (2014). *The Neuroscience of human relationships: Attachment and the developing social brain*. New York, NY: WW Norton & Company.

Crescioni, A., Ehrlinger, J., Alquist, J. L., Conlon, K. E., Baumeister, R. F., Schatschneider, C., & Dutton, G. R. (2011). High trait self-control predicts positive health behaviors and success in weight loss. *Journal of Health Psychology*, *16*(5), 750–759.

Crittenden, P. M., DiLalla, D. L. (1988). Compulsive compliance: The development of an inhibitory coping strategy in infancy. *Journal of Abnormal Child Psychology, 16*(5), 585–599.

Crockett, M. J., Clark, L., & Robbins, T. W. (2009). Reconciling the role of serotonin in behavioral inhibition and aversion: Acute tryptophan depletion abolishes punishment-induced inhibition in humans. *Journal of Neuroscience*, *29*(38), 11993–11999.

Crofts, H. S., Dalley, J. W., Collins, P., Van Denderen, J. C., Everitt, B. J., Robbins, T. W., et al. (2001). Differential effects of 6-OHDA lesions of the frontal cortex and caudate nucleus on the ability to acquire an attentional set. *Cerebral Cortex, 11*, 1015–1026.

Dahmen, B., Pütz, V., Herpertz-Dahlmann, B., & Konrad, K. (2012). Early pathogenic care and the development of ADHD-like symptoms. *Journal of Neural Transmission: Translational Neuroscience, Neurology and Preclinical Neurological Studies, Psychiatry and Preclinical Psychiatric Studies*, *119* (9), 368–384.

D'Andrea, W., Ford, J., Stolbach, B., Spinazzola, J., & Van Der Kolk, B. A. (2012). Understanding interpersonal trauma in children: Why we need a developmentally appropriate trauma diagnosis. *American Journal of Orthopsychiatry*, *82*(2), 187–200.

Data Resource Center for Child and Adolescent Health. (2013). Child and Adolescent Health Measurement Initiative (CAHMI). *2011/12 national survey of children's health.*

David, A. S. (1992). Frontal lobology: Psychiatry's new pseudoscience. *The British Journal of Psychiatry*,*61*(2), 244-248.

Davids, E., & Gastpar, M. (2005). Attention deficit hyperactivity disorder and borderline personality disorder. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 29,* 865–877.

De Bellis, M. D. (2001). Developmental traumatology: The psychobiological development of maltreated children and its implications for research, treatment, and policy. *Development and Psychopathology*, *13*(3), 539–564.

De Bellis, M. D., & Thomas, L. A. (2003). Biologic findings of post-traumatic stress disorder and child maltreatment. *Current Psychiatry Reports*, *5*(2), 108–117.

De Bellis, M. D., Woolley, D. P., & Hooper, S. R. (2013). Neuropsychological findings in pediatric maltreatment: Relationship of PTSD, dissociative symptoms, and abuse/neglect indices to neurocognitive outcomes. *Child Maltreatment*, *18*(3), 171–183.

Dębiec, J., Bush, D. E., LeDoux, J.E. (2011). Noradrenergic enhancement of reconsolidation in the amygdala impairs extinction of conditioned fear in rats: A possible mechanism for the persistence of traumatic memories in PTSD. *Depression and Anxiety*, *28*,186–193.

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan executive function system (D-KEFS)*. Psychological Corporation

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (2000). CVLT-II. *The Psychological Corporation*.

DePrince, A. P., Weinzierl, K. M., & Combs, M. D. (2009). Executive function performance and trauma exposure in a community sample of children. *Child Abuse & Neglect*, *33*(6), 353–361.

Diamond, A. (2005). Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurobiologically and behaviorally distinct disorder from attention-deficit/hyperactivity disorder (with hyperactivity). *Development and Psychopathology*, *17*(3), 807–825.

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science, 318,* 1387–1388.

Diamond, A., & Doar, B. (1989). The performance of human infants on a measure of frontal cortex function, the Delayed Response task. *Developmental Psychobiology, 22,* 271–294.

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "do as I say, not as I do". *Developmental Psychobiology, 29,* 315–334.

Dirnberger, G., Fuller, R., Frith, C., & Jahanshahi, M. (2014). Neural correlates of executive dysfunction in schizophrenia: Failure to modulate brain activity with task demands. *Neuroreport*, *25*(16), 1308–1315.

Donders, J. (1999). Structural equation analysis of the California Verbal Learning Test—children's version in the standardization sample. *Developmental Neuropsychology*, *15*(3), 395–406.

Dong, M., Anda, R. F., Felitti, V. J., Dube, S. R., Williamson, D. F., Thompson, T. J., ... & Giles, W. H. (2004). The interrelatedness of multiple forms of childhood abuse, neglect, and household dysfunction. *Child Abuse & Neglect*, *28*(7), 771–784.

Dornbusch, S. M., Carlsmith, J. M., Bushwall, S. J., Ritter, P. L., Leiderman, H., Hastorf, A. H., & Gross, R. T. (1985). Single parents, extended households, and the control of adolescents. *Child Development, 45,* 326–341.

Durston, S. (2010). Imaging genetics in ADHD. *Neuroimage*, *53*(3), 832–838.

Eakin, L., Minde, K., Hechtman, L., Ochs, E., Krane, E., Bouffard, R., ... & Looper, K. (2004). The marital and family functioning of adults with ADHD and their spouses. *Journal of Attention Disorders*, *8*(1), 1–10.

Endo, T., Sugiyama, T., & Someya, T. (2006). Attention-deficit/hyperactivity disorder and dissociative disorder among abused children. *Psychiatry and Clinical Neurosciences, 60,* 434–438.

Epstein, J. N., Keith Conners, C., Hervey, A. S., Tonev, S. T., Eugene Arnold, L., Abikoff, H. B., ... & Hinshaw, S. P. (2006). Assessing medication effects in the MTA study using neuropsychological outcomes. *Journal of Child Psychology and Psychiatry*, *47*(5), 446-456.

Evans, S. W., Owens, J. S., & Bunford, N. (2014). Evidence-based psychosocial treatments for children and adolescents with attention-deficit/hyperactivity disorder. *Journal of Clinical Child and Adolescent Psychology, 43,* 527–551.

Fair, D. A., Bathula, D., Nikolas, M. A., & Nigg, J. T. (2012). Distinct neuropsychological subgroups in typically developing youth inform heterogeneity in children with ADHD. *Proceedings of the National Academy of Sciences*, *109*(17), 6769–6774.

Fairchild, G., van Goozen, S. H., Stollery, S. J., Aitken, M. R., Savage, J., Moore, S. C., & Goodyer, I. M. (2009). Decision making and executive function in male adolescents

with early-onset or adolescence-onset conduct disorder and control subjects. *Biological Psychiatry*, *66*(2), 162–168.

Fay-Stammbach, T., Hawes, D. J., & Meredith, P. (2014). Parenting influences on executive function in early childhood: A review. *Child Development Perspectives*, *8*(4), 258–264.

Feagans, L. V., Kipp, E., & Blood, I. (1994). The effects of otitis media on the attention skills of day-care-attending toddlers. *Developmental Psychology, 30,* 701–708.

Felitti, V. J. R. F., Nordenberg, D., Williamson, D. F., Spitz, A. M., Edwards, V., & Marks, J. S. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: The Adverse Childhood Experiences (ACE) Study. *American Journal of Preventive Medicine*, *14*(4), 245–258.

Filipek, P. A., Semrud-Clikeman, M., Steingrad, R., Kennedy, D., & Biederman, J. (1997). Volumetric MRI analysis: Comparing subjects having attention-deficit hyperactivity disorder with normal controls. *Neurology, 48*, 589–601.

Floresco, S. B., Magyar, O., Ghods-Sharifi, S., Vexelman, C., & Maric, T. L. (2006). Multiple dopamine receptor subtypes in the medial prefrontal cortex of the rat regulate set-shifting. *Neuropsychopharmacology*, *31*(2), 297.

Ford, J. D., Racusin, R., Daviss, W. B., Ellis, C. G., Thomas, J., Rogers, K., ... & Sengupta, A. (1999). Trauma exposure among children with oppositional defiant disorder and attention deficit–hyperactivity disorder. *Journal of Consulting and Clinical Psychology*, *67*(5), 786.

Ford, T., Goodman, R., & Meltzer, H. (2004). The relative importance of child, family, school and neighborhood correlates of childhood psychiatric disorder. *Social Psychiatry and Psychiatric Epidemiology, 39*, 487–496.

Frazier, T. W., Demaree, H. A., & Youngstrom, E. A. (2004). Meta-analysis of intellectual and neuropsychological test performance in attention-deficit/hyperactivity disorder. *Neuropsychology, 18*, 543–555.

Freitag, C. M., Hänig, S., Schneider, A., Seitz, C., Palmason, H., Retz, W., & Meyer, J. (2012). Biological and psychosocial environmental risk factors influence symptom severity and psychiatric comorbidity in children with ADHD. *Journal of Neural Transmission*, *119*(1), 81–94.

Friedman, R. A. (2012). Why are we drugging our soldiers. *The New York Times*, *21*.

Friedman, N. P., Miyake, A., Corley, R. P., Young, S. E., DeFries, J. C., & Hewitt, J. K. (2006). Not all executive functions are related to intelligence. *Psychological Science*, *17*(2), 172–179.

Froehlich, T. E., Lanphear, B. P., Epstein, J. N., Barbaresi, W. J., Katusic, S. K., & Kahn, R. S. (2007). Prevalence, recognition, and treatment of attention-deficit/hyperactivity disorder in a national sample of US children. *Archives of Pediatric Adolescent Medicine, 161,* 857–864.

Gabowitz, D., Zucker, M., & Cook, A. (2008). Neuropsychological assessment in clinical evaluation of children and adolescents with complex trauma. *Journal of Child & Adolescent Trauma*, *1*(2), 163–178.

Gaub, M., & Carlson, C. L. (1997). Gender differences in ADHD: A meta-analysis and critical review. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(8), 1036–1045.

Giedd, J. N., Castellanos, F. X., Casey, B. J., Kozuch, P., King, A. C., Hamburger, S. D., et al. (1994). Quantitative morphology of the corpus callosum in attention deficit hyperactivity disorder. American Journal of Psychiatry, 151, 665−669

Gioia, G., Isquith, P., Guy, S., & Kenworthy, L. (2000). Test review Behavior Rating Inventory of Executive Function. *Child Neuropsychology, 6*(3), 235-238

Gioia, G., Isquith, P., Kenworthy, L., & Barton, R. (2010). Profiles of everyday executive function in acquired and developmental disorders. *Child Neuropsychology, 8*(2), 121–137.

Gioia, G. A., Isquith, P. K., Retzlaff, P. D., & Espy, K. A. (2002). Confirmatory factor analysis of the Behavior Rating Inventory of Executive Function (BRIEF) in a clinical sample. *Child Neuropsychology*, *8*(4), 249-257.

Goldman-Rakic, P. S. (1996). The prefrontal landscape: implications of functional architecture for understanding human mentation and the central executive. *Phil. Trans. R. Soc. Lond. B*, *351*(1346), 1445-1453.

Guttmann-Steinmetz, S., & Crowell, J. A. (2006). Attachment and externalizing disorders: A developmental psychopathology perspective. *Journal of the American Academy of Child & Adolescent Psychiatry*, *45*(4), 440–451.

Hackman, D. A., Gallop, R., Evans, G. W., & Farah, M. J. (2015). Socioeconomic status and executive function: Developmental trajectories and mediation. *Developmental Science*, *18*(5), 686–702.

Hanson, J. L., Adluru, N., Chung, M. K., Alexander, A. L., Davidson, R. J., Pollak, S. D. (2013). Early neglect is associated with alterations in white matter integrity and cognitive functioning. *Child Development, 84*(5), 1566–1578.

Hashemi, T., & Abbasi, N. M. (2013). *Comparison of executive functions in subtypes of attention-deficit/hyperactivity disorder based on Barkley's model.* 6th International Congress on Child and Adolescent Psychiatry. Tabtiz University of Medical Sciences.

Harms, M. B., Shannon Bowen, K. E., Hanson, J. L., & Pollak, S. D. (2017). Instrumental learning and cognitive flexibility processes are impaired in children exposed to early life stress. *Developmental Science*. *21*(4), e12596

Hauser, P., Zametkin, A. J., Martinez, P., Vitielo, B., Matochick, J., Mixson, J., & Weintraub, B. D. (1993). Attention-deficit/hyperactivity disorder in people with generalized resistance to thyroid hormone. *The New England Journal of Medicine, 328,* 997–1001.

Hauser, R. M. (1994). Measuring socioeconomic status in studies of child development. *Child Development*, *65*(6), 1541–1545.

Hill, D. E., Yeo, R. A., Campbell, R. A., Hart, B., Vigil, J., & Brooks, W. (2003). Magnetic resonance imaging correlates of attention deficit/hyperactivity disorder in children. *Neuropsychology, 17,* 496–506.

Hechtman, L. (2018). Considerations in selecting pharmacological treatments for attention deficit hyperactivity disorder. *Lung Cancer*, *15*, 05.

Heiervang, E., Stormark, K. M., Lundervold, A. J., Heimann, M., Goodman, R., Posserud, M.-B., … Gillberg, C. (2007). Psychiatric disorders in Norwegian 8- to 10-year-olds: An epidemiological survey of prevalence, risk factors, and service use. *Journal of the American Academy of Child & Adolescent Psychiatry, 46,* 438–447.

Herbst, E., McCaslin, S., & Kalapatapu, R. K. (2017). Use of stimulants and performance enhancers during and after trauma exposure in a combat veteran: A possible risk factor for posttraumatic stress symptoms. *American Journal of Psychiatry*, *174*(2), 95–99.

Herringa, R., Phillips, M., Almeida, J., Insana, S., & Germain, A. (2012). Post-traumatic stress symptoms correlate with smaller subgenual cingulate, caudate, and insula volumes in unmedicated combat veterans. *Psychiatry Research: Neuroimaging*, *203*(2), 139–145.

Homack, S., Lee, D., & Riccio, C. A. (2005). Test review: Delis-Kaplan Executive Function System. *Journal of Clinical and Experimental Neuropsychology*, *27*(5), 599–609.

Hostinar, C. E., Stellern, S. A., Schaefer, C., Carlson, S. M., & Gunnar, M. R. (2012). Associations between early life adversity and executive function in children adopted internationally from orphanages. *Proceedings of the National Academy of Sciences, 109,* 17208–17212.

Houghton, S., Douglas, G., West, J., Whiting, K., Wall, M., Langsford, S., ... & Carroll, A. (1999). Differential patterns of executive function in children with attention-deficit hyperactivity disorder according to gender and subtype. *Journal of child neurology*, *14*(12), 801-805.

Husain, S. A., Allwood, M. A., & Bell, D. J. (2008). The relationship between PTSD symptoms and attention problems in children exposed to the Bosnian war. *Journal of Emotional and Behavioral Disorders, 16,* 52–62.

Jacques, S., & Zelazo, P. (2001). The Flexible Item Selection Task (FIST): A measure of executive function in preschoolers. *Developmental Neuropsychology*, *0*(3), 573-591.

Jensen, P. S., Hinshaw, S. P., Kraemer, H. C., Lenora, N., Newcorn, J. H., Abikoff, H. B., ... & Elliott, G. R. (2001). ADHD comorbidity findings from the MTA study: Comparing comorbid subgroups. *Journal of the American Academy of Child & Adolescent Psychiatry*, *40*(2), 147–158.

Joëls, M., & Baram, T. Z. (2009). The neuro-symphony of stress. *Nature Reviews Neuroscience*, *10*(6), 459.

Johnson, A. C. (2015). Developmental pathways to attention-deficit/hyperactivity disorder and disruptive behavior disorders: Investigating the impact of the stress response on executive functioning. *Clinical Psychology Review*, *36*, 1–12.

Kerr, A., & Zelazo, P. D. (2004). Development of "hot" executive function: The children's gambling task. *Brain and Cognition*, *55*(1), 148–157.

Klorman, R., Hazel-Fernandez, L. A., Shaywitz, S. E., Fletcher, J. M., Marchione, K. E., Holahan, J. M., ... & Shaywitz, B. A. (1999). Executive functioning deficits in attention-deficit/hyperactivity disorder are independent of oppositional defiant or reading disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, *38*(9), 1148-1155.

Kobel, M., Bechtel, N., Weber, P., Specht, K., Klarhöfer, M., Scheffler, K., ... & Penner, I. K. (2009). Effects of methylphenidate on working memory functioning in children with attention deficit/hyperactivity disorder. *European Journal of Paediatric Neurology*, *13*(6), 516-523.

Kooistra, L., van der Meere, J. J., Vulsma, T., & Kalverboer, A. F. (1996). Sustained attention problems in children with early-treated congenital hypothyroidism. *Acta Paediatrica, 85,* 452–429.

Krain, A. L., & Castellanos, F. X. (2006). Brain development and ADHD. *Clinical Psychology Review*, *26*(4), 433–444.

Krause, K.-H., Dresel, S. H., Krause, J., Kung, H. F., Tatsch, K, Douglas, V. I., & Benezra, E. (1990). Supraspan verbal memory in attention deficit disorder with hyperactivity,

normal, and reading disabled boys. *Journal of Abnormal Child Psychology, 18,* 617–638.

Kreppner J. M., Rutter, M., Beckett, C., Castle, J., Colvert, E., Groothues, C. … Sonuga-Barke, E. J. S. (2007). Normality and impairment following profound early institutional deprivation: A longitudinal follow-up into early adolescence. *Developmental Psycholology, 43,* 931–946.

Krikorian, R., & Bartok, J. (1998). Developmental data for the Porteus Maze Test. *The Clinical Neuropsychologist, 12,* 305–310.

Kuhar, B. (2014). Pharmacological interventions for adolescents and adults with ADHD: Stimulant and nonstimulant medications and misuse of prescription stimulants. *Psychology Research and Behavior Management*, *7*, 223–249.

Leung, A. K. C., & Hon, K. L. (2016). Attention-deficit/hyperactivity disorder. *Advances in Pediatrics*, *63*(1), 255–280.

Lewin-Bizan, S., Bowers, E. P., & Lerner, R. M. (2010). One good thing leads to another: Cascades of positive youth development among American adolescents. *Development and Psychopathology*, *22*(4), 759–770.

Lewis-Morrarty, E., Dozier, M., Bernard, K., Terracciano, S., & Moore, S. (2012). Cognitive flexibility and theory of mind outcomes among foster children: Preschool follow-up results of a randomized clinical trial. *Journal of Adolescent Health*, *51*, S17–S22.

Lezak, M. D., Howieson, D. B., Loring, D. W., & Fischer, J. S. (2004). *Neuropsychological assessment*. Oxford, New York: Oxford University Press.

Lijffijt, M., Kenemans, J. L., Verbaten, M. N., & van Engeland, H. (2005). A meta-analytic review of stopping performance in attention-deficit/hyperactivity disorder: Deficient inhibitory motor control? *Journal of Abnormal Psychology*, *114*(2), 216.

Loge, D. V., Staton, R. D., & Beatty, W. W. (1990). Performance of children with ADHD on tests sensitive to frontal lobe dysfunction. *Journal of the American Academy of Child & Adolescent Psychiatry*, *29*(4), 540–545.

Logue, S. F., & Gould, T. J. (2014). The neural and genetic basis of executive function: Attention, cognitive flexibility, and response inhibition. *Pharmacology Biochemistry and Behavior*, *123*, 45–54.

Ludbrook, J. (1998). Multiple comparison procedures updated. *Clinical and Experimental Pharmacology and Physiology*, *25*(12), 1032–1037.

Luna, M. (2006). The traumatic impact of growing up in community violence: How that impact compares to the impact on children growing up in war-torn countries. *School Social Work Journal, 31,* 19–29.

Lupien, S. J., Ouellet-Morin, I., Herba, C. M., Juster, R., & McEwen, B. S. (2016). From vulnerability to neurotoxicity: A developmental approach to the effects of stress on the brain and behavior. In *Epigenetics and neuroendocrinology* (pp. 3-48). Springer, Cham.

Mahone, E. M., & Hoffman, J. (2007). Behavior ratings of executive function among preschoolers with ADHD. *The Clinical Neuropsychologist*, *21*(4), 569–586.

Makris, N., Biederman, J., Monuteaux, M. C., & Seidman, L. J. (2009). Towards conceptualizing a neural systems-based anatomy of attention-deficit/hyperactivity disorder. *Developmental Neuroscience, 31*(1–2), 36–49.

Malarbi, S., Abu-Rayya, H. M., Muscara, F., & Stargatt, R. (2017). Neuropsychological functioning of childhood trauma and post-traumatic stress disorder: A meta-analysis. *Neuroscience and Biobehavioral Reviews*, *72*, 68–86.

Marsac, M. L., Kassam-Adams, N., Delahanty, D. L., Widaman, K. F., & Barakat, L. P. (2014). Posttraumatic stress following acute medical trauma in children: A proposed model of bio-psycho-social processes during the peri-trauma period. *Clinical Child and Family Psychology Review*, *17*(4), 399–411.

Martínez, L., Prada, E., Satler, C., Tavares, M. C. H., & Tomaz, C. (2016). Executive dysfunctions: The role in attention deficit hyperactivity and post-traumatic stress neuropsychiatric disorders. *Frontiers in Psychology*, *7*, 1230.

Marx, B. P., Doron-Lamarca, S., Proctor, S. P., & Vasterling, J. J. (2009). The influence of pre-deployment neurocognitive functioning on post-deployment PTSD symptom outcomes among Iraq-deployed Army soldiers. *Journal of the International Neuropsychological Society*, *15*(6), 840-852.

Masson, M., Bussières, E. L., East-Richard, C., R-Mercier, A., & Cellard, C. (2015). Neuropsychological profile of children, adolescents and adults experiencing maltreatment: A meta-analysis. *The Clinical Neuropsychologist*, *29*(5), 573–594.

Maughan, A., & Cicchetti, D. (2002). Impact of child maltreatment and interadult violence on children's emotion regulation abilities and socioemotional adjustment. *Child Development*, *73*(5), 1525–1542.

McClelland, M. M., & Cameron, C. E. (2011). Self-regulation and academic achievement in elementary school children. *New Directions for Child and Adolescent Development*, *2011*(133), 29-44.

McClelland, M., Geldhof, J., Morrison, F., Gestsdóttir, S., Cameron, C., Bowers, E., ... & Grammer, J. (2018). Self-regulation. In *Handbook of life course health development* (pp. 275-298). Springer, Cham.

McDermott, J. M., Westerlund, A., Zeanah, C. H., Nelson, C. A., & Fox, N. A. (2012). Early adversity and neural correlates of executive function: Implications for academic adjustment. *Developmental Cognitive Neuroscience*, (*2)*, 290–291.

McDonald, C. R., Delis, D. C., Norman, M. A., Wetter, S. R., Tecoma, E. S., & Iragui, V. J. (2005). Response inhibition and set shifting in patients with frontal lobe epilepsy or temporal lobe epilepsy. *Epilepsy & Behavior*, (*7)*, 438–446.

McKlveen, J. M., Myers, B., & Herman, J. P. (2015). The medial prefrontal cortex: Coordinator of autonomic, neuroendocrine and behavioral responses to stress. *Journal of Neuroendocrinology*, *27*(6), 446–456.

McMillen, J. C., Zima, B. T., Scott, L. D., Auslander, W. F., Munson, M. R., Ollie, M. T., Spitznagel, E. L. (2005). Prevalence of psychiatric disorders among older youths in the foster care system. *Journal of the American Academy of Child and Adolescent Psychiatry 44*, 88–95.

McNally, R. J. (2006). Cognitive abnormalities in post-traumatic stress disorder. *Trends in Cognitive Sciences*, *10*(6), 271–277.

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

Moench, K. M., & Wellman, C. L. (2015). Stress-induced alterations in prefrontal dendritic spines: Implications for post-traumatic stress disorder. *Neuroscience Letters*, *601*, 41–45.

Mulsow, M. H., O'Neal, K. K., & Murry, V. M. (2001). Adult attention deficit hyperactivity disorder, the family, and child maltreatment. *Trauma, Violence & Abuse, 2,* 36–50.

Nanni, V., Uher, R., & Danese, A. (2012). Childhood maltreatment predicts unfavorable course of illness and treatment outcome in depression: A meta-analysis. *American Journal of Psychiatry*, *169*(2), 141–151.

Nigg, J. T. (2001). Is ADHD a disinhibitory disorder?. *Psychological bulletin*, *127*(5), 571.

Nigg, J. T. (2006). *What causes ADHD?: Understanding what goes wrong and why*. New York, NY: Guilford Press.

Nigg, J. T. (2001). Is ADHD a disinhibitory disorder?. *Psychological bulletin*, *127*(5), 571.

Nigg, J. T., Blaskey, L. G., Huang-Pollock, C. L., & Rappley, M. D. (2002): Neuropsychological executive functions and DSM-IV ADHD subtypes. *Journal of the American Academy of Child and Adolescent Psychiatry, 41*, 59–66.

Nigg, J. T., Knottnerus, G. M., Martel, M. M., Nikolas, M., Cavanagh, K., Karmaus, W., & Rappley, M. D. (2008). Low blood lead levels associated with clinically diagnosed attention-deficit/hyperactivity disorder and mediated by weak cognitive control. *Biological Psychiatry*, *63*(3), 325–331.

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

Nolin, P., & Ethier, L. (2007). Using neuropsychological profiles to classify neglected children with or without physical abuse. *Child Abuse Neglect 31*(6), 631–643.

O'Donnell, T., Hegadoren, K. M., & Coupland, N. C. (2004). Noradrenergic mechanisms in the pathophysiology of post-traumatic stress disorder. *Neuropsychobiology, 50*, 273–283.

Oswald, S. H., Heil, K., & Goldbeck, L. (2009). History of maltreatment and mental health problems in foster children: A review of the literature. *Journal of pediatric psychology*, *35*(5), 462-472.

Pallant, J. (2010). *PASW and SPSS survival manual* (4th ed.). Maidenhead: Open University Press.

Pennington, B. F. (1997). Dimensions of executive functions in normal and abnormal development. In N. A. Krasnegor, G. R. Lyon., & P. Goldman-Rakic (Eds.), *Development of the prefrontal cortex: Evolution, neurobiology, and behavior* (pp. 265–281). Baltimore, MD: Paul H Brooks Publishing Company.

Petrovic, P., & Castellanos, F. X. (2016). Top-down dysregulation—from ADHD to emotional instability. *Frontiers in Behavioral Neuroscience*, *10*, 70.

Perry-Burney, G., Logan, S. M. L., Denby, R. W., & Gibson, P. A. (2007). Poverty, special education, and ADHD. In S. L. Logan, R. W. Denby, & P. A. Gibson (Eds.), *Mental health care in the African-American community* (pp. 139–153). New York, NY: Haworth Press.

Pine, D. S., Mogg, K., Bradley, B. P., Montgomery, L., Monk, C. S., McClure, E., … Kaufman, J. (2005). Attention bias to threat in maltreated children: Implications for vulnerability to stress-related psychopathology. *American Journal of Psychiatry, 162*, 291–296.

Pitcher, T. M., Piek, J. P., & Hay, D. A. (2003). Fine and gross motor ability in males with ADHD. *Developmental Medicine and Child Neurology*, *45*(8), 525–535.

Pitman, R. K., Rasmusson, A. M., Koenen, K. C., Shin, L. M., Orr, S. P., Gilbertson, M. W., & ... Liberzon, I. (2012). Biological studies of post-traumatic stress disorder. *Nature Reviews. Neuroscience*, *13*(11), 769-787.

Pollak, S. D., Nelson, C. A., Schlaak, M. F., Roeber, B. J., Wewerka, S. S., Wiik, K. L., ... & Gunnar, M. R. (2010). Neurodevelopmental effects of early deprivation in postinstitutionalized children. *Child development*, *81*(1), 224-236.

Pritchard, A. E., Nigro, C. A., Jacobson, L. A., & Mahone, E. M. (2012). The role of neuropsychological assessment in the functional outcomes of children with ADHD. *Neuropsychology Review*, *22*(1), 54–68.

Putnam, F. W. (1997). *Dissociation in children and adolescents: A developmental perspective*. New York, NY: Guilford Press.

Oswald, S. H., Heil, K., & Goldbeck, L. (2010). History of maltreatment and mental health problems in foster children: A review of the literature. *Journal of Pediatric Psychology, 35*, 462–472.

Rapport, M. D., Orban, S. A., Kofler, M. J., & Friedman, L. M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review*, *33*(8), 1237–1252.

Reyes-Perez, C. D., Martinez-Taboas, A., & Ledesma-Amador, D. (2005). Dissociative experiences in children with abuse histories: A replication in Puerto Rico. *Journal of Trauma & Dissociation, 6*, 99–112.

Rhodes, S. M., Coghill, D. R. & Matthews, K. (2006). Acute neuropsychological effects of methylphenidate in stimulant drug-naïve boys with ADHD II—Broader executive and non-executive domains. *Journal of Child Psychology and Psychiatry, 47*, 1184–1194.

Robbins, T. W., James, M., Owen, A. M., Sahakian, B. J., Lawrence, A. D., McInnes, L., & Rabbitt, P. M. (1998). A study of performance on tests from the CANTAB battery sensitive to frontal lobe dysfunction in a large sample of normal volunteers: Implications for theories of executive functioning and cognitive aging. *Journal of the International Neuropsychological Society*, *4*(5), 474-490.

Robbins, T. W., & Roberts, A. C. (2007). Differential regulation of fronto-executive function by the monoamines and acetylcholine. *Cerebral Cortex*, *17*(suppl_1), i151-i160.

Roberts, B. A., Martel, M. M., & Nigg, J. T. (2017). Are there executive dysfunction subtypes within attention-deficit/hyperactivity disorder? *Journal of Attention Disorders*, *21*(4), 284–293.

Roskam, I., Stievenart, M., Tessier, R., Muntean, A., Escobar, M. J., Santelices, M. P., ... Pierrehumbert, B. (2014). Another way of thinking about ADHD: The predictive role of early attachment deprivation in adolescents' level of symptoms. *Social Psychiatry and Psychiatric Epidemiology: The International Journal for Research in Social and Genetic Epidemiology and Mental Health Services*, *49*(1), 133–144.

Roth, R. M., Isquith, P. K., & Gioia, G. A. (2014). Assessment of executive functioning using the Behavior Rating Inventory of Executive Function (BRIEF). In *Handbook of executive functioning* (pp. 301–331). New York, NY: Springer.

Rubia, K. (2011). “Cool” inferior frontostriatal dysfunction in attention-deficit/hyperactivity disorder versus “hot” ventromedial orbitofrontal-limbic dysfunction in conduct disorder: a review. *Biological psychiatry*, *69*(12), e69-e87.

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Science, 102*, 14931–14936.

Samuelson, K. W., Neylan, T. C., Metzler, T. J., Lenoci, M., Rothlind, J., Henn-Haase, C., ... & Marmar, C. R. (2006). Neuropsychological functioning in posttraumatic stress disorder and alcohol abuse. *Neuropsychology*, *20*(6), 716.

Schmitt, J., Romanos, M., Schmitt, N., Meurer, M., & Kirch, W. (2009). Atopic eczema and attention-deficit/hyperactivity disorder in a population-based sample of children and adolescents. *Journal of the American Medical Association, 301*, 724–726.

Schore, A. (2000). Attachment and the regulation of the right brain. *Attachment & Human Development, 2*(1), 23–47.

Schore, J. R., & Schore, A. N. (2008). Modern attachment theory: The central role of affect regulation in development and treatment. *Clinical Social Work Journal*, *36*(1), 9–20.

Seidman, L. J., Valera, E. M., & Makris, N. (2005). Structural brain imaging of attention-deficit/hyperactivity disorder. *Biological Psychiatry*, *57*(11), 1263–1272.

Sergeant, J. A., Geurts, H., & Oosterlaan, J. (2002). How specific is a deficit of executive functioning for attention-deficit/hyperactivity disorder?.*Behavioural Brain Research*, *130*(1), 3–28.

Seymour, K. E., Mostofsky, S. H., & Rosch, K. S. (2016). Cognitive load differentially impacts response control in girls and boys with ADHD. *Journal of Abnormal Child Psychology*, *44*(1), 141–154.

Snyder, H. R., Kaiser, R. H., Warren, S. L., & Heller, W. (2015). Obsessive-compulsive disorder is associated with broad impairments in executive function: A meta-analysis. *Clinical Psychological Science*, *3*(2), 301–330.

Sonuga-Barke, E. J. (2003). The dual pathway model of AD/HD: An elaboration of neuro-developmental characteristics. *Neuroscience & Biobehavioral Reviews*, *27*(7), 593–604.

Sonuga-Barke, E. (2005). Causal models of attention-deficit/hyperactivity disorder: From common simple deficits to multiple developmental pathways. *Biological Psychiatry 57*(11), 1231–1238.

Sonuga-Barke, E., Bitsakou, P., & Thompson, M. (2010). Beyond the dual pathway model: Evidence for the dissociation of timing, inhibitory, and delay-related impairments in attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 49*(4), 345–355.

Sonuga-Barke, E. J., & Halperin, J. M. (2010). Developmental phenotypes and causal pathways in attention deficit/hyperactivity disorder: Potential targets for early intervention? *Journal of Child Psychology and Psychiatry*, *51*(4), 368–389.

Sonuga-Barke, E., Rubia, K. (2008). Inattentive/overactive children with histories of profound institutional deprivation compared with standard ADHD cases: A brief report. *Child Care Health Development, 34*(5), 596–602.

Sowell, E. R., Thompson, P. M., Welcome, S. E., Henkenius, A. L.,Toga, A. W., & Peteron, B. (2003). Cortical abnormalities in children and adolescents with attention-deficit hyperactivity disorder. *Lancet, 362*, 1699–1707.

Spencer, A. E., Faraone, S. V., Bogucki, O. E., Pope, A. L., Uchida, M., Milad, M. R., Spencer, T. J., Woodworth, K. Y., & Biederman, J. (2016). Examining the association between posttraumatic stress disorder and attention-deficit/hyperactivity disorder: A systematic review and meta-analysis.The Journal of clinical psychiatry,77(1), 72-83.

Spencer, T. J., Brown, A., Seidman, L. J., Valera, E. M., Makris, N., Lomedico, A., ... & Biederman, J. (2013). Effect of psychostimulants on brain structure and function in ADHD: a qualitative literature review of MRI-based neuroimaging studies. *The Journal of clinical psychiatry*, *74*(9), 902.

Sripada, R. K., Rauch, S. A., Tuerk, P. W., Smith, E., Defever, A. M., Mayer, R. A., ... & Venners, M. (2013). Mild traumatic brain injury and treatment response in prolonged exposure for PTSD. *Journal of Traumatic Stress*, *26*(3), 369-375.

Stams, G. J., Juffer, F., & van IJzendoorn, M. H. (2002). Maternal sensitivity, infant attachment, and temperament in early childhood predict adjustment in middle childhood: The case of adopted children and their biologically unrelated parents. *Developmental Psychology, 38,* 806–821.

Straus, M. (2017). *Treating trauma in adolescents: Development, attachment, and the therapeutic relationship*. New York, NY: Guilford Press.

Stuss, D. T., Shallice, T., Alexander, M. P., & Picton, T. W. (1995). A multidisciplinary approach to anterior attentional functions. *Annals of the New York Academy of Sciences*, *769*(1), 191–212.

Szymanski, K., Sapanski, L., & Conway, F. (2011). Trauma and ADHD–Association or diagnostic confusion? A clinical perspective. *Journal of Infant, Child & Adolescent Psychotherapy*, *10*(1), 51–59.

Tavares, J. V. T., Clark, L., Cannon, D. M., Erickson, K., Drevets, W. C., & Sahakian, B. J. (2007). Distinct profiles of neurocognitive function in unmedicated unipolar depression and bipolar II depression. *Biological Psychiatry*, *62*(8), 917–924.

Teicher, M. H., & Samson, J. A. (2013). Childhood maltreatment and psychopathology: A case for ecophenotypic variants as clinically and neurobiologically distinct subtypes. *American Journal of Psychiatry*, *170*(10), 1114–1133.

Teicher, M. H., & Samson, J. A. (2016). Annual research review: Enduring neurobiological effects of childhood abuse and neglect. *Journal of Child Psychology and Psychiatry*, *57*(3), 241–266.

Thorell, L. B., Rydell, A. M., & Bohlin, G. (2012). Parent-child attachment and executive functioning in relation to ADHD symptoms in middle childhood. *Attachment & Human Development*, *14*(5), 517–532.

Thornton, A., & Camburn, D. (1987). The influence of the family on premarital sexual attitudes and behavior. *Demography, 24*, 323–340.

Toplak, M. E., Bucciarelli, S. M., Jain, U., & Tannock, R. (2008). Executive functions: Performance-based measures and the Behavior Rating Inventory of Executive Function (BRIEF) in adolescents with attention deficit/hyperactivity disorder (ADHD). *Child Neuropsychology*, *15*(1), 53–72.

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

U.S. Department of Health and Human Services. (2011). National Center for Health Statistics. *Health, United States, 2010: With special feature on death and dying.* Hyattsville, MD.

Vaidya, C. J., & Stollstorff, M. (2008). Cognitive neuroscience of attention deficit hyperactivity disorder: Current status and working hypotheses. *Developmental Disabilities Research Reviews, 14*(4), 261–267.

Van der Kolk, B. A. (2005). Developmental trauma disorder. *Psychiatric Annals*, *35*(5), 401–408.

Van Mourik, R., Oosterlaan, J., & Sergeant, J. A. (2005). The Stroop revisited: A meta-analysis of interference control in AD/HD. *Journal of Child Psychology and Psychiatry*, *46*(2), 150–165.

Vasterling, J. J., Duke, L. M., Brailey, K., Constans, J. I., Allain Jr, A. N., & Sutker, P. B. (2002). Attention, learning, and memory performances and intellectual resources in Vietnam veterans: PTSD and no disorder comparisons. *Neuropsychology*, *16*(1), 5.

Wåhlstedt, C., Thorell, L. B., & Bohlin, G. (2009). Heterogeneity in ADHD: Neuropsychological pathways, comorbidity and symptom domains. *Journal of Abnormal Child Psychology*, *37*(4), 551–564.

Weinstein, D., Staffelbach, D., & Biaggio, M. (2000). Attention-deficit hyperactivity disorder and posttraumatic stress disorder: Differential diagnosis in childhood sexual abuse. *Clinical Psychology Review, 20,* 359–378.

Wellman, H. M., Phillips, A. T., Dunphy-Lelii, S., & LaLonde, N. (2004). Infant social attention predicts preschool social cognition. *Developmental Science, 7*, 283–288.

Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology*, *7*(2), 131–149.

Weyandt, L. L., Oster, D. R., Marraccini, M. E., Gudmundsdottir, B. G., Munro, B. A., Rathkey, E. S., & McCallum, A. (2016). Prescription stimulant medication misuse: Where are we and where do we go from here? *Experimental and Clinical Psychopharmacology*, *24*(5), 400.

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

Wodka, E. L., Mahone, E. M., Blankner, J. G., Larson, J. C., Fotedar, S., Denckla, M. B., & Mostofsky, S. H. (2007). Evidence that response inhibition is a primary deficit in ADHD. *Journal of Clinical and Experimental Neuropsychology, 29,* 345–356.

Wolf, R. C., & Herringa, R. J. (2016). Prefrontal–amygdala dysregulation to threat in pediatric posttraumatic stress disorder. *Neuropsychopharmacology*,*41*(3), 822–831.

Wu, K. K., Anderson, V., & Castiello, U. (2002). Neuropsychological evaluation of deficits in executive functioning for ADHD children with or without learning disabilities. *Developmental Neuropsychology*, *22*(2), 501–531.

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. *Blackwell Handbook of Childhood Cognitive Development*, 445–469.

APPENDIX A

Letter of Dartmouth IRB approval

Trustees of Dartmouth College Dartmouth-Hitchcock Medical Center COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS Howard Hughes, PhD, Chair CPHS A

Title of Study: Clinical Correlates of Executive Functioning in Children with ADHD Risk Level: No greater than minimal risk Notes: +Parental permission and assent waived per 45 CFR 46.116(d) and Authorization waived per 45 CFR 164.512(i)(2)(ii) for data existing from July 2007 to July 2017. +CPHS determines this research involving minors to be research not involving greater than minimal risk [45 CFR 46.404 and 21 CFR 50.51].
Documents Reviewed: Data_Research Plan_ACEs_August 1, 2017; children form.

The Committee for the Protection of Human Subjects has approved this submission. Approval by CPHS is based on the study's appropriate balance of risk and benefit to subjects, a study design in which risks to subjects are minimized, and a determination that the criteria for approval at 45 CFR 46.111 and 21 CFR 56.111 are satisfied as appropriate.

This submission has received Expedited review based on the federal regulation(s):

Category 5: Research involving materials (data, documents, records, or specimens) that have been collected or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis). (Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(4). This listing refers only to research that is not exempt.)

CPHS approval of this study expires on 9/10/2018. It is your responsibility as Principal Investigator to ensure that all other appropriate institutional approvals are obtained. You are required to submit a continuing review at least 30 days before expiration or study closure. You can submit a continuing review by navigating to the active study and clicking Create Modification / CR.

Any modification to previously approved materials must be approved by the CPHS prior to initiation. You can submit a modification by navigating to the active study and clicking Create Modification / CR.
Navigate to the active study and click “Report New Information” to report unanticipated problems involving risks to subjects or others, as well as certain adverse drug events and medical device effects. In addition, please promptly report any known instances of noncompliance and complaints.

If you have any questions, please direct them to CPHS.Tasks@Dartmouth.edu.

Kimberly A. Lyford, CIP Senior Research Analyst Committee for the Protection of Human Subjects

cc: Jonathan Lichtenstein

APPENDIX B

Adverse Childhood Experience (ACE) Questionnaire

While you were growing up, during your first 18 years of life:

1. Did a parent or other adult in the household often …

Swear at you, insult you, put you down, or humiliate you?

or

Act in a way that made you afraid that you might be physically hurt?

Yes No If yes enter 1 _____

2. Did a parent or other adult in the household often …

Push, grab, slap, or throw something at you?

or

Ever hit you so hard that you had marks or were injured?

Yes No If yes enter 1 _____

3. Did an adult or person at least 5 years older than you ever…

Touch or fondle you or have you touch their body in a sexual way?

or

Try to or actually have oral, anal, or vaginal sex with you?

Yes No If yes enter 1 _____

4. Did you often feel that …

No one in your family loved you or thought you were important or special?

or

Your family didn't look out for each other, feel close to each other, or support each other?

Yes No If yes enter 1 _____

5. Did you often feel that …

You didn't have enough to eat, had to wear dirty clothes, and had no one to protect you?

or

Your parents were too drunk or high to take care of you or take you to the doctor if you needed it?

Yes No If yes enter 1 _____

6. Were your parents ever separated or divorced?

Yes No If yes enter 1 _____

7. Was your mother or stepmother:

Often pushed, grabbed, slapped, or had something thrown at her?

or

Sometimes or often kicked, bitten, hit with a fist, or hit with something hard?

or

Ever repeatedly hit over at least a few minutes or threatened with a gun or knife?

Yes No If yes enter 1 _____

8. Did you live with anyone who was a problem drinker or alcoholic or who used street drugs?

Yes No If yes enter 1 _____

9. Was a household member depressed or mentally ill or did a household member attempt suicide?

Yes No If yes enter 1 _____

10. Did a household member go to prison?

Yes No If yes enter 1 _____

Now add up your "Yes" answers: _____ This is your ACE Score

APPENDIX C

Adapted Adverse Childhood Events Checklist

(Brown, Brown, Briggs, Germán, Belamarich, & Oyeku, 2017).

1. How often has it been very hard to get by on your family's income?
2. Did the child ever live with a parent or guardian who got divorced after the child was born?
3. Did the child ever live with a parent or guardian who died?
4. Did the child ever live with a parent or guardian who serviced time in jail or prison after the child was born?
5. Did the child ever see or hear any parent's guardians or other adults in his/her home slap, hit, kick, punch, or beat each other up?
6. Was the child ever a victim of violence or witness any violence in his/her neighborhood?
7. Did the child ever live with anyone who was mentally ill, suicidal, or severely depressed for more than a couple of weeks?
8. Did the child ever live with anyone who had a problem with alcohol or drugs?
9. Was the child ever treated or judged unfairly because of his/her race or ethnic group?

APPENDIX D

Adverse Childhood Events Checklist for file reviews in this study (yes = 1)

1. Socioeconomic hardship (established based on use of state insurance)
2. Parental divorce
3. Death of a Parent or guardian
4. Jail time served by parent or guardian
5. Exposure to domestic violence
6. Exposure to community violence – includes bullying
7. Mental illness/suicidality in the home
8. Substance use in the home
9. Unfair treatment – includes child abuse and neglect

APPENDIX E

Demographics collected

1. Age
2. Sex
3. Race
4. Gender
5. Diagnosis
6. Type of insurance
7. IQ
8. Medical history

Table1

Categories of Executive Functions and Associated Behavioral and Cognitive Variables

Executive Functions	Dependent Variables (Behavioral)	Dependent Variables (Cognitive)
Attentional Control	Inhibit (BRIEF)	Color-Word Interference Test Condition 3: Total Time (D-KEFS)
Information Processing	Monitor (BRIEF)	Verbal Fluency: Condition 1 Total Correct Responses(D-KEFS)
Cognitive Flexibility	Shift Scale (BRIEF)	Trail Making Test: Condition 4 Total Time (D-KEFS)
Goal Setting	Plan/Organize (BRIEF)	Semantic Clustering Index (CVLT-C or II)

Note: Behavior Rating Inventory of Executive Functions (BRIEF); Delis-Kaplan Executive Function System (D-KEFS); California Verbal Learning Test (CVLT), both children's and adult version were used.

Table 2

Regression Table for Cognitive Variables of Executive Functioning

Model	*B*	*SE B*	*B*	*T*	*P*
Inhibition	-.111	.122	-.132	-.910	.368
Task Completion	-.092	.089	-.123	-1.034	.305
Set Shifting	-.259	.100	-.297	-.297	.001*
Plan/Organize	-.018	.076	-.028	-.242	.810

Note. * Correlation is significant at the .05 level (2-tailed).

Table 3

Regression Table for Behavioral Variables of Executive Functioning

Model	*B*	*SE B*	*B*	*T*	*p*
Inhibition	.267	.079	.340	3.391	.002*
Self-Monitoring	.242	.097	.261	2.497	.014*
Set Shifting	.290	.080	.359	3.605	.001*
Plan/Organize	.065	.067	.101	.967	.336

Note. * Correlation is significant at the .05 level (2-tailed).

Table 4

Correction for Multiple Comparisons with Cognitive Variables

Model	Uncorrected	Bonferroni	Holm-Bonferroni
I	P	C x p	(C – i + 1) x p
Inhibit	.368	1.47	.736
Fluency	.305	1.22	.915
Shift	.012*	.048*	.048*
Planning	.810	3.24	.810

Note. * Correlation is significant at the .05 level (2-tailed).

Table 5

Correction for Multiple Comparisons with Behavioral Variables

Model	Uncorrected	Bonferroni	Holm-Bonferroni
I	P	C x p	(C – i + 1) x p
Inhibit	.001*	.004*	.004*
Monitor	.014*	.056	.028*
Shift	.001*	.004*	.003*
Planning	.336	1.344	.336

Note. * Correlation is significant at the .05 level (2-tailed).

Figure 1

Bivariate Linear Regression Scatterplot of Cognitive Flexibility: Trails Regression Line

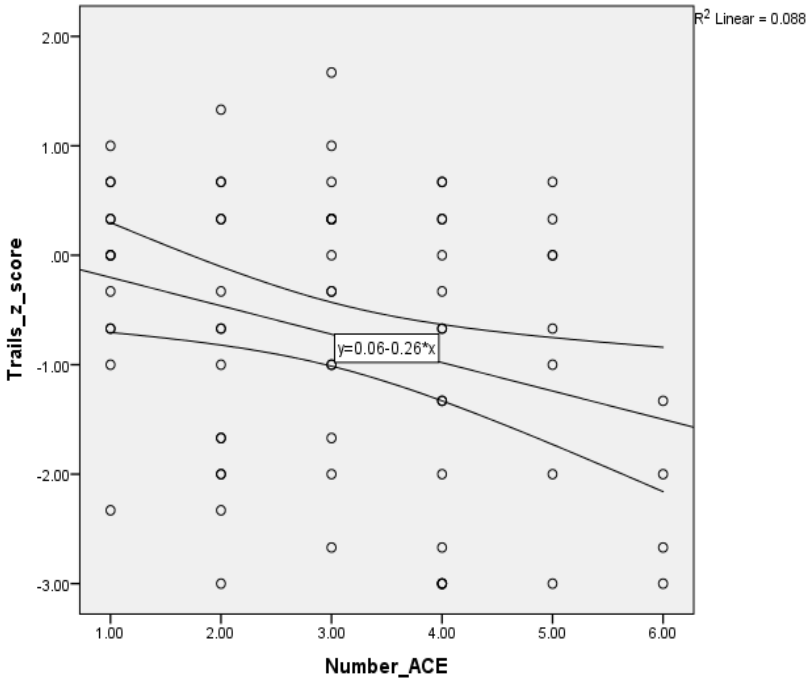

Figure 2

Bivariate Linear Regression Scatterplot of BRIEF: Inhibit Regression Line

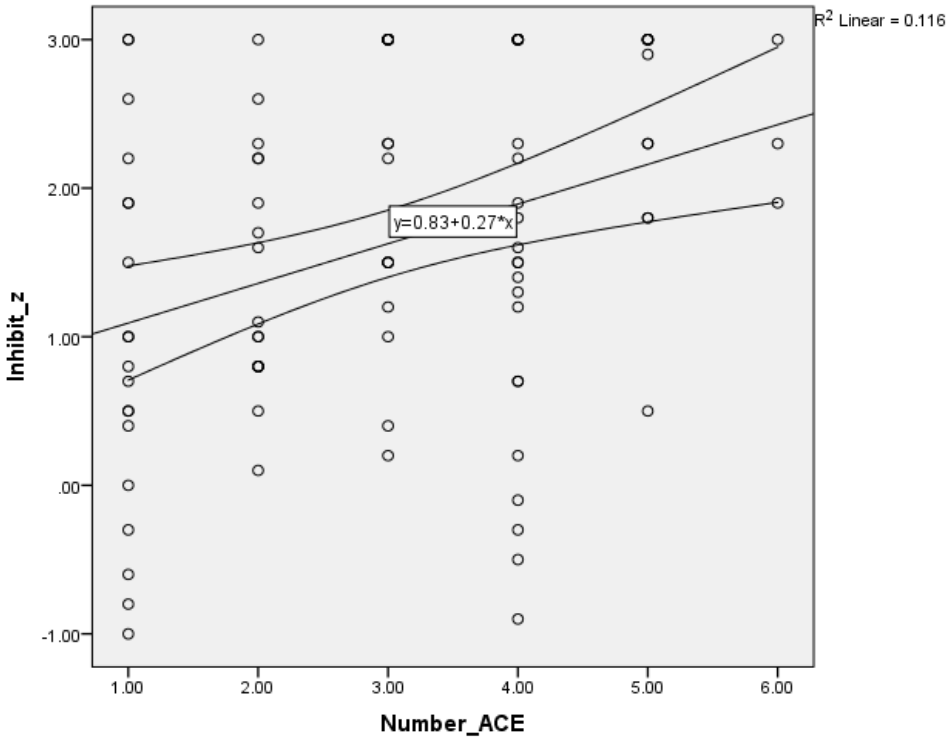

Figure 3

Bivariate Linear Regression Scatterplot of BRIEF: Self-Monitor Regression Line

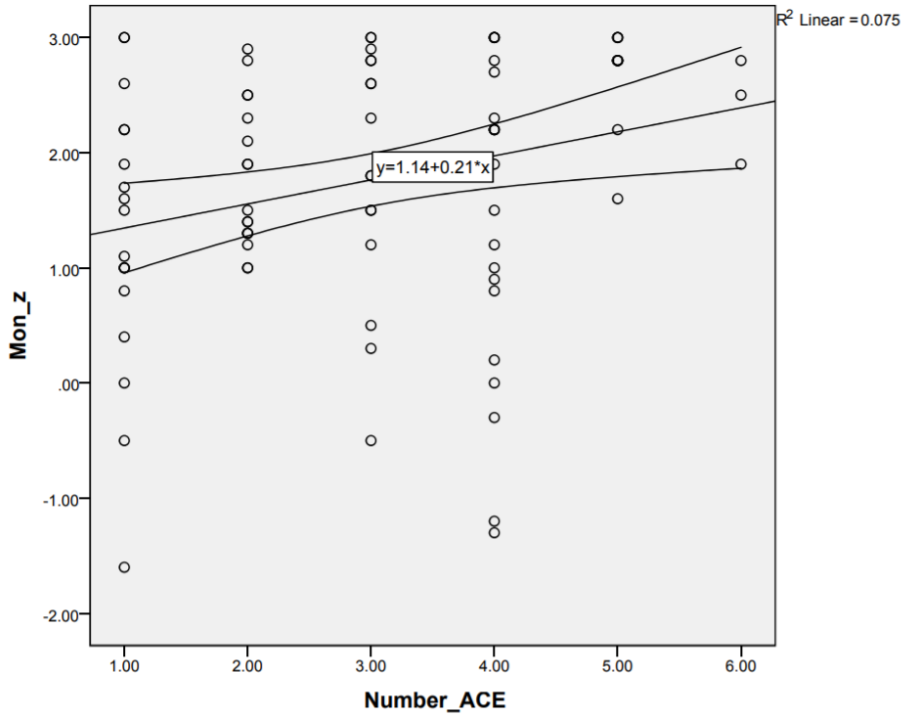

Figure 4

Bivariate Linear Regression Scatterplot of BRIEF: Shift Regression Line