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Assessing the Validity of the Quotient Adhd System and Its Value in a Comprehensive Diagnostic Assessment Battery for Adult ADHD

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ASSESSING THE VALIDITY OF THE QUOTIENT ADHD SYSTEM AND ITS VALUE IN A COMPREHENSIVE DIAGNOSTIC ASSESSMENT BATTERY FOR ADULT ADHD

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Dissertation Approval

This is to certify that the thesis presented to us by _____ on the _____ day of _____, 20___, in partial fulfillment of the requirements for the degree of Doctor of Psychology, has been examined and is acceptable in both scholarship and literary quality.

Committee Members' Signatures:

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Abstract

The purpose of this study was to determine the validity and reliability of the Quotient ADHD System (the Quotient) as a tool for the assessment of adult ADHD. At the time of this study, the Quotient was a widely accepted measure, yet there was a paucity of empirical evidence for its use with adults. This study reviewed the relationship between adult participants' (N = 151) scores on two self-reported measures, the Barkley Deficits in Executive Functioning Scale (BDEFS) and the Barkley Adult ADHD Rating Scale – IV (BAARS-IV), and the Quotient at a university-based ADHD-specialty outpatient clinic in a large city in the Northeastern U.S. It was predicted that participants' scores on the self-report measures would correlate with and predict the behavioral correlates of ADHD, the latter as measured by the Quotient. The present study determined that the Global Scaled Score metric of the Quotient correlates with the Total Executive Functioning (EF) Summary Score of the BDEFS and the ADHD Total Score of the BAARS-IV. Furthermore, this study found a significant, positive correlation between the Motion Scaled Scores of the Quotient and the ADHD Hyperactivity scale on the BAARS-IV. Additionally, through a post-hoc analysis, a correlation was found between the Inattention Scaled Scores of the Quotient and the Self-Restraint scale on the BDEFs. These findings may lend support that some of the core characteristics of ADHD, such as inattention and impulsivity, are less accurately measured by continuous performance tests (CPTs), while the behavioral traits of hyperactivity are more accurately captured by CPTs.

Keywords: adult attention-deficit/hyperactivity disorder, adult ADHD, symptoms, executive functions, assessment of ADHD

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Chapter 1: Introduction

Statement of the Problem

Attention-deficit/hyperactivity disorder (ADHD) is characterized by a persistent pattern of inattentiveness, hyperactivity-impulsivity, or a combined presentation (American Psychiatric Association [APA], 2013). For both children and adults, the inattentive presentation may manifest as a number of symptoms, including being easily distracted by extraneous stimuli, overlooking details, poor concentration, difficulties starting and finishing tasks, procrastination, difficulties comprehending reading materials, disorganization, daydreaming, and forgetfulness. The symptoms of hyperactivity and impulsivity may manifest differently in the childhood, adolescent, and adulthood presentations of ADHD. Although some of these symptoms may subside completely in adulthood, more often, they manifest as more subtle symptoms, such as restlessness or fidgetiness. Hyperactive and impulsive symptoms may include talking excessively, interrupting others, impatience, mental restlessness, and discomfort when sedentary. Other symptoms that are more common in adolescents and adults include impulsive spending and substance use (APA, 2013; Barkley, 2015b; Ramsay & Rostain, 2008).

Prior to 2013, the APA's (2000) fourth edition of its *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV-TR) stipulated that ADHD symptoms of inattentiveness and/or hyperactivity-impulsivity had to be present prior to an individual being seven years of age to meet criteria for this disorder. Although the age-of-onset criterion was consistent with the research regarding ADHD in children, it did not account for cases in which symptoms went undetected until later in life, particularly in adults. Additionally, due to the age-of-onset criterion of the DSM-IV-TR, minimal research

explored how the symptoms of ADHD manifested in adults, but instead focused on ADHD in children. This focus on ADHD in children created disparities with adult ADHD research and generated a widespread trend of adults with ADHD being underdiagnosed or misdiagnosed (Barkley, 2015a).

In 2013, the APA updated the definition of ADHD within the *DSM-5* to more accurately characterize the experience of affected adults. The updated criteria were based on longitudinal research exploring the presence of ADHD symptomatology in adults who were diagnosed with ADHD as children (APA, 2013). Despite this modification of diagnostic criteria, the research exploring ADHD in adults is still lacking, and adult ADHD continues to be underdiagnosed, misdiagnosed, under-treated, or not treated at all (Adler, 2007). In an effort to better diagnose adults with ADHD, assessment tools were developed to specifically identify life challenges of adults, such as challenges in home life, occupation, and social functioning, which previous ADHD measures failed to address due to their focus on childhood phenomena.

Currently, it is estimated that approximately 5% of children are affected by ADHD. Of those children, 50% will continue to experience persistent symptoms of ADHD in adulthood. Additionally, 65% to 75% of these children will experience some form of functional impairment as adults due to residual symptoms (Barkley, Murphy, & Fischer, 2008; Biederman, Petty, Clarke, Lomedico, & Faraone, 2011; Biederman, Petty, Evans, Small, & Faraone, 2010; Mannuzza & Klein, 1999; Wilens, Biederman, & Spencer, 2002). It is estimated that about 2.5% of adults are affected by ADHD (APA, 2013; Barkley, 2015a). This population equates to roughly 8 to 10 million adults in the United States and includes adults who were diagnosed as children with symptoms

persisting into adulthood in addition to individuals who were diagnosed as adults (Bachmann, Lam, & Philipsen, 2016; Ramsay & Rostain, 2015). Consequently, there is a huge population for which effective tools for assessing ADHD symptomatology are necessary. If adults are properly diagnosed with ADHD, researchers can better understand how ADHD symptomatology impacts their lives and provide appropriate and effective assessment and treatment recommendations.

To ensure a diagnosis of ADHD is accurate and appropriate for adults presenting for treatment, a clinician should complete a comprehensive diagnostic assessment battery. This evaluation often includes symptom rating scales and a neuropsychological screening. Symptom rating scales include self-report measures that assess current and childhood symptom severity and deficits in executive functioning, as well as other-report measures, completed by collaterals, which also assess current and childhood symptom severity and deficits in executive functioning (Barkley, 2011a; Barkley 2011b). The Barkley Deficits in Executive Functioning Scale (BDEFS; Barkley, 2011b) and the Barkley Adult ADHD Rating Scale-IV (BAARS-IV; Barkley, 2011a) are both widely accepted, brief, empirically-based self-report assessments that were developed to assess for ADHD symptomatology in adults. Also introduced in 2011, the Quotient ADHD System (the Quotient), a neuropsychological screening provides objective evidence of the signs to go along with the symptoms suggested by symptom-rating scales for ADHD (Pearson, 2014). The Quotient is a portable system that includes an attached keyboard and contains installed testing software. The software, in conjunction with the head reflector and system's camera, detect these signs by measuring an individual's motor activity, and ability to inhibit motor activity, sustain attention, and suppress impulsive

responses. According to the Quotient's manufacturer, deficits in response inhibition is theorized to be directly related to the core symptoms of ADHD: hyperactivity, inattention, and impulsivity. With the Quotient, clinicians are able to obtain information about executive functions, which have a strong correlation with core symptoms of ADHD. Nevertheless, aside from the clinical trials conducted by the manufacturers of the Quotient (Pearson, 2014), empirical evidence supporting the validity and reliability of this assessment tool is sparse.

Purpose of the Study

The purpose of this study was to determine the validity and reliability of the Quotient ADHD System (Pearson, 2014) as a tool for the assessment of adult ADHD. As stated, the BDEFS (Barkley, 2011b) and the BAARS-IV (Barkley, 2011a) are brief, empirically-based self-report assessments that were developed to assess for ADHD symptomatology in adults. More specifically, the BDEFS assesses executive functioning deficits in daily life activities. Barkley defined executive functioning as "self-regulation across time for the attainment of one's goals" (Barkley, 2008, p. 13). The BDEFS assesses five domains: Self-Management to Time, Self-Organization/Problem-Solving, Self-Restraint, Self-Motivation, and Self-Regulation of Emotions. The BAARS-IV assesses current, problematic ADHD symptoms, specifically inattention, hyperactivity, and impulsivity, and domains of impairment, specifically in regard to home life, social functioning, education, and occupation, in addition to recollections of childhood symptoms. These two validated instruments are self-report measures that could be argued to be more subjective in nature than objective behavioral measures such as the Quotient.

Recently, Pearson announced its plan to cease the distribution of the Quotient, effective December 31, 2019 (Pearson, 2019). While this study was being conducted, the Quotient purported to measure the neurobiological functions, as indicated by specific behaviors, relevant to ADHD (Pearson, 2014). A literature review indicated a paucity of empirical evidence for the use of this widely accepted measure with adults (Gibbins & Weiss, 2007; Murillo, Cortese, D. Anderson, Di Martino, & Castellanos, 2015; Polcari, Fourligas, Navalta, & Teicher, 2010). This study examined participants' performance on these three assessment measures to determine whether the self-report measures correlated with and predicted the behavioral correlates of ADHD, the latter as measured by the Quotient. It was hoped that this study would provide evidence as to the validity and reliability of the Quotient. If the current study supported the Quotient as a valid, reliable measure of adult ADHD, it may have lent support for an objective instrument that should further enhance the assessment and treatment of this disorder.

Chapter 2: Literature Review

History of the Diagnosis

In 1775, Melchoir Adam Weikard published a short chapter about disorders of attention in a medical textbook (Barkley & Peters, 2012). The German physician described symptoms of distractibility, poor persistence, impulsive actions, and inattention in both adults and children. In 1798, Dr. Alexander Crichton published a medical textbook that contained a chapter on disorders of attention. Within his writings, he stated that attention is a central feature of one's awareness, attention is effortful and not automatic, and attention is a willful activity (Barkley & Peters, 2012). He theorized innate forms of inattention would diminish with age and that social learning could improve or worsen disorders of attention (Barkley, 2015a; Barkley & Peters, 2012).

Research regarding attention disorders in medical literature remained stagnant for just over 100 years; however, in 1902, George Still published three lectures describing his clinical work. He discussed 43 children who were experiencing problems with sustained attention and moral control of their behaviors. Moral control of behavior was described as the "regulation of behavior relative to the moral good of all" (Still, 1902, as cited in Barkley et al., 2008, p. 9). Not only were the children inattentive, but Still also noted that most were also overactive. Still proposed immediate gratification was the primary motivation for these children, with heightened emotionality also being fairly common. Still believed this defect in moral control was relatively chronic and that these behaviors may persist into adulthood (Barkley, 2015a, p. 5). This defect in moral control could present as a function of three distinct impairments: a "(1) defect of cognitive

relation to the environment, (2) defect of moral consciousness, and (3) defect in inhibitory volition" (Still, 1902, as cited in Barkley, 2015a, p. 5).

In 1952, The APA published the first *DSM*, which did not contain any diagnoses that described disordered attention or hyperactivity. Within the second edition of the *DSM*, published in 1968, a condition termed hyperkinetic reaction was introduced and listed within the category of behavioral disorders of childhood and adolescence. It was defined as a disorder "characterized by overactivity, restlessness, distractibility, and short attention span, especially in young children," and it noted the problematic behavior typically diminished in adolescence (APA, 1968, pp. 49-50). If this condition was considered to be result of brain damage, it was specified in the diagnosis. The *DSM-II* stated this condition could be easily observed in many young children, although it did not include a specific age of onset. The criteria for hyperkinetic reaction was strictly for diagnosing children and adolescents, but it could be specified as a residual condition if observed in adults (APA, 1968; Barkley et al., 2008).

In the third edition of the *DSM*, the term hyperkinetic syndrome was changed to attention deficit disorder (ADD; APA, 1980). *DSM-III* included a detailed description of the disorder, a set of diagnostic criteria, and other features to help distinguish this disorder from other psychiatric issues. Criteria suggested children must display at least three symptoms of inattention and at least two symptoms of impulsivity and hyperactivity. To receive a diagnosis, a child must have displayed symptoms for at least six months prior to age seven. Again, if an individual displayed the symptoms of ADD in adulthood, it was recommended to use the specifier, residual type (APA, 1980; Barkley et al., 2008).

After much controversy regarding the significance of hyperactivity in this condition, the publication of *DSM-III-R* renamed the diagnosis attention-deficit hyperactivity disorder (ADHD), reflecting a more comprehensive understanding of the disorder (APA, 1987). There were two other major revisions within the *DSM-III-R*. For the first time, adults could also be diagnosed with ADHD. Additionally, this edition included specified levels of severity for ADHD: mild, moderate, and severe.

The *DSM-IV* modified the term from *DSM-III-R* to what is still the currently accepted nomenclature, attention-deficit/hyperactivity disorder (ADHD; APA, 1994). The criteria for the *DSM-IV* required at least six symptoms for a diagnosis of ADHD (APA, 1994; Barkley, Fischer, Smallish, & Fletcher, 2002; Faraone, Biederman, & Mick, 2006). Similar to the *DSM-III*, the *DSM-IV* reiterated that both children and adults can be diagnosed with ADHD, even in the absence of hyperactivity, as this symptom was no longer a necessary factor in the criteria. Although the diagnosis of ADHD could now be given to adults, some argue the current criteria were not suitable for adults (Barkley, 2015a).

Within the *DSM-IV*, the age-of-onset-criterion was seven years of age. It may be very challenging for adults to recall the nature of their symptoms when they were seven years old. Moreover, many *DSM-IV* symptoms were inappropriate for adults, such as "runs and climbs excessively" or "has difficulty playing quietly" (APA, 1994), making a diagnosis for an adult more difficult. In time, further corrections to this edition were made, leading to the publication of the *DSM-IV-Text Revision* (*DSMIV-TR*) in 2000. Although the criteria and definitions did not change from the *DSM-IV*, the *DSM-IV-TR* updated the statistics to reflect the current prevalence rates through 2000 and

synchronized the criteria with the updated *International Statistical Classification of Diseases and Related Health Problems* (*ICD*) codes (APA, 2000).

As previously noted, some *DSM-IV* criteria reflected childhood presentations. These criteria made it challenging for adults to meet the diagnostic requirement of at least six symptoms. Taking this into account, the publication of *DSM-5* included revised criteria, suggesting that older adolescents or adults (ages 17 or older) need only five symptoms for diagnostic criteria to be met, with impairment evident in two or more settings (e.g. work, home life, social functioning, educational activities; APA, 2013). Symptoms were also revised to better relate to adult presentations (APA, 2013). Age of onset had been an obstacle in meeting criteria for ADHD in previous editions. Currently, in order for a diagnosis of ADHD to be made, symptoms are required to be present before the age of 12 (APA, 2013). Barkley (2015b) acknowledged this modification of age-of-onset criterion as a step in the right direction, as 93% of cases of ADHD may now be captured; however, based on his research, he argued for the age-of-onset criterion to be raised to 16 years of age (Barkley & Biederman, 1997; Barkley et al., 2008). Inattention, hyperactivity/impulsivity, and combined presentation remain as the three primary subtypes of ADHD in the *DSM-5* (APA, 2013).

ADHD Subtypes

Inattention. About 20% to 30% of all individuals with ADHD are diagnosed with the inattentive presentation (Wilens et al., 2009; Wilens et al., 2002). For adults with the inattentive presentation, it is challenging to willfully focus and allocate attention and concentration efficiently, particularly when tasks are not enjoyable, such as, for many, when paying bills, studying, or planning projects at work. Adults with ADHD find

it difficult to resist the lure of distracters when they offer immediate positive or negative reinforcement. Once an individual with ADHD is distracted, he or she often has a more difficult time reengaging in the previous activity. As a result, he or she has a more difficult time initiating, persisting through, and working to complete tasks that are not inherently appealing (Ramsay & Rostain, 2008).

Unlike symptoms of hyperactivity and impulsivity that decline with age for most children with ADHD, symptoms of inattention remain relatively constant throughout life. Additionally, the demands for the ability to concentrate, remain organized, and have good time management skills generally increase into adulthood; thus, the negative consequences of inattentiveness become more severe as inattention interferes with other executive functions. Also, unlike hyperactive/impulsive or combined presentations, adults with an inattentive presentation generally do not report behavioral problems at home or school when they were younger. Instead, they most likely received feedback noting their need for supervision or received unsatisfactory grades for turning in assignments late or not at all (Ramsay & Rostain, 2008).

The term *hyperfocus* may be understood as a form of perseveration, or the inability to disengage from one task to start another, which frequently occurs in adults with ADHD. In the short-term, it may be viewed as productive, but it is often likely to distract from higher priority tasks (Ramsay & Rostain, 2015). It may be considered productive if an individual is focusing on a work task for hours on end; however, in this instance, the individual may be neglecting other tasks, including self-care habits. As such, hyperfocusing may represent the end stage of a cycle of insufficient coping, as a manifestation of the inability to shift attention once engaged (Ramsay & Rostain, 2015).

Below are the criteria for the inattentive presentation of ADHD, as stipulated in the *DSM-5* (APA, 2013).

Inattentive symptoms of ADHD. Six or more of the following symptoms have persisted for the last six months and cause impairment in daily functioning. It should be noted that only five symptoms are required for individuals age 17 and older.

a. Often fails to give close attention to details or makes careless mistakes in schoolwork, at work, or during other activities (e.g., overlooks or misses details, work is inaccurate).
b. Often has difficulty sustaining attention in tasks or play activities (e.g., has difficulty remaining focused during lectures, conversations, or lengthy reading).
c. Often does not seem to listen when spoken to directly (e.g., mind seems elsewhere, even in the absence of any obvious distraction).
d. Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (e.g., starts tasks but quickly loses focus and is easily sidetracked).
e. Often has difficulty organizing tasks and activities (e.g., difficulty managing sequential tasks; difficulty keeping materials and belongings in order; messy, disorganized work; has poor time management; fails to meet deadlines).
f. Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (e.g., schoolwork or homework; for older

adolescents and adults, preparing reports, completing forms, reviewing lengthy papers).

g. Often loses things necessary for tasks or activities (e.g., school materials, pencils, books, tools, wallets, keys, paperwork, eyeglasses, mobile telephones).

h. Is often easily distracted by extraneous stimuli (for older adolescents and adults, may include unrelated thoughts).

i. Is often forgetful in daily activities (e.g., doing chores, running errands; for older adolescents and adults, returning calls, paying bills, keeping appointments). (APA, 2013, p. 59)

Hyperactivity/impulsivity. Impulsivity, which is closely related to hyperactivity, is generally defined as "difficulty delaying gratification and regulating one's behavior, or acting without thinking" (Ramsay & Rostain, 2008, p. 5). Hyperactivity/impulsivity is the least common presentation, affecting only 15% of all individuals with ADHD (Wilens et al., 2009; Wilens et al., 2002). Hyperactive children are described as "being driven by a motor," "unable to sit still," and "always talking or making other noises" (Ramsay & Rostain, 2008, p. 5). Impulsive children are often described as children who do not think before acting or speaking or learn from mistakes. These behaviors cause problems in structured settings, such as classrooms, and unstructured settings, such as waiting for a turn in a game (Ramsay & Rostain, 2008).

Although there is a reduction in symptoms of hyperactivity and impulsivity with age, adolescents and adults with ADHD do not "grow out of" these symptoms, as previously believed. Instead, hyperactivity may present as a sense of restlessness,

fidgetiness, or subtler signs of physical restlessness, such as excessive talking, playing with things with their hands, impulsive spending, or bouncing their legs (Ramsay & Rostain, 2008).

Many adults with ADHD report experiencing "mental hyperactivity," such as having their train of thought easily disrupted by new thoughts or ideas. These internal distractions may interfere with their motivation to complete a task or negatively impact academic functioning, social functioning, and occupational performance. These individuals may have a propensity to jump to conclusions or arrive at decisions without sufficient evidence, such as going on a road trip with considering costs (Solanto, 2011). Hyperactive/impulsive symptoms (either alone or as part of the combined presentation of ADHD), particularly when combined with conduct disorder, are linked to higher risk of comorbid psychiatric, substance use, and behavioral problems (Ramsay & Rostain, 2015). Below are the criteria for the hyperactive/impulsive presentation of ADHD, as stipulated in the DSM-5 (APA, 2013).

Hyperactive and impulsive symptoms of ADHD. Six or more of the following symptoms have persisted for the last six months and cause impairment in daily functioning. It should be noted that only five symptoms are required for individuals age 17 and older.

a. Often fidgets with or taps hands or feet or squirms in seat.
b. Often leaves seat in situations when remaining seated is expected (e.g., leaves his or her place in the classroom, in the office or other workplace, or in other situations that require remaining in place).

c. Often runs about or climbs in situations where it is inappropriate. (Note: In adolescents or adults, may be limited to feeling restless).

d. Often unable to play or engage in leisure activities quietly.

e. Is often "on the go," acting as if "driven by a motor" (e.g., is unable to be or uncomfortable being still for extended time, as in restaurants, meetings; may be experienced by others as being restless or difficult to keep up with).

f. Often talks excessively.

g. Often blurts out an answer before a question has been completed (e.g., completes people's sentences; cannot wait for turn in conversation).

h. Often has difficulty waiting his or her turn (e.g., while waiting in line).

i. Often interrupts or intrudes on others (e.g., butts into conversations, games, or activities; may start using other people's things without asking or receiving permission; for adolescents and adults, may intrude into or take over what others are doing). (APA, 2013, p. 60)

Combined presentation. Combined is the most frequently diagnosed presentation of ADHD, and is seen in about 50% to 75% of all individuals with ADHD (Nigg, 2006; Wilens et al., 2009). Individuals with combined type tend to be the most impaired of all three presentations of ADHD, as they experience both cognitive and behavioral difficulties (Ramsay & Rostain, 2008). The inattentive symptoms are comprised of issues that overlap with executive function categories of organization, time management, and motivation. The hyperactive-impulsive symptoms overlap with the executive domains of emotional regulation and self-restraint (Ramsay & Rostain, 2015).

Inattentive (restrictive): A proposed, but rejected category. Preliminary versions of the *DSM-5* suggested a fourth presentation category, an inattentive (restrictive) presentation. This proposed category was defined as the presence of inattentive symptoms in quantity and severity that met the diagnostic threshold, but with endorsement of no more than two symptoms of hyperactivity/impulsivity symptoms. This presentation was formulated to identify individuals with pure inattentive symptoms who did not have behavioral disinhibition symptoms. Although a strong case could be made for a more purely inattentive manifestation of ADHD, the presentation was not retained in the final edition of the *DSM-5* (Ramsay & Rostain, 2015).

Sluggish cognitive tempo/concentration deficit disorder: A proposed category. Sluggish cognitive tempo (SCT) is not a presentation of ADHD. SCT, also known as concentration deficit disorder (CDD), is an attentional-motivational construct that has been associated traditionally with ADHD, inattentive type (Barkley, 2011a; J. J. Bauermeister, Barkley, J. A. Bauermeister, Martinez, & McBurnett, 2001). More recently, it has been posited as a distinct impairment that is comorbid to ADHD. In fact, 68% of adults with ADHD also display symptoms of SCT/CDD. SCT/CDD is characterized by sluggishness, passivity, confusion, and hypoactivity. Individuals with SCT/CDD have difficulties orienting and engaging attention, effort, and alertness. They may be described as daydreamers. (Ramsay & Rostain, 2015). Individuals with both ADHD and SCT/CDD tend to experience greater impairment compared to individuals with ADHD alone. Higher levels of SCT predict higher levels of academic impairment, social impairment, and attention (Lee, Burns, Beauchaine, & Becker, 2016). Although there is substantial literature on the difficulties encountered by individuals with

SCT/CDD, it is neither a standalone diagnosis nor in the ADHD criteria in the *DSM-5* (Combs, Canu, Fulks, & Nieman, 2014).

Executive Functioning

The concept of executive functions originated more than 150 years ago, in scientists' initial efforts to understand the functions of what is known today as the frontal lobes and the prefrontal cortex (PFC; Barkley, 2011b; Luria, 1966). When the term *executive function* initially appeared in scientific literature in the 1970s, it was conflated with functions of the prefrontal lobes, when it was assumed that the PFC was largely involved in executive functioning (Barkley, 2011b; Pribram, 1973, 1976). In contrast, the current research indicates that executive functions do not reside exclusively in the PFC, as the PFC has various networks of connections to other cortical and subcortical zones, including the basal ganglia, limbic system, amygdala, anterior cingulate, and cerebellum (Barkley, 2011b; Luria, 1966; Stuss & Benson, 1986).

In the 1980s, there were still a wide variety of opinions regarding the nature of executive functions. In 1986, Stuss and Benson stated that executive functions are called into action in novel situations and provide conscious direction for efficient processing of information. Accordingly, executive functions represent many of the important activities that are almost universally attributed to the frontal lobes, which become active in novel situations that require new solutions. Indeed, executive functions include the following behavioral components: anticipation, goal selection, preplanning, monitoring, and the use of feedback (Barkley, 2011b; Stuss & Benson, 1986).

Welsh and Pennington (1988) further elaborated on the executive functions of the brain. They described executive functions as the ability to maintain an appropriate

problem-solving set for attainment of a future goal. According to these researchers, the components of executive functions include the intention to inhibit a response or to defer it to a later more appropriate time, a strategic plan of action sequences, and the mental representation of the task (Barkley, 2011b; Welsh & Pennington, 1988). Lezak (1995) added that executive functions consist of those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior. He posited that executive functions influence how and whether a person goes about doing something (Barkley, 2011b; Lezak, 1995).

Later, Brown (1996) posited that ADHD was a developmental disorder of impaired executive functions. According to Brown, the hyperactive/impulsive and inattentive presentations of ADHD are manifestations of impairment of executive functions. Development of the executive functions of the brain may be delayed in individuals with ADHD, as compared to their counterparts without ADHD. For some individuals, these functions may develop and mature, whereas for others, they may remain impaired throughout adolescence and adulthood (Brown, 1996; Ramsay & Rostain, 2008). Problems emerge in adolescence and adulthood when demands of life exceed one's executive functioning abilities (Barkley, 2011b; Ramsay & Rostain, 2008). Based on his research, Brown formed six clusters of executive functions: activation (initiation of tasks and prioritization), attention (sustained and shifting focus), memory (working and short-term), effort (sustained), and affect (managing and modulating emotions; Barkley 2015b; Brown, 1996).

Conversely, Barkley's (1997) early model originally proposed that ADHD was a disorder of behavior disinhibition. Behavioral inhibition allows an individual to inhibit a

first response to a setting event and stop an ongoing response, which allows a delay between the event and the response and prevents other self-directed responses from interfering with or disrupting this delay period. According to Barkley, when behavioral inhibition is compromised, as in ADHD, the areas of executive functioning that require effective response inhibition to function properly would also become compromised. Deficits in executive functioning were hypothesized to lead to additional issues, including impaired motor control and goal-directed persistence. This could manifest as distractibility or difficulty reengaging in an activity after being disrupted, both hallmark symptoms of ADHD (Barkley, 1997, 2001). At this time, Barkley proposed that behavioral inhibition was not directly responsible for adaptive executive function. Instead, behavioral inhibition simply provided the delay in which these cognitive processes could occur, therefore enabling individuals to self-regulate responding and persist toward goals (Barkley, 1997, 2001).

Barkley (1997) initially introduced four executive functions: working memory; self-regulation of affect; motivation, arousal, and internalization of speech; and reconstitution. Working memory was best described as the ability to hold and manipulate events in the mind, as well as hindsight, foresight, and the organization of purposeful behavior across time (Baddeley & Hitch, 1994; Barkley, 1997). The self-regulation of affect, motivation, and arousal included the ability to take an outside perspective of a situation and impairment in a setting where self-motivation and emotion regulation are needed for success. Internal speech was defined as the ability to reflect, describe, and problem-solve through the use of language, which eventually leads to moral reasoning.

Lastly, reconstitution consisted of verbal and behavioral fluency and creativity (Barkley, 1997).

In his later work, Barkley (2006, 2012c) reconceptualized and modified the various terms associated with specific executive functions in terms of self-directed activities. Non-verbal working memory became self-directed sensing. Verbal working memory was changed to self-directed speech. Self-regulation of affect, motivation, and arousal became self-directed emotion. Finally, reconstitution was renamed self-directed play. Within the adapted versions of executive functions, self-directed sensing included the ability to sense oneself through internally represented images and sounds, as well as perceive oneself through time; self-directed speech was the ability to have internal monologue and problem-solve; self-directed emotion was self-directed experience of feelings, including self-motivation; and self-directed play included the ability to generate novel ideas through analysis of old ideas and synthesize these old ideas into new ideas or behaviors (Barkley, 2001, 2012c). Barkley redefined behavioral inhibition as self-restraint.

Barkley (2012c) placed less emphasis on behavioral inhibition as the main contributor to the deficits in executive functioning in ADHD and placed more emphasis on executive functions in self-regulation and goal attainment. Based on his research, Barkley developed numerous scales for children, adolescents, and adults, including the Barkley Deficits in Executive Functioning Scale (BDEFS; 2011b), the Barkley Deficits in Executive Functioning Scale for Children and Adolescents (BDEFS-CA; 2012a), the Barkley Adult ADHD Rating Scale – IV (BAARS-IV; 2011a), the Barkley Functional

Impairment Scale (BFIS; 2011c), and the Barkley Functional Impairment Scale for Children and Adolescents (BFIS-CA; 2012b).

Although there is still debate regarding the source of executive functions, executive dysfunction is increasingly associated with differences in the function and structure of the ADHD brain. Structural and functional neuroimaging studies in adults with ADHD have revealed deficits in the volume and activation of regions of the prefrontal cortex and other cortical and subcortical loci known to regulate these executive functions (Seidman, Valera, & Bush, 2004; Solanto, 2011). Although beyond the scope the current work, the genetic factors and neurobiology of ADHD are briefly examined, as they are pertinent to understanding how executive dysfunction causes impairment for adults with ADHD. The five dimensions of adult executive functioning in daily life, established by Barkley within the BDEFS (Barkley, 2011b), are more pertinent for this present work, as they are examined in the study. These five dimensions include self-management to time, self-organization/problem-solving, self-restraint, self-motivation, and self-regulation of emotions (Barkley, 2011b).

Genetics

In terms of environmental and genetic variables and presentation of ADHD, shared environmental factors (e.g., social class and home environment) account for 0 to 6% of variance in ADHD, non-shared environmental factors including non-genetic physiological variables (e.g., neurologic injury or exposure to toxins) account for 9% to 20 percent of variance, and genetic factors account for up to 80% of variance in ADHD, making ADHD one of the most heritable psychiatric disorders and similar in inheritability percentages as height (Barkley, 2006; Coolidge, Thede, & Young, 2000;

Faraone et al, 2000; McGuffin, Riley, & Plomin, 2001; Nigg, 2006; Ramsay & Rostain, 2008).

Some of the primary candidate genes associated with ADHD are related to dopamine receptors and transporters (Franke et al., 2011). For example, the 7-repeat allele of the D4 dopamine receptor causes the D4 receptor to be subsensitive to dopamine and increases the risk of ADHD. Individuals possessing the 7-repeat allele show a more persistent outcome of ADHD. There is estimated to be a worldwide prevalence of 21% of the 7-repeat allele (Franke et al., 2011; Ramsay & Rostain, 2008).

The dopamine transporter (DAT) on chromosome 5 has also been a candidate gene of ADHD. The DAT oversees the reuptake of dopamine from the synaptic cleft into the neuron. Alterations in its normal functioning have been detected in neuroimaging studies of patients with ADHD (J. Krause, H. K. Krause, Dresel, la Fougere, & Ackenheil, 2006; K. H. Krause, Dresel, J. Krause, la Fougere, & Ackenheil, 2003). Since reuptake into the presynaptic terminal is the prime method by which the effect of dopamine is stopped, increased activity of the DAT leads to more swift clearance of the neurotransmitter from the synapse and, eventually, functional depletion of dopamine (Pliska, 2003; Ramsay & Rostain, 2008; Swanson et al., 2000). This depletion may explain the pathophysiology of ADHD. Other chromosomal regions containing genes potentially implicated in the etiology of ADHD have been identified as 5p13, 11q22-25, and 17p11. A meta-analysis of studies revealed a region on chromosome 16 at bin 16.4 having the most consistent evidence of linkage to ADHD (Cortese, 2012).

Neurobiology

Valera et al. (2007) conducted a meta-analysis of childhood studies and compared 565 children with ADHD to 583 controls. The largest reductions in children with ADHD compared to controls were found in the cerebellum regions, total and right cerebellum volumes; the right caudate nucleus; and the splenium of the corpus callosum. Ellison-Wright et al. (2008) also conducted a meta-analysis of childhood studies comparing 114 children with ADHD and 143 controls. They reported that ADHD was associated with gray matter reductions in the right putamen and globus pallidus. Impairment in these regions impact how dopamine is regulated in the brain. Furthermore, response inhibition may be attributed to these impairments in the brain. Behavioral inhibition may lead to deficits in nonverbal working memory, self-regulation of emotions, reconstitution, and internalization of speech (Barkley, 1997).

Two other meta-analyses explored whether brain abnormalities observed in children with ADHD persist into adulthood. Nakao et al. (2011) examined 202 children and adolescents with ADHD, 176 adults with ADHD, and 344 controls. Frodl and Skokauskas (2012) included 175 children and adolescents with ADHD, 145 adults with ADHD, and 288 controls. Both studies confirmed that volume reductions of the right globus pallidus and putamen that were related to ADHD.

Gender

Historically, it has been generally assumed that the prevalence of ADHD is higher in males than in females. In fact, in the general population, males are more frequently diagnosed with ADHD as compared to females (Kessler et al., 2006). Examining exclusively childhood ADHD diagnoses, males are two times more likely than females to

be diagnosed with ADHD (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007). In adults, the ratio of males to females diagnosed with ADHD is 1.6:1 (Kessler et al., 2006). Several factors may play a role in the higher prevalence of ADHD in males as children, as compared to lesser disparity between adult males and females. First, young males are more likely than females to display observable and disruptive behaviors and are, therefore, more likely to be referred to treatment (Faraone & Biederman, 2009; Novik, Hervas, Ralston, Rodriquez Pereira, & Lorenzo, 2006). In general, females are more likely to experience, if not report, less observable problems with inattention (Fedele, Lefler, Hartung, & Canu, 2012) and are more often diagnosed with the inattentive type of ADHD (Kessler et al., 2006). Therefore, the ADHD symptoms of female youth may be less likely to be noticed by others, such as teachers and parents. Conversely, in adulthood, women are more likely than men to refer themselves to treatment for ADHD. These women presenting to treatment as adults are less likely to have been diagnosed or treated as children. This may partly account for the discrepancies gender diagnosis disparities in childhood versus adulthood (Biederman, 2004). Additionally, adult women with ADHD are at a greater risk for comorbidities such as eating disorders (Biederman, et al., 2010).

Age and Symptom Progression

ADHD presents differently throughout the stages of development (Hinshaw, Owens, Sami, & Fargeon, 2006; Ramtekkar, Reiersen, Todorov, & Todd, 2010). When early-onset ADHD is left untreated, it is more likely to lead to higher severity and persistence of symptoms and impairment into adulthood (Karam et al., 2009). Although there is frequently a decline in symptoms as individuals with ADHD age, some

symptoms are more likely to persist into adulthood (Faraone et al., 2006; J. J. Bauermeister et al., 2011; Harpin, 2005; Turgay et al., 2012). For instance, overt hyperactivity may diminish or become less problematic in adolescent years. In adults, remaining traces of hyperactivity may be more manageable. In addition, it may become less noticeable to others which, in turn, may be viewed as progress; however, rather than complete remission, hyperactivity often changes in presentation in adults, from overt hyperactivity to inner restlessness (Volkow & Swanson, 2013). Impulsivity also lessens in intensity in adulthood (Kumperscak, 2013). Contrarily, symptoms of inattention tend to persist into adulthood (Todd et al., 2008).

Childhood presentation. Developmental deficits have been shown to greatly impact individuals with ADHD throughout their lifespans. As individuals transition from childhood to adolescence to adulthood, they acquire adaptive life skills. Often, children with ADHD are less likely to attain these adaptive skills (Barkley 2015b; Jarratt, Riccio, & Siekierski, 2005). Deficits are common in the areas of daily living, social communication, and internalization of speech (Barkley, 2015b; Stein, Szumowski, Blondis, & Roizen, 1995). Motor skills are often impaired for children with ADHD, specifically visual-motor coordination and dexterity (Barkley, 2015b). Lastly, these children may face more challenges academically. In a meta-analysis, DuPaul, Gormley, and Laracy (2013) concluded that as many as 45% of children with ADHD also have a learning disability.

Certain presentations of ADHD may be more observable in children. Hyperactivity may be observed by parents of young children, but is often dismissed or minimized as normal behavior during this stage of development. Inattention may be

more difficult to observe, especially in young children, as most tasks targeted to this age group do not require sustained attention. Disruptive behaviors performed by youth are more likely to be observable by others, including parents and teachers. These behaviors may be more likely to be viewed as bothersome or intolerable and, therefore, lead to a referral for an ADHD assessment (Weiss, Worling, and Wasdell, 2003).

As children begin elementary school, parents or teachers may start to observe consequences of inattention, as these children may make careless mistakes or have problems following instructions. As previously noted, children with ADHD may also demonstrate poor social skills, which may be a result of inattention, hyperactivity, and/or impulsivity (Realmuto et al., 2009; Stormont, 2001).

Parents and others may also observe a pattern of forgetfulness in their children with ADHD, which is a deficit in working memory. A child may not follow through on a task despite repeated requests, even when the child acknowledges the requests. Such incomplete tasks may include finishing homework, putting laundry away, or getting dressed for school. Children who are impulsive and/or oppositional/defiant (a frequent comorbidity) often elicit negative responses from parents, such as “You never put your laundry away!” This recurring pattern of negative interactions may impact the child’s beliefs about himself or herself. The child may develop beliefs such as “I’m not good at remembering things,” or a more personal, pervasive, and permanent belief, such as "I'm a failure” (Ostrander & Herman, 2006; Ramsay & Rostain, 2008). Such maladaptive core beliefs can understandably cause distress and impairment into adulthood.

Adult presentation. As individuals age, they tend to face more and greater demands. This increase in demands may be more difficult for someone with ADHD.

Similar to children, adults with ADHD struggle with time management, disorganization, and the ability to follow through on tasks; however, forgetfulness, for example, may have more severe consequences for adults as compared to children. Whereas children may forget to put their laundry away, adults with ADHD may forget to pay their bills, attend appointments, or return phone calls. ADHD symptoms have a negative impact on identity, satisfaction, life options, and self-esteem (Harpin, Mazzone, Raynaud, Kahle, & Hodgkins, 2016). Adults with ADHD have poorer occupational outcomes **(**Halmoy, Fasmer, Gillberg, & Haavik, 2009; Reynolds, 2008), poorer relationships (Barkley, 2008; Barkley et al., 2008; Reynolds, 2008), and auto accidents and speeding infractions, and are more likely to engage in substance use (Barkley, 2008; Barkley et al., 2008; Biederman et al., 1994).

Functional Impairment

Education. Both individuals who were diagnosed with ADHD as children and individuals diagnosed as adults have some similar types of academic challenges in their histories. Nevertheless, individuals who have been diagnosed as adults tend to have higher intellectual levels and higher high school graduation rates, and are more likely to attend college, as compared to their counterparts who were diagnosed with ADHD as children. This higher level of intellectual functioning makes sense, given that those later diagnosed may have been able to use their intellect to compensate for many symptoms in childhood (Barkley, 2015a).

Most adults diagnosed with ADHD are self-referred. This fact makes it more likely that these individuals have employment and health insurance. They could also be expected to have higher levels of intellect and self-awareness, given that they perceived

themselves as being in need of assistance for their psychiatric problems. According to Barkley (2015a), children with ADHD brought to clinics by their parents are less likely to have these attributes by the time they reach adulthood. Often, they are not as educated, struggle to maintain employment, are more likely to have histories of aggression, and are less self-aware of their symptoms as adults, as compared to individuals diagnosed with ADHD in adulthood (Barkley, 2015a).

Most adults diagnosed with ADHD in childhood reported being retained in grade, enrolled in special education, and/or diagnosed with learning disabilities or behavior disorders in school. These individuals have a significantly lower likelihood of graduating from high school (Barkley et al., 2008; Miller, Nigg, & Faraone, 2007). Twenty-one percent or fewer individuals with ADHD attend college, as compared to those without ADHD. Of those who attend college, these individuals are more likely to have unsatisfactory grades or withdraw from one or more courses than their neuro-typical peers (Barkley et al., 2008).

Occupational functioning. Adults with ADHD report experiencing problems in their occupational histories. In a University of Massachusetts Study, Barkley and colleagues (2008) found that individuals with ADHD reported experiencing a number of problems in previous jobs in higher proportions than their counterparts without ADHD. These problems included difficulty getting along with others, behavior problems, being fired, quitting out of boredom, and being disciplined by supervisors (Barkley et al., 2008). Adults with ADHD have a $10,300 to $15,400 lower income annually than those without ADHD which, collectively, reflects a total annual income loss of $67 to $116 billion associated with ADHD (Ramsay & Rostain, 2015).

For adults with ADHD, disorganization, procrastination, and a pattern of leaving tasks incomplete can lead to poorer performance in the workplace (Ramsay, 2002). Compared to individuals without ADHD, these individuals tend to have a 4% to 5% decrease in job performance (Kessler, Lane, Stang, & Van Brunt, 2008). On average, adults with ADHD have 13.6 days of absenteeism (missed days of work) and 21.7 days of "presenteeism" (underperformance on the job) yearly, as compared to 15.8 days of absenteeism and 22.1 days of presenteeism when controls without ADHD are included in the sample (Kessler et al., 2005; Ramsay & Rostain, 2015). Over 120 million days of work are lost in the United States each year because of ADHD, costing approximately $19.5 billion (Kessler et al., 2005).

Social impairment. ADHD impacts relationships with family, friends, classmates, coworkers, and employers. Adults with ADHD report poorer qualities of relationships and higher rates of martial dissatisfaction (Barkley et al., 2008). Furthermore, these individuals have a two times higher divorce rate (Barkley & Gordon, 2002; Biederman et al., 2006). These problems may be attributable to a number of factors. For example, individuals with ADHD tend to have greater difficulties with affect recognition (Rapport, Friedman, Tzelepis, & Vas Voorhis, 2002). This deficit may contribute to relational difficulties, as they may miss important social cues. Others may view them as insensitive or socially awkward rather than them having an inability to detect subtle social signals (Kessler et al., 2006). When these individuals are not listening in a fully engaged manner because of inattention, it may appear insensitive to others. Similarly, difficulty remembering plans may generate disappointment in others. Moreover, individuals with ADHD often find it difficult to delay responses in

conversations and may interrupt others or precipitously change the topic of conversations. Lastly, personal messiness or disorganization may impact others in a household, school, or work setting (Solanto, 2011).

Impairments in other important life activities. Individuals with ADHD tend to have more difficulties managing their finances, as compared to individuals in the general population (Barkley, 2011a). According to Barkley et al. (2008), adults with ADHD have problems managing money, saving money, buying on impulse, nonpayment of utilities resulting in termination, missing loan payments, exceeding credit card limits, having poor credit ratings, and not saving for retirement.

Driving risk is the most thoroughly researched major life activity affected by ADHD. The research has shown that adults with ADHD have significantly more difficulties operating motor vehicles safely and have experienced more adverse outcomes related to driving than other adults (Barkley, 2011a). Compared to the general population, adults with ADHD are more likely to have their licenses revoked or suspended, to have crashed while driving, to have been at fault in motor vehicle accidents, to have been cited for speeding, and to have driven without valid driver's licenses (Barkley et al., 2008).

Substance use may also further impair the lives of these individuals (Kessler et al., 2006). ADHD is associated with some elevated risk for tobacco and alcohol use. A study comparing the substance use of adults with and without ADHD showed that more individuals with ADHD tried cocaine and lysergic acid diethylamide (LSD; Barkley et al., 2008). Worth noting is that there is no evidence that treatment with stimulants in childhood was associated with increased drug use or abuse in any category of illegal

drugs. In fact, some evidence suggests being treated with stimulants as a child actually reduced the likelihood of using certain drugs, such as other amphetamines (Barkley, 2015a).

Adults with ADHD are more likely to have problems with the law or be arrested (Biederman et al., 2006). Within their research, Barkley et al. (2008) found the most common forms of crime among adults with ADHD were shoplifting (53%), assaulting someone with their fists (35%), and selling illegal drugs (21%). Although individuals with ADHD are less likely to abide by the law, severity of ADHD only account for about 7% to 8% of this risk. Greater predictors of criminal risk include childhood conduct problems, teen antisocial behavior, drug use, and education (Barkley et al., 2008).

ADHD and Psychiatric Comorbidities

It is important to differentiate whether an individual's presenting problems are caused by the core symptoms of ADHD or are better explained by another disorder. This differential diagnosis ensures proper care for the person presenting to treatment. Nevertheless, in most cases, adults presenting for treatment often present with a more complex clinical picture, including emotional symptoms and lifelong stressors (Ramsay & Rostain, 2008). Approximately 70% to 75% of adults with ADHD have at least one other psychiatric condition (Biederman et al., 2012; Fischer et al., 2007; Garcia et al., 2012; Kessler et al., 2006; Klein et al., 2012). Additionally, 50% have two other disorders and approximately 33% have three or more other disorders (Barkley, 2015a).

The type of comorbid condition is strongly influenced by the type of ADHD, inattention or hyperactivity/impulsivity. Individuals with the inattentive presentation are more likely to also be diagnosed with internalizing disorders, including anxiety and/or

depression. Those with the hyperactive/impulsive type are more likely to be diagnosed with externalizing disorders, such as conduct disorder, oppositional defiant disorder (ODD), and/or substance use disorders (Friedrichs, Igl, H. Larsson, & J. Larsson, 2012).

A review of studies suggests gender differences in the prevalence of comorbid conditions with ADHD. Substance use disorders, conduct disorder, and antisocial personality disorder were more prevalent in males with ADHD, whereas mood and anxiety disorders were more common in women with ADHD (Simon, Czobor, & Bitter, 2013). Based on data from their 107 participants with ADHD, Wilens et al. (2009) reported higher rates of comorbid conduct disorder and substance use disorders among men, and higher rates of persistent depressive disorder and anxiety disorders in women.

Internalizing disorders. Anxiety and mood disorders, such as depression and bipolar disorder, have been found to be comorbid with ADHD.

Anxiety. Anxiety is the most frequent comorbid condition with ADHD in adults (Barkley et al., 2008; Kessler et al., 2006; Safran, Lanka, Otto, & Pollack, 2001; Schatz & Rostain, 2006). Of those individuals diagnosed with ADHD, up to 47.1% also meet criteria for some type of anxiety condition, with the three most common being specific phobia, social phobia, and posttraumatic stress disorder (APA, 2000; Kessler et al., 2006). In some cases, the comorbidity of ADHD and anxiety may be coincidental, but in other instances, anxiety may develop secondary to the symptoms and challenges of ADHD. Since individuals with ADHD generally face greater difficulty when attempting to manage tasks, many simple tasks may become perceived as threats. These threats may instill feelings of fear, shame, or embarrassment within these individuals.

To better differentially diagnose ADHD from an anxiety condition, a clinician should inquire about whether an individual's symptoms (e.g., avoidance) are a result of a specific threat or stressor or if the symptoms create pervasive and enduring difficulties (Ramsay & Rostain, 2008). In most cases, the latter would be attributed to ADHD.

In a study containing 421 undergraduate students, Jarrett (2016) found that self-reported executive functioning deficits were most strongly related to inattention, but also significantly related to anxiety symptoms. Results showed that individuals with both ADHD and anxiety had particularly pronounced deficits in self-regulation of emotion and self-organization/problem-solving. Eysenck et al. (2007) found that in typical adults, anxiety can mimic symptoms of or exacerbate ADHD by interfering with efficient cognitive processing on tasks involving executive functions. Within their study, Roth and Saykin (2004) found that state anxiety explained the relationship between ADHD and decreased verbal memory and learning.

Ameringer and Leventhal (2013) examined the comorbidity of anxiety and ADHD in adults by reviewing charts of 129 individuals consecutively admitted to an anxiety clinic. Of the 129 participants, 27.9% also met the criteria for ADHD. In a national study, Friedrichs et al. (2012) examined 17,899 sets of Swedish twins to investigate coexisting psychiatric conditions in adults with ADHD. They found ADHD was strongly associated with generalized anxiety disorder (GAD), with an odds ratio of 5.56. They also observed significant differences in diagnoses for presentations of ADHD. Individuals with the inattentive type were more likely than those with the hyperactive/impulsive type to be diagnosed with anxiety or depression. This evidence

further suggests a relationship between internalizing disorders and the inattentive presentation of ADHD.

Depression. Major depressive disorder (MDD) is characterized by depressed mood and/or loss of pleasure or interest in previously enjoyed activities most of the day, nearly every day for, at minimum, two weeks (APA, 2013). When co-occurring with ADHD, individuals have a poorer outcome than when diagnosed with either condition alone (Spencer, Wilens, Biederman, Wozniak, & Harding-Crawford, 2000). For adults with ADHD who already may struggle with difficulty concentrating and procrastination, the symptoms of depression may further exacerbate these problems and problems associated with activating behavior or sustaining attention (Ramsay & Rostain, 2008).

In 2001, Kessler et al. (2006) replicated the National Comorbidity Survey (NCS-R). Between 2001 and 2003, they gathered self-reports and conducted diagnostic interviews, assessing a variety of disorders classified within the *DSM-IV*. Of adults diagnosed with ADHD (N = 3,199), 31.4% reported also experiencing depressive symptoms (MDD or dysthymia [now persistent depressive disorder]; APA, 2000, 2013). Another study was conducted at an outpatient clinic and included 320 adults diagnosed with ADHD. One fourth (25.31%) of the participants also met criteria for MDD (Fischer et al., 2007). Secnik, Swensen, and Lage (2005) utilized a large claim database that captured inpatient, outpatient, and prescription drug services. Within the sample population of adults with ADHD (N = 2,254), the researchers found 35.9% of individuals were also prescribed an antidepressant.

When considering a differential diagnosis between ADHD and MDD, a clinician should ask about onset, periodicity, and duration, as well as whether symptoms

(including poor concentration and restlessness) typically improve as mood improves. For individuals with ADHD, these functional problems persevere despite changes in mood (Ramsay & Rostain, 2008).

Bipolar disorder. Friedrich et al. (2012) found individuals with ADHD were at a higher risk than their counterparts without ADHD for bipolar disorder in the same study of Swedish twins, with an odds ratio of 7.98 (N = 17,899 sets of twins). In another study, individuals with both bipolar disorder and ADHD, as opposed to solely bipolar disorder, had lower levels of functioning, lower levels of education, fewer relationships, more suicide attempts, more legal problems, and extreme instability in functioning (Nierenberg et al., 2005); however, it is necessary to note that many symptoms overlap for ADHD and bipolar disorder, which may complicate these diagnoses and conclusions. Similar symptoms of mania and ADHD include distractibility, being more talkative, increase in activity, flight of ideas, and excessive involvement in pleasurable activities without regard for consequences. Often, ADHD is misdiagnosed as bipolar disorder. Although individuals with ADHD often report perseverating, this period of perseveration is usually brief, in contrast to a manic or hypomanic episode, which can last for several days or even weeks. Individuals with ADHD also report difficulty sleeping at night, but acknowledge feeling fatigued throughout the day. Individuals experiencing manic or hypomanic symptoms often report—subjectively—functioning seemingly well, despite a lack of sleep. Finally, whereas individuals with ADHD may experience outbursts of anger or other emotions when upset, these periods do not extend for several days or more, as they would during manic or hypomanic episodes (Ramsay & Rostain, 2008).

Externalizing disorders. ADHD and externalizing (behavioral) disorders are highly comorbid. Three common co-occurring externalizing disorders are conduct disorder, ODD, and substance use disorders. Conduct disorder is viewed as a more severe, persistent pattern of behavior, which involves violating the rights of others and may include aggression toward people or animals, destruction of property, theft, or serious violation of rules (APA, 2013). In contrast, ODD is characteristically observed in childhood, as a result of negativistic or hostile patterns of behavior, including blaming others for mistakes, frequent arguments, and refusing others' requests (APA, 2013). As both are typically diagnosed in children, some professionals question whether the importance of these behaviors are meaningful for adults. In addition to conduct disorder and ODD, substance use is considered a behavioral problem, and may include alcohol or illicit substances. Substance use disorder becomes more prevalent in adolescence and adulthood.

Conduct disorder. Research examining adult ADHD and childhood conduct disorder is ample. Dowson (2008) examined the association between a conduct disorder diagnosis in childhood and an ADHD diagnosis in adulthood. Individuals who were diagnosed with conduct disorder in childhood had an adult ADHD profile with greater impulsivity, including rapid responses to stimuli, reduced ability to delay gratification, maladaptive affect regulation, poor planning, and under-concern for consequences of behavior, as compared to adults with ADHD never diagnosed with conduct disorder.

The relationship between childhood conduct disorder and ADHD-related impulsivity in adults might, in part, reflect shared etiology and symptom overlap (Dowson, 2008). Within their study of 458 participants with ADHD, Vitola et al. (2012)

found that the presence of childhood or adolescent conduct disorder was associated with increased severity and impairment of ADHD, a greater likelihood of impulsivity, and a higher prevalence of comorbidities. ODD was also associated with increased severity and impairment of ADHD (Vitola et al., 2012).

Oppositional defiant disorder. A 2013 study aimed to examine the prevalence of ODD traits in adults with ADHD (Reimherr, Marchant, Olsen, Wender, & Robison, 2013). Sixty-five adult participants met criteria for ADHD, as measured on the Wender Utah Rating Scale (WURS). ODD was assessed through self-report and a scale developed by the investigators, the Self-Report Wender-Reumherr Adult Attention Deficit Disorder Scale (SR-WRAADDS). Of the 65 participants, 42% met criteria for ODD, based on participants' scores on the SR-WRAADDS. ODD was associated with higher endorsement of childhood ADHD symptoms, particularly hyperactive/impulsive items.

Substance use disorder. A relationship between substance abuse and ADHD has been demonstrated in numerous studies. Between 32% and 53% of adults with ADHD report alcohol use problems and 8% to 32% report problems with others substances (Barkley, 2006; Huntley et al., 2012; McGough et al., 2005). For individuals with ADHD, alcohol, tobacco, and cannabis are the most commonly abused substances (Upadhyaya & Carpenter, 2008). Adults with ADHD are two times more likely to use tobacco, as compared to the general population (Adler, Spencer, Stein, & Newcorn, 2008). Use of these substances may reflect an attempt at self-medication. For instance, individuals often report these substances can "slow down" their thoughts. On the other hand, those prone to performing impulsive behaviors may be even more likely to engage

in risky behaviors involving substances without fully considering the consequences (Ramsay & Rostain, 2008). Young and colleagues (2015) reported that 44% of participants in their study met the criteria for concurrent ADHD and a substance use disorder.

Wilens et al. (2011) examined this relationship in 268 individuals diagnosed with ADHD and 229 individuals without ADHD over a 10-year period. Participants were assessed through the utilization of a structured interview developed by the investigators. Results of the study suggested participants with ADHD were 1.47 times more likely to develop a substance use disorder, as compared to the controls.

As previously suggested, individuals with ADHD may use substances to self-medicate in an attempt to manage uncontrollable symptoms. These individuals may also be more impulsive, increasing the likelihood of engaging in risky behaviors, such as using substances. Regardless of how substance use may develop, it is necessary to address early in treatment because the effects of the substances may interfere with prescribed pharmacotherapy and newly acquired coping skills (Ramsay & Rostain, 2008). As a means of understanding substance use and other behaviors and symptoms common in ADHD, a comprehensive diagnostic assessment battery that can assist clinicians in providing accurate diagnoses of ADHD, identifying comorbidities, and ruling out differential diagnoses is provided below.

Assessment of ADHD

A misdiagnosis of ADHD may lead to improper treatment or no treatment at all. To ensure a diagnosis of ADHD is accurate and appropriate for adults presenting for treatment, a clinician should complete a comprehensive diagnostic assessment battery.

This evaluation typically consists of a review of history of presenting problems, a review of developmental history, an assessment of past and present ADHD symptoms, clinical questionnaires, and a neuropsychological screening, such as the Quotient (Ramsay & Rostain, 2008, 2015). Goals of the evaluation include determining whether the symptoms of ADHD are currently present in sufficient scope, frequency, and severity to meet criteria, ascertaining whether the symptoms were present in childhood (12 years or younger [APA, 2013]), and determining what other conditions may be present (comorbidities or differential diagnoses), such as anxiety, depression, bipolar disorder, or substance use disorder (Solanto, 2011).

As with all clinical assessments, it is important to inquire why patients are seeking treatment. It is also necessary to determine how patients conceptualize their difficulties, and how these difficulties reflect changes in previous functioning. It is also useful to ask how patients became aware of the diagnosis of ADHD (Ramsay & Rostain, 2008). Many adults are referred for the first time ever after their children have been diagnosed with ADHD (McKee, Harvey, Danforth, Ulaszek, & Friedman, 2004).

Clinicians should explore the patient's developmental history and inquire about the individual's emotional, behavioral, cognitive, and social growth and development, as well as response to family stressors. Developmental history includes report and previous records of psychological/psychiatric and medical evaluations, as well as prior treatment. These records may help confirm or refute a childhood history of ADHD and rule out the presence of brain injuries or other diagnoses (Ramsay & Rostain, 2008; Solanto, 2011). Whenever possible, it is invaluable for clinicians to get the input of collateral individuals who knew the patient in childhood, such as parents, friends or other family members. A

review of family history may shed light on genetic predispositions to ADHD, medical problems, and emotional problems.

When assessing for ADHD in the adult population, clinicians are advised to inquire about academic and behavioral performance for each level of education. Clinicians should explore academic performance and study skills and, if possible, acquire standardized test scores. Inquiring about classes failed, grade levels repeated, the need for academic support, and classes dropped in college can be illuminating, as can exploring patients' abilities to listen during lectures, complete reading assignments, and take timed, in-class exams (Ramsay & Rostain, 2015). Similarly, a detailed review of the patient's work history is important. Clinicians should encourage patients to discuss work-related challenges, reasons for changing jobs, and specific duties that have been challenging (Ramsay & Rostain, 2015).

It is beneficial to ask direct questions about patients' functioning in life domains impacted by ADHD. Clinicians should inquire about how patients handle work and/or school, manage time, work independently, meet deadlines, and organize paperwork, all examples of executive functioning in everyday life. Clinicians are advised to encourage patients to discuss how they manage their personal affairs. They should ask patients whether they keep appointments, pay their bills, utilize financial budgets, and complete chores. Clinicians are encouraged to explore self-care and inquire about how patients manage their health, whether they pursue hobbies, and whether they spend too much time pursuing interests instead of focusing on pressing responsibilities. Also, clinicians should inquire about patients' relationships with technology (Ramsay & Rostain, 2015).

In addition to a diagnostic interview, symptoms checklists should also be utilized. Symptoms checklists have been utilized for over 60 years and are an efficient, reliable, and valid way to assess for the presence of both childhood and adult symptoms of ADHD relative to other adults in the general population (Gualtieri & Johnson, 2005; Ramsay & Rostain, 2015; Solanto, 2011). Despite the usefulness and quality of these objective measures, a diagnosis of ADHD should not be based on the results of a single questionnaire, as these questionnaires only rely on patients' or others' *perceived* degree of difficulties and reveal little objective data about the origins of ADHD (Solanto, 2011). Therefore, it is beneficial to pair a clinical interview and symptom assessments with measures of neurobiological functioning to attain more objective data (Ramsay & Rostain, 2008).

Rating scales. The first symptom rating scales, the Connors rating scales, were introduced in 1969 (Conners, 1969). These scales assessed symptoms of hyperactivity in children and were completed by parents and teachers (Barkley, 2015b). Throughout the years, additional scales were developed to assess the symptomatology of ADHD in children: the Children Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983, 1986), modified Conners rating scales (Barkley, 1988), and the ADHD Rating Scale (DuPaul, 1991). The first symptom rating scale targeting symptoms of ADHD in the adult population, the Brown Attention-Deficit Disorder Scales (BADDS) was introduced in 1996 (Brown, 1996). Typically, patients will complete an objective rating scale. Generally, choosing a rating scale depends on the preference of the clinician/clinic. If possible, a family member of the patient, typically a spouse, sibling, or parent, can also fill out a scale based on his or her observations of the patient's behaviors. A combination

of both self- and other-observer reports of symptoms of ADHD increases reliability of diagnostic information (Barkley, Knouse, & Murphy, 2011).

The Conners' Adult ADHD Rating Scales (CAARS; Conners, Erhardt, & Sparrow, 1999), although not utilized in this study, is another widely-accepted and commonly used scale. The CAARS was developed as a solution to the lack of reliable and valid measures of ADHD symptoms for the adult population. The CAARS was developed to measure the presence and severity of ADHD symptoms in order to better determine whether ADHD is a contributing factor to a patient's difficulties. There are long and short versions of both the self-report and observer scales. Inattention and memory problems, hyperactivity and restlessness, impulsivity and emotional lability, and problems with self-concept are the primary constructs assessed through these scales (Conners et al., 1999). Respondents' scores are calculated and transformed as t-scores (mean = 50; standard deviation = 10). One strength of the scale is that it is normed for both age and gender; however, unlike the BAARS-IV, the CAARS only focuses on aspects of adults' current functioning and does not address childhood behaviors or difficulties (Ganellen, 2003). This may be viewed as a drawback of this scale.

The Barkley Adult ADHD Rating Scale-IV (BAARS-IV) is a norm-based, essential tool for assessing current ADHD symptoms and domains of impairment, as well as recollections of childhood symptoms (Barkley, 2011a). Directly linked to *DSM-5* diagnostic criteria, the scale includes both self-report and observer-report forms (for example, spouse, parent, or sibling). Unlike any other rating scales developed for assessing ADHD symptoms in adults, the BAARS-IV includes a section of items for assessing sluggish cognitive tempo (SCT)/concentration deficit disorder (CDD). The

BAARS-IV was also created by Barkley and introduced to the public in 2011 (Barkley, 2011a).

Prior to publishing the BAARS-IV, Barkley (2011a) observed a higher agreement between the prototype of the BAARS and a structured clinical interview containing the 18 *DSM-IV* items, as compared to the CAARS and the structured clinical interview. Based on additional research, Barkley proposed that clinicians should utilize the BAARS-IV in conjunction with the BDEFS when assessing for ADHD, as executive functioning deficits on the BDEFS share between 21% and 69% of their variance with the BAARS-IV subscales. Although a significant and positive relationship has been established between these two factors, it is still necessary to assess for the symptoms of ADHD and problems with executive functioning in daily activities.

The Barkley Deficits in Executive Functioning Scale (BDEFS for Adults) is a normed, empirically-based tool for evaluating dimensions of adult executive functioning in daily life (Barkley, 2011b). The BDEFS is a theoretically-based scale developed from models of executive functioning, primarily Barkley's model, but also included models of Stuss and Benson (1986), Welsh and Pennnington (1988), Lezak (1995), and Brown (1996). The BDEFS offers a valid snapshot of the capacities involved in time management, organization and problem-solving, self-restraint, self-motivation, and self-regulation of emotions. Both self- and other-report versions are available (Barkley, 2011b; Ramsay & Rostain, 2015). In a recent study, the BDEFS was found to correlate more closely with impairment in adults with ADHD than results of neuropsychological testing of executive functions (Barkley & Fischer, 2011).

Continuous performance tests. As ADHD is conceptualized as stemming, in large part, from deficits in executive functions, there has been a rise in neuropsychological research geared toward identifying deficits associated with ADHD. Neurocognitive screening helps to identify areas of cognitive dysfunction and illustrates a patient's ADHD profile. Neurocognitive screenings may be conducted by use of continuous performance tests (CPTs). Rosvold, Mirsky, Sarason, Bransome, and Beck (1956) introduced a CPT in the mid-1950s. Their CPT was a sequential, visual, language-based A-X task, during which participants responded whenever they saw an "A" followed by an "X" on the computer screen. Research on the initial CPT did not show very promising results. These CPTs focused on omission and commission scores with inaccurate measures of response time. Throughout the years, it has become more apparent that accurate response time and variability of response time are critical variables for CPTs to be sensitive and useful (Greenberg, Kindschi, Dupuy, & Hughes, 2016). Currently, CPTs measure overall cognitive functioning as well as how patients handle tasks that require impulse control, sustained attention, and working memory (Ramsay & Rostain, 2015). Most CPTs account for correct answers, incorrect answers, and time completion (Ramsay & Rostain, 2008).

The Gordon Diagnostic System (GDS) is a portable, computerized CPT device (Gordon, 1983). When it was introduced in 1983, the GDS was the first commercially available device that could provide an objective assessment of ADHD. The GDS contained two tests. One of the tests was a CPT, which measured vigilance and impulsivity, and the other was a direct reinforcement of low rates (DLR), which assessed impulse control. The DLR test proved to be insensitive to stimulant medication effects,

and this test of the GDS became less prominent (Barkley, Fischer, Newby, & Breen, 1988). Nevertheless, the CPT accurately discriminated between children with and without ADHD and was sensitive to medication effects (Barkley et al., 1988; Gordon & Mettleman, 1988). Although less frequently used presently, the CPT test of the GDS had a wide clinical following for nearly a decade (Barkley, 2015b).

The Test of Variables of Attention (TOVA), formerly called the Minnesota Computer Assessment (MCA) and created by Greenberg (1991), is a normed, fixed-interval CPT used to assess ADHD and monitor the effects of medication treatment in children and adults ages 4 to 80. The TOVA measures attention during a 21.6-minute task. It records the accuracy, speed, and consistencies of the responses to a series of squares (in the visual TOVA test) or tones (in the auditory TOVA test) that are presented in 2-second intervals. The TOVA variables include errors of omission (measure of inattention), errors of commission (measure of impulsivity), mean correct response times (measure of processing and response time), standard deviations of response times (measure of variability or consistency of performance), anticipatory responses, post-commission mean correct response time, and multiple responses (Greenberg et al., 2016). Despite being one of the more commonly utilized CPTs, the TOVA generates high false positive rates (30%) in normal controls and individuals with other psychiatric disorders (Gualtieri & Johnson, 2005).

The Conners Continuous Performance Test 3rd Edition (Conners CPT 3; 2014*)* is designed to assess attention-related problems in individuals ages 8 years and older and may be used in the evaluation process for disorders such as ADHD. Unlike the format of most CPTs, the test administration requires the individual to respond to letters displayed

on a computer screen, with the exception of the target letter, X, by pressing the keyboard's space bar or the mouse button. Each letter is displayed for 250 milliseconds, and the intervals between presentations are 1, 2, and 4 seconds. An administration consists of 360 trials across 14 minutes. The measures of omissions and reaction time variability assess an individual's sustained attention and the measures of commissions and reaction time assess response inhibition. The Conners CPT 3 was designed for individual administration in a formal testing environment with limited distractions (Conners, 2014).

The Quotient ADHD System is an FDA-cleared device intended to provide clinicians with objective measures of hyperactivity, impulsivity, and inattention to aid in the clinical assessment of ADHD. The Quotient ADHD Test (previously known as McLean Motion and Attention Test [MMAT]) provides objective, quantitative data on micro-motion and shifts in attention state (Pearson, 2014). Participants' results are integrated into three composite scores: High Motion Scaled Score (SS), Inattention SS, and Global SS. The scores range from 0 to 10 in four categories: Unlikely, Plausible, Probably, Likely. The average SS for a person without ADHD is 4. The average SS for an individual with ADHD is 7. Results correlate directly to the three core symptom domains of ADHD (hyperactivity, impulsivity, and inattention), which are often assessed through symptom-rating scales (Pearson, 2014).

In contrast to traditional CPTs, the Quotient analyzes the individual's ability to sustain an attentive state over the course of a task (Pearson, 2014). The Quotient measures a participant's ability to control motor activity, sustain attention, and inhibit impulsive responses within developmentally appropriate expectations. The test utilizes

an infrared motion analysis system to track head movement while the person takes a monotonous, yet demanding, attention test. The motion tracking system measures micro-motion of the head 50 times per second by following the reflector on the headband. The motion sensor tracks movements greater than 0.4 millimeters at a distance of 30 inches (Pearson, 2014). It may also provide indirect measures of leg movements during the tasks, as moving legs can be registered in head movement (Ramsay & Rostain, 2015). Higher numbers of movement may indicate greater hyperactivity.

In addition to tracking movement, the Quotient tracks the participant's ability to pay attention by tracking overall accuracy (omission and commission errors), the percentage of targets missed (omission errors), the percentage of incorrect hits to non-targets (commission errors), and response time (in milliseconds). Overall accuracy and response time may suggest whether the participant was attentive or acted impulsively (Pearson, 2014). The results indicate the percentage of time a participant was attentive, impulsive, distracted, or disengaged (Pearson, 2014).

Although the Quotient is being utilized in numerous prestigious clinics that specialize in adult ADHD throughout the United States, there is limited published research to support the reliability and validity of the Quotient for diagnosing ADHD in adults (Gibbins & Weiss, 2007; Murillo et al., 2015; Polcari et al., 2010). The majority of the landmark studies on the Quotient utilized children as their samples. In one pediatric study, the Quotient had an accuracy of 93.1% and a test-retest reliability of approximately 90% (Teicher, Polcari, & McGreenery, 2008). In contrast, the Conners Kiddie Continuous Performance Test 2nd Edition (CPT 2; 2000) and TOVA have low test-retest reliability and are only accurate in classifying individuals with and without

ADHD in 60% to 70% of cases (Matier, Halperin, Sharma, Newcorn, & Sathaye, 1992; O'Toole, Abramowitz, Morris, & Dulcan, 1997). It is purported that the dramatic improvement in performance on the Quotient is a result of the combined measurements of micro-motion to quantify the ability to sustain body stillness in space and the analyzed shifts in attention state to determine the capacity to sustain attention, ultimately capturing a participant's ability to sit still and remain focused on the task (Teicher et al., 2003). The integrated motion and sustained attention analyses of the Quotient objectively measure deficits in neural control, particularly the ability to attend to a task, control motor activity, and respond without impulsivity. These neural deficits coincide with the core symptomatology of ADHD: inattention, hyperactivity, and impulsivity (Pearson, 2014).

Although published research containing adult participants remains sparse, one landmark study compared adult participants' activity and attention levels on the Quotient and the Conners CPT 2. This study demonstrated the superiority of the Quotient to the Conners CPT 2, which may be considered a traditional CPT (Polcari et al., 2010; Teicher, Polcari, Fourligas, Vitaliano, & Navalta, 2012). The researchers compared the two CPTs by plotting participants' results on a Receiving Operating Characteristic (ROC) Curve. The area under the ROC curve provides the best indicator of the discriminative capacity of a test. A perfectly accurate test has a ROC area of 1.0. Contrarily, a score of ROC area of 0.5 signifies a test is no better than chance. The researchers found that computerized measures of inattention, the primary component of the CPT 2, had limited ability to identify participants with ADHD (ROC area between 0.63-0.65). In comparison, motor activity measures, which are components of the Quotient, had a good

ability to detect ADHD (ROC area of 0.83). When combined, such as in the Quotient, the ability to detect ADHD is even greater (ROC area of 0.96), making the case for the use of the Quotient in diagnostic batteries (Polcari et al., 2010; Teicher, Polcari, Fourligas, Vitaliano, & Navalta, 2012). In a more recent study with adult participants, Gastelle (2018) found that the Global SS and Motion SS metrics of the Quotient correlated with the Hyperactive/Restlessness scale on the CAARS. Furthermore, this study found a significant positive correlation between the Inattentive Metric of the Quotient and the Inattention/Memory scale on the CAARS.

Summary

The role of executive functions and behavioral inhibition in adults with ADHD has been explored extensively by numerous researchers. Most researchers agree that there is a strong relationship between problems with executive functioning and the symptoms of ADHD (inattention, hyperactivity, impulsivity). Adults with ADHD typically endure some form of social, occupational, or educational impairment because of their ADHD symptoms. Barkley (2011b) established five domains of impaired executive functions for adults with ADHD: self-management to time, self-organization/problem-solving, self-restraint, self-motivation, and self-regulation of emotions.

An accurate diagnosis of ADHD within adults can best be attained through the completion of a comprehensive diagnostic assessment battery. An exemplary battery would include a clinical interview that explores the history of the individual's presenting problem; developmental, family, educational, and occupational history; the completion of psychometrically sound rating scales (both self- and other-report), such as the BDEFS and the BAARS-IV; and a neurocognitive screening, such as the Quotient (Ramsay &

Rostain, 2008). Empirical support for the Quotient is lacking. It was hoped that this study would help to determine the validity and reliability of the Quotient in an adult ADHD population to aid in accurately diagnosing ADHD to allow researchers and clinicians to better understand the mechanisms of ADHD and adapt treatments to better suit the needs of these individuals.

Chapter 3: Hypotheses

The current study explored the relationship between an objective, behavioral assessment of ADHD, specifically the Quotient, and two widely-accepted self-report ADHD measures, specifically the BDEFS and BAARS-IV. Five hypotheses were proposed.

Hypothesis 1

It was hypothesized that a self-reported measurement ADHD severity, operationalized as the Total Executive Functioning (EF) Summary Score of the BDEFS (computed from subscales: Self-Management to Time, Self-Organization/ Problem-Solving, Self-Restraint, Self-Motivation, Self-Regulation of Emotions) and ADHD total score of the BAARS-IV (computed from subscales: ADHD Inattention, ADHD Hyperactivity, and ADHD Impulsivity) would predict in a significant and positive manner behavioral ADHD symptom severity, operationalized as the Quotient ADHD System Global SS (computed from 19 indices: 13 Attention indices and six Motion indices). According to existing research, the Quotient provides valid and reliable information about brain function with a strong correlation to the presence or absence of a level of symptom burden sufficient for the diagnosis of ADHD (Pearson, 2014).

Hypothesis 2

It was hypothesized that self-reported ADHD Hyperactivity and ADHD Impulsivity (BAARS-IV) and Self-Restraint (BDEFS) would predict in a significant and positive manner observable, behavioral impulsiveness and hyperactivity (increased scores on the Quotient Impulsive Metric [Attention State]). The Quotient

objectively measures a participant's ability to control motor activity and inhibit impulsive responses. These results purportedly correlate to the core symptoms of impulsivity and hyperactivity (Sumner, 2010; Teicher, Ito, Glod, & Barber, 1996; Teicher, Lowen, Polcari, Foley, & McGreenery, 2004; Teicher et al., 2006).

Hypothesis 3

It was hypothesized that self-reported ADHD Hyperactivity and ADHD Impulsivity (BAARS-IV) and Self-Restraint (BDEFS) would predict in a significant and positive manner observable, behavioral impulsiveness and hyperactivity (increased scores on the Quotient Motion SS).

Hypothesis 4

It was hypothesized that self-reported Self-Organization/Problem-Solving scores (BDEFS) and ADHD Inattention scores (BAARS-IV) would predict in a significant and positive manner observable, behavioral inattentiveness (increased Quotient scores on Distracted Metric [Attention State], based on errors of omission). The Quotient objectively measures a participant's ability to sustain attention. By analyzing attention state shifts as a dynamic temporal process, the Quotient more precisely identifies the nature of the attention disturbance and objectively measures a participant's ability to sustain attention, a core symptom of ADHD (Sumner, 2010; Teicher et al., 1996; Teicher et al., 2004; Teicher et al., 2006).

Hypothesis 5

It was hypothesized that there would be a significant and positive relationship between self-reported SCT (BAARS-IV) and inattentiveness (Quotient Disengaged Metric [Attention State]). The Disengaged Metric suggests response patterns that are

not as accurate as would be expected by chance and reflect a failure of the individual to engage in the task. Varied engagement in a task over an extended period of time may be common for individuals with ADHD. Sluggish cognitive tempo (SCT) is an attentional-motivational construct that has traditionally been associated with ADHD, inattentive type (Barkley, 2011a; J. J. Bauermeister et al., 2001). SCT is characterized by sluggishness, passivity, confusion, and hypoactivity. Individuals with SCT may have difficulties orienting and engaging attention, effort, and alertness (Ramsay & Rostain, 2015). SCT may explain the disengagement of the participant.

Chapter 4: Method

Design and Justification

This study utilized an archival, correlational research design to examine whether participants' outcomes on the BAARS and BDEFS, both self-reported measures, correlated with the behavioral correlates of ADHD, as measured by the Quotient. A regression analysis was used to determine whether the former predicted the presence of the latter.

Participants

Archival data were gathered from the charts of 151 adults who presented to a university-based outpatient clinic in a large northeastern city of the United States, specializing in the assessment and treatment of adult ADHD. Consumers at this clinic are typically self- or other-referred adults who are suspected to have ADHD. Fees are primarily private payment and university-based insurance reimbursement.

Inclusion criteria. Individuals between the ages of 18 and 81 were included in the study. The upper age limit was defined by the normed ages for the BDEFS. The BAARS-IV is normed for individuals between the ages of 18 and 89, and the Quotient is normed for individuals who are 6 years and older. There is no upper age limit set for the Quotient. Each adult who completed an intake assessment battery at this adult ADHD specialty outpatient clinic was considered for inclusion if he or she completed the following measures when previously assessed: the BDEFS (Barkley, 2011b), the BAARS (Barkley, 2011a), and Quotient (Pearson, 2014). Inclusion criteria required the presence of ADHD or ADHD-like symptoms according to the BDEFS, the BAARS, the Quotient, and *DSM-5* criteria for ADHD.

Exclusion criteria. Patients are generally screened on initial contact and during the intake for severe posttraumatic stress disorder, traumatic brain injury, severe and current substance use, and schizophrenia or other psychotic disorders. These individuals are generally referred out and excluded from treatment and, therefore, it is believed they were not be included in this study, although archival data did not specifically include this information.

Measures

Barkley Deficits in Executive Functioning Scale. The BDEFS is an empirically-based tool for evaluating dimensions of adult executive functioning in daily life. The BDEFS offers a valid snapshot of the capacities involved in time management, organization and problem-solving, self-restraint, self-motivation, and self-regulation of emotions. It comprises both self- and other-reports in a long form (15 to 20 minutes for completion) and a short form (4 to 5 minutes). An individual's total score on the BDEFS Self-Report Long Form, which was utilized in the present study, can range from 0 to 356. A unique feature of the BDEFS is an adult executive functioning summary score, ADHD-EF index, in the long form, which purports to assess for the risk of ADHD within adults. The ADHD-EF index may suggest an individual should be further evaluated for ADHD. An individual's score on the ADHD-EF index may range from 0 to 44 (Barkley, 2011b). Higher scores on the ADHD-EF index and subscale indicate more pathology.

The BDEFS is based on more than 16 years of research by the developer. A large normative sample (N = 1,249) was representative of the U.S. population in terms of region, socioeconomic status, education, ethnicity/race, and gender, based on the 2000 U.S. Census. Scoring sheets present the percentiles for the normative sample by sex and

age (18-34, 35-49, 50-64, and 65-81 years old). The normative sample was a true general population sample, not limited to those with an Internet connection and not excluding those with psychiatric disorders, psychiatric medication use, learning disabilities, neurological disorders, or serious medical illnesses.

Reliability is satisfactory, as evidenced by high internal consistency (Cronbach's alpha ranging from .91 to .95 across the five scales), good interobserver agreement (.66 to .79 across scales), and high test–retest reliability over a 2-to-3-week interval (ranging from .62 to .90 across scales and .84 for the Total EF Summary Score). Subscales of the BDEFS were correlated to numerous EF tests, including the Conners CPT and the Stroop Color–Word Test. The correlations ranged with *r* between .04 to .41 and -.01 to -.31, respectively. Those with ADHD were more likely to score in the clinically significant range than those in the control group. Correlations from the normative sample and pilot studies (University of Massachusetts and Milwaukee studies) were used to examine how scores on the BDEFS relate to concurrent outcomes. The BDEFS was correlated to ADHD severity using an adult ADHD rating scale, which found statistically significant Pearson correlations at $p < .001$ (M. W. Anderson, 2014; Barkley, 2011b; Schraw, 2014).

BDEFS Self-Report Long Form Subscales. A number of subscales from the BDEFS Self-Report Long Form were utilized in this study. These include Self-Management to Time, Self-Organization/Problem-Solving, Self-Restraint, Self-Motivation, and Self-Regulation of Emotions.

Self-Management to Time. Items pertain to sense of time, time management, planning, preparing for deadlines, and other goal-directed behavior. (Total score range from 0 to 84.)

Self-Organization/Problem-Solving. Items pertain to organizing one's actions and thoughts and thinking quickly when encountering unexpected obstacles. (Total score range from 0 to 96.)

Self-Restraint. Items pertain to impulsive decision making and completing actions without considering the consequences. (Total score range from 0 to 76.)

Self-Motivation. Items pertain to being described as lazy, not putting effort into one's work, and being easily bored. (Total score range from 0 to 48.)

Self-Regulation of Emotions. Items pertain to having sustained concentration during uninteresting activities and daydreaming. (Total score range from 0 to 52.)

Barkley Adult ADHD Rating Scale-IV. The BAARS-IV is a psychometrically supported self-report tool for assessing current ADHD symptoms and domains of impairment, as well as reported childhood symptoms. Directly linked to *DSM-IV* diagnostic criteria, the scale includes both self- and other-report forms (for example, spouse, parent, or sibling). The long version, which is utilized in the present study, takes the average adult 5 to 7 minutes to complete, and the Quick Screen takes only 3 to 5 minutes. An individual's total score on the BAARS-IV current symptoms self-report can range from 0 to 108, with higher scores indicating greater pathology. A unique feature of the BAARS-IV is a section of items assessing the newly identified syndrome of sluggish cognitive tempo (SCT), also known as concentration deficit disorder (CDD).

The BAARS-IV is based on more than 16 years of research by the developer using prototypes of the BAARS-IV. The large normative sample (N = 1,249) was representative of the U.S. population in terms of region, socioeconomic status, education, ethnicity/race, and gender, based on the 2000 U.S. Census. Scoring sheets present norms

for three age groups of adults (18-39, 40-59, and 60-89 years old). Reliability of the scores is quite satisfactory as evidenced by high internal consistency (Cronbach's alpha of .92 for current ADHD and .95 for childhood ADHD symptom scores), good interobserver agreement (.67 to .75 across scales), and high test-retest reliability over a 2 to 3 week interval (.75 for current ADHD and .79 for childhood ADHD symptom scores). Validity of the scaled scores was evident in numerous analyses, including factor analyses, correlations with other measures of ADHD symptoms (.85 to .87 correlation between a structured clinical interview using the 18 *DSM-IV* symptoms and the BAARS-IV current symptoms scale), and high correlations between self-rating and other-ratings (ranging from .67 to .70 for current ratings and from .73 to .75 for symptoms recalled from childhood; Barkley, 2011a; Crumpton, 2014; Suppa, 2014).

BAARS-IV Current Symptoms Self-Report Long Form Subscales. The subscales on the BAARS-IV Current Symptoms Self-Report Long Form include Inattention, Hyperactivity, Impulsivity, and Sluggish Cognitive Tempo.

Inattention. Items reflect the *DSM-IV-TR*'s nine inattentive symptoms of ADHD. (Total score range from 0 to 36.)

Hyperactivity. Items reflect the *DSM-IV-TR*'s hyperactivity criteria for ADHD, with the exception of "talking excessively." (Total score range from 0 to 20.)

Impulsivity. Items reflect the *DSM-IV-TR*'s four impulsivity criteria for ADHD, plus "talking excessively," as it loaded more highly with this factor (Barkley, 2011b). (Total score range from 0 to 16.)

Sluggish Cognitive Tempo. Items pertain to hypoactivity, lethargy, and slow movement. (Total score range from 0 to 36.)

Quotient ADHD System. The Quotient, which will be available through December 31, 2019, has the intended use of providing clinicians with objective measures of hyperactivity, impulsivity, and inattention to aid in the clinical assessment of ADHD (Pearson, 2014; 2019).

The Quotient contains two tests: the child test and the adult test, the latter of which will be utilized in the present study. The adult test is a 20-minute task, during which individuals are instructed to press the space bar on a keyboard when 5-point, 8-point, or 16-point stars appear on the screen. They are instructed to not press any key when a 4-point star appears on the computer screen. Unlike the child test, there is a random interval between stimuli presentation, and the stimulus density is 90% to 10%.

Studies have demonstrated that the Quotient has high sensitivity and specificity; it is very sensitive to treatment effect, and results correlate with neuroimaging assessments of brain functions in regions associated with ADHD (C. M. Anderson, Polcari, Lowen, Renshaw, & Teicher, 2002; Slaughter et al., 2010). The Quotient has an accuracy of 93.1% and a test-retest reliability of 90%. The Quotient is believed to more useful than traditional CPTs, in that it offers the combined power of measuring micro-motion to quantify the ability to sustain body stillness in space and analyzing shifts in attention state to determine the capacity to sustain attention (Pearson 2014; Teicher et al., 2008).

Quotient ADHD System Scales scoring. For scoring the scales of the Quotient, the mean is 4 for individuals without ADHD and 7 for individuals with ADHD. The following describes the System Scales.

High Motion. Composite of how an individual's motion compares to individuals 15 to 55 years old without ADHD. It is calculated from the six Motion metrics. (Total score range from 0 to 10; score possibilities are Unlikely, Possible, Probable, or Likely.)

Inattention. Composite of how an individual's attention compares to individuals 15 to 55 years old without ADHD. It is calculated from the 13 Attention metrics. (Total score range from 0 to 10; score possibilities are Unlikely, Possible, Probable, or Likely.)

Global Scaled Score. Demonstrates the combination of the 19 indices (13 Attention metrics and six Motion metrics) for the individual as compared to individuals 15 to 55 years old without ADHD. (Total score range from 0 to 10; score possibilities are Unlikely, Possible, Probable, or Likely.)

Motion Analysis Metrics. The Motion Analysis Metrics correspond to Reflector Location. They are described below.

Immobility Duration. The average amount of time not moving greater than 1 millimeter over course of 20-minute task (measured in milliseconds).

Movements. The number of position changes greater than 1 millimeter.

Displacement. The total distance moved by the marker over the course of the 20-minute task (measured in meters).

Area. The total area covered by the marker's path over the course of the 20-minute task (measured in centimeters squared).

Spatial Complexity. The complexity of the movement path, with scores ranging from 1 to 2. Lower values indicate simple, back-and-forth movements (scale score).

Temporal Scaling. The pattern of movement in time, with scores ranging from 0 to 1. Frequent movement produces values closer to 1 (scale score).

Attention State Metrics. The Attention State Metrics are described below.

Accuracy. Overall accuracy based on omission and commission errors (recorded as a percentage).

Omission Errors. The percentage of targets missed. Targets included a 5-point star, an 8-point star, and a 16-point star. This measures inattention or level of distraction (recorded as a percentage).

Commission Errors. The percentage of incorrect hits to non-targets. The non-target is the 4-point star. This measures impulsivity or inability to inhibit a response (recorded as a percentage).

Latency. The average amount of time to respond to a target (measured in milliseconds).

Variability. The standard deviation of response time to targets (measured in milliseconds).

C.O.V. Variability correct for response latency (C.O.V. = 100 x Variability/ Latency). This is a stricter measure of response consistency.

Number of Shifts. How many times a change in behavioral states occurs during the 20-minute test.

Attentive. Percent of 30-second blocks in which individual performed with both accuracy and consistent response latency. (The summation of Attentive State, Impulsive State, Distracted State, and Disengaged State is 100%. This exemplifies the percentage of time the participant was attentive, impulsive, distracted, or disengaged over the course of the 20-minute task).

Impulsive. Percent of 30-second blocks in which an individual either makes an excessive number of commission errors or responds too rapidly. (The summation of Attentive State, Impulsive State, Distracted State, and Disengaged State is 100%. This exemplifies the percentage of time the participant was attentive, impulsive, distracted, or disengaged over the course of the 20-minute task).

Distracted. Percent of 30-second blocks in which an individual makes an excessive number of omission errors or responds too slowly. (The summation of Attentive State, Impulsive State, Distracted State, and Disengaged State is 100%. This exemplifies the percentage of time the participant was attentive, impulsive, distracted, or disengaged over the course of the 20-minute task).

Disengaged/R.M.C. Percent of 30-second blocks in which an individual performed no better than chance; R.M.C. = Random, Minimal, Contrary. (The summation of Attentive State, Impulsive State, Distracted State, and Disengaged State is 100%. This exemplifies the percentage of time the participant was attentive, impulsive, distracted, or disengaged over the course of the 20-minute task).

Procedure

The current study was approved by the Institutional Review Board (IRB) of the university associated with the treatment center and the Philadelphia College of Osteopathic Medicine IRB as a chart review study. Archival data for this study were retrieved from patients' charts on file in an electronic database at a specialty university-based outpatient adult ADHD treatment center in a large Northeastern city. Data were originally collected in the following manner: After being referred to the ADHD specialty clinic, all patients were required to complete an intake packet of forms before being

evaluated by a clinician; the packet contained release waivers, an intake assessment questionnaire, a health information questionnaire, and a variety of measures including the BDEFS and the BAARS. The evaluations also included a semi-structured clinical interview, which explored background history, as well as other information pertaining to any other barriers that may or may or may not be caused by ADHD. All information is kept in an encrypted, password-protected file for future relevant research in this field.

Additionally, patients completed the Quotient, a computerized test, at initial on-site intake, to further assess the behavioral correlates of ADHD.

The responsible investigator reviewed the records on file and gathered data (i.e., each patient's age, gender, and scores on the BDEFS, BAARS, and the Quotient). Protected health information and other identifying data for each subject were removed through a selective coding process and the deidentified data were then transferred to an electronic database for the investigator to analyze using SPSS. No identifying information was collected.

Chapter 5: Results

Statistical analyses were computed to examine whether the BDEFS and BAARS-IV, self-report measures for ADHD correlate with and predict the behavioral correlates of ADHD, the latter as measured by the Quotient. Facets of the BDEFS (Total EF Summary Score, Self-Restraint, and Self-Regulation of Emotions) and the BAARS-IV (ADHD Total Score, ADHD Hyperactivity, ADHD Impulsivity, ADHD Inattention, and SCT) were used to predict ADHD symptoms, as measured by the Quotient (Global SS, Impulsive Metric [Attention State], Motion SS, Distracted Metric [Attention State], and Disengaged Metric [Attention State]).

Statistical Analyses

The variables of interest were analyzed through the use of SPSS 22.0. The first power analysis was for a multiple regression with two predictors. In this analysis, the effect size was set at 0.15, which is considered a medium effect size for multiple regression (Cohen, 1988, 1992), the significance level was set at 0.05, and the power level was set at 0.90, as per conventional standards (Cohen, 1988, 1992). This analysis determined that 87 participants were needed to perform the multiple regression analyses for hypotheses 1 and 4. The second power analysis was for a multiple regression with three predictors. In this analysis, the effect size was also set at 0.15, the significance level was set at 0.05, and the power level was set at 0.90. This analysis determined that 98 participants were needed to perform the multiple regression analyses for hypotheses 2 and 3. The last power analysis was for a Pearson product-moment correlation. In this analysis, the effect size was set at 0.30, which is considered a medium effect size for correlation (Cohen, 1988, 1992), the significance level was set at 0.05, and the power

level was set at 0.95, as per conventional standards (Cohen, 1988, 1992). This analysis determined that 138 participants were needed to compute the correlation for hypothesis 5. The number of required participants was, therefore, set at the higher value of 151.

Demographic Analyses

Demographically, the sample consisted of 104 males and 47 females, with a mean age of 34 (*SD* = 12.97) and an age range of 18 to 72. Participants identified as 83.9% Caucasian, followed by 7.0% as Other, 3.5% African American, 2.8% as Hispanic, and 2.8% as Asian American. The mean years of education was 15.8 years.

Hypothesis 1

To examine whether self-reported ADHD severity (operationalized as the Total EF Summary Score of the BDEFS and ADHD Total Score of the BAARS-IV) significantly and positively predicted behavioral ADHD symptom severity (operationalized as the Quotient Global SS), a Pearson correlation analysis and a multiple linear regression were conducted. Means, standard deviations, range, and minimum and maximum values for these scores are presented in Table 1.

Table 1

Summary of Descriptive Statistics for BDEFS Total EF Summary Score, BAARS-IV Total Score, and Quotient ADHD System Global Scaled Score

Variable	*M*	*SD*	Range	Minimum	Maximum
BDEFS Total EF Summary Score	221.85	42.85	209	125	334
BAARS-IV Total Score	46.12	10.38	53	19	72
Quotient Global Scaled Score	6.04	2.01	8.21	1.19	9.40

A Pearson product-moment correlation coefficient was computed to assess the relationship between each individual predictor and behavioral ADHD symptom severity and determine whether the variables were related significantly. As Table 2 shows, there were significant, positive correlations between each individual variable and behavioral ADHD symptom severity. These results indicate that both of these variables were related significantly to the Quotient Global SS. Results indicated a significant positive relationship between the BAARS-IV Total Score and the Quotient Global SS (r = .251, p = .001) and the BDEFS Total EF Summary Score and the Quotient Global SS (r = .214 p = .004).

Table 2

Correlations for BDEFS Total EF Summary Score, BAARS-IV Total Score, and Quotient ADHD System Scaled Score

Variable	Quotient Global Scaled Score
BDEFS Total EF Summary Score	--
Pearson Correlation	.214*
Significance	.004
BAARS-IV Total Score	--
Pearson Correlation	.251*
Significance	.001

*Correlation is significant at the 0.01 level (1-tailed).

Using the enter method, a multiple linear regression analysis was conducted using self-reported ADHD severity (as measured by two variables, the BDEFS Total EF Summary Score and BAARS-IV Total Score) as the predictor variable and behavioral ADHD symptom severity (as measured by the Quotient Global SS) as the criterion variable. Tests of assumptions and multiple linear regression were conducted, including the Durbin-Watson statistic tests for "serial correlations between errors in regression models" (Field, 2009, p.785). Specifically, this test examines whether adjacent residuals are correlated. This is useful when assessing the assumption of independent errors. The Durbin-Watson statistic varies between 0 and 4. A value of 2 indicates that the residuals are uncorrelated (Field, 2009). The Durbin-Watson value was equal to 1.968, which would indicate that the residuals are uncorrelated.

The collinearity diagnostics revealed that for both predictor variables, there was no evidence of multicollinearity. Tolerance statistics measure multicollinearity. Values below 0.1 are problematic (Field, 2009). All of the tolerance statistics were above this value, suggesting multicollinearity was not present. The variance inflation factor (VIF) is another measure of multicollinearity that measures whether a predictor is strongly related to other predictors (Field, 2009). According to Field (2009), values of 10 are suggestive of problems in this area. The VIF value for both variables was 1.561, suggesting there was no concerns in this area.

As Table 3 shows, the results of the multiple linear regression analysis revealed a multiple correlation of $R = .263$ with a coefficient of determination of .069 ($R^2 = .069$), indicating that approximately 6.9% of the variance observed can be attributed to the combination of these two predictor variables. The adjusted coefficient of determination

($AdjR^2$ = .057) suggests that there would be some shrinkage from sample to population if the entire population had been evaluated. The overall regression analysis, as shown in Table 4, revealed a significant regression (F(2,148) = 5.513, $p < .005$), indicating that the combination of these predictors made a significant contribution to the prediction of behavioral ADHD symptoms. Nevertheless, as shown in Table 5, an examination of each of the predictor variables revealed that only one predictor , the BAARS-IV Total Score, approached significance in predicting severity of behavioral ADHD symptoms.

Table 3

Model 1 Summary of the Predictor Variables (BAARS-IV Total Score and BDEFS Total EF Summary Score) to the Criterion Variable (Quotient ADHD System Scaled Score)

Model	R	R^2	Adjusted R^2	Std. Error of Est.	R^2 Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.263	.069	.057	1.949	.069	5.513	2	148	.005	1.968

Table 4

Overall Regression Analysis with Predictor Variables (BAARS-IV Total Score and BDEFS Total EF Summary Score) to the Criterion Variable (Quotient ADHD System Scaled Score)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	41.903	2	20.952	5.513	.005*
	Residual	562.415	148	3.800		
	Total	604.318	150			

* = Significant; Criterion variable: severity of behavioral ADHD symptom severity

Table 5

Coefficients of Predictor Variables (BAARS-IV Total Score and BDEFS Total EF Summary Scores) to the Criterion Variable (Quotient ADHD System Scaled Score)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
1 (constant)	3.300	.880		3.748	.000		
BDEFS Total EF Summary Score	.005	.005	.099	1.000	.319	.640	1.561
BAARS-IV Total Score	.037	.019	.192	1.934	.055	.640	1.561

Hypothesis 2

To identify whether self-reported ADHD Hyperactivity and ADHD Impulsivity (BAARS-IV) and Self-Restraint (BDEFS) significantly and positively predicted behavioral impulsiveness (increased scores on the Quotient Impulsive Metric [Attention State]), a multiple linear regression was to be conducted; however, there were no significant relationships between the Quotient Impulsive Metric (Attention State) and ADHD Hyperactivity (BAARS-IV), ADHD Impulsivity (BAARS-IV), or Self-Restraint (BDEFS). Correlations can be found in Table 6.

Table 6

Correlations for BDEFS Self-Restraint, BAARS-IV ADHD Hyperactivity, BAARS-IV ADHD Impulsivity, and Quotient Impulsive Metric (Attention State)

Variable	Quotient Impulsive Metric
BDEFS Self-restraint	--
Pearson Correlation	-.067
Significance	.417
BAARS-IV ADHD Hyperactivity	--
Pearson Correlation	-.007
Significance	.931
BAARS-IV ADHD Impulsivity	--
Pearson Correlation	-.025
Significance	.765

Note: No significant findings at 0.01 level (1-tailed).

Hypothesis 3

To determine whether self-reported ADHD Hyperactivity and ADHD Impulsivity (BAARS-IV) and Self-Restraint (BDEFS) were significantly and positively predictive of behavioral hyperactivity (increased scores on the Quotient Motion SS), Pearson correlation analyses and a linear regression were conducted. As Table 7 shows, only ADHD Hyperactivity (BAARS-IV) had a significant, positive correlation with the criterion variable, the Quotient Motion SS ($r = .298$, $p = .001$). Given ADHD Hyperactivity (BAARS-IV) was the only significant predictor variable of the Quotient

Motion SS, a linear regression analysis was conducted with this variable using the enter method. Means, standard deviations, range, and minimum and maximum for these scores are presented in Table 8.

Table 7

Correlations for BDEFS Self-Restraint, BAARS-IV ADHD Hyperactivity, BAARS-IV ADHD Impulsivity, and Quotient Motion Scaled Score

Variable	Quotient Motion Scaled Score
BDEFS Self-Restraint	--
Pearson Correlation	.044
Significance	.297
BAARS-IV ADHD Hyperactivity	--
Pearson Correlation	.298*
Significance	.000
BAARS-IV ADHD Impulsivity	--
Pearson Correlation	.118
Significance	.075

*Correlation is significant at the 0.01 level (1-tailed).

Table 8

Summary of Descriptive Statistics for BAARS-IV ADHD Hyperactivity and Quotient Motion Scaled Score

Variable	*M*	*SD*	Range	Minimum	Maximum
ADHD Hyperactivity (BAARS-IV)	11.02	4.04	15	5	20
Quotient Motion Scaled Score	5.95	2.68	9.66	0.00	9.66

The results of the linear regression analysis, as shown in Table 9, revealed a correlation of $R = .298$ with a coefficient of determination of .089 ($R^2 = .089$), indicating that approximately 8.9% of the variance observed in the sample can be attributed to the predictor variable, ADHD Hyperactivity (BAARS-IV). The adjusted coefficient of determination ($AdjR^2 = .083$) suggests that there would be some shrinkage from sample to population if the entire population had been evaluated, and that about 8.3% of the variance in the general population could be attributed to the predictor variable, ADHD Hyperactivity (BAARS-IV). The overall regression analysis, as shown in Table 10, revealed a significant regression ($F(1,149) = 14.564$, $p = .000$), indicating that this predictor variable made a significant contribution to the prediction of observable, behavioral hyperactivity, with the Quotient Motion SS as the criterion variable. Table 11 also displays the significant, positive between the two variables.

Table 9

Model 1 Summary of the Predictor Variable (BAARS-IV ADHD Hyperactivity) to the Criterion Variable (Quotient Motion Scaled Score)

Model	R	R^2	Adjusted R^2	Std. Error of Est.
1	.298	.089	.083	2.565

Table 10

Overall Regression Analysis with Predictor Variable (BAARS-IV ADHD Hyperactivity) to the Criterion Variable (Quotient Motion Scaled Score)

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	95.795	1	95.795	14.564	.000*
	Residual	980.034	149	6.577		
	Total	1075.830	150			

*= Significant; Criterion variable: severity of behavioral hyperactivity

Table 11

Coefficients of Predictor Variable (BAARS-IV ADHD Hyperactivity) to the Criterion Variable (Quotient Motion Scaled Score)

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
1 (constant)	3.768	.609		6.191	.000
ADHD Hyperactivity (BAARS-IV)	.198	.052	.298	3.816	.000

Hypothesis 4

To examine whether self-reported Self-Organization/Problem-Solving scores (BDEFS) and ADHD Inattention scores (BAARS-IV) would predict in a significant and positive manner observable, behavioral observable, behavioral inattentiveness (increased Quotient scores on Distracted Metric [Attention State], based on errors of omission), a multiple linear regression was to be conducted; however, there were no significant relationships between the Quotient Distracted Metric ([Attention State], based on errors of omission) and ADHD Inattention (BAARS-IV) and Self-Organization/Problem-Solving (BDEFS). Correlations can be found in Table 12.

Table 12

Correlations for BDEFS Self-Organization/Problem-Solving, BAARS-IV ADHD Inattention, and Quotient Distracted Metric ([Attention State], Errors of Omission)

Variable	Quotient Distracted Metric
BDEFS Self-Organization/ Problem-Solving	--
Pearson Correlation	-.144
Significance	.078
BAARS-IV Inattention	--
Pearson Correlation	.124
Significance	.130

Note: No significant findings at 0.01 level (1-tailed).

Hypothesis 5

To determine whether there was a significant and positive relationship between self-reported SCT (BAARS-IV) and inattentiveness (Quotient Disengaged Metric [Attention State]), a Pearson product-moment correlation coefficient was computed. The criterion variable is inattentiveness, as measured by the Quotient Disengaged Metric (Attention State), and the predictor variable is SCT as measured by the BAARS-IV. There was no significant relationship between SCT (BAARS-IV) and the Quotient Disengaged Metric (Attention State). The correlation can be found in Table 13.

Table 13

Correlation for BAARS-IV SCT and Quotient Disengaged Metric (Attention State)

Variable	Quotient Distracted Metric
BAARS-IV SCT	--
Pearson Correlation	.117
Significance	.076

Note: No significant findings at 0.01 level (1-tailed).

Post Hoc Analyses

For post hoc analyses, an additional Pearson product-moment correlation coefficient was computed to assess the relationship between two predictor variables, ADHD Impulsivity (BAARS-IV) and Self-Restraint (BDEFS) and the criterion variable,

the Quotient Inattention SS. As Table 14 shows, there was a significant and positive correlation only between Self-Restraint (BDEFS) and the Inattention SS on the Quotient. This indicates that these variables were significantly related (r = .222 p = .003).

Table 14

Correlation for BAARS-IV ADHD Impulsivity, BDEFS Self-Restraint, and Quotient Inattention Scaled Score

Variable	Quotient Inattention Scaled Score
BDEFS Self-Restraint	--
Pearson Correlation	.222*
Significance	.003
BAARS-IV Impulsivity	--
Pearson Correlation	.112
Significance	.085

*Correlation is significant at the 0.01 level (1-tailed).

Chapter 6: Discussion

Findings and Clinical Implications

Overall, self-reported symptom severity, as measured by the BDEFS Total EF Summary Score and the BAARS-IV Total Score predicted 6.9% of the variance in the more behavioral, observable Global SS on the Quotient. Interestingly, each of the variables independently predicted scores on the Global SS. Although the overall regression was significant with these predictor and criterion variables, neither predictor variable on its own was a significant predictor. Although not significant, only the BAARS-IV Total Score approached significance.

This study also found that symptoms related to hyperactivity and restlessness (as measured by the ADHD Hyperactivity Scale on the BAARS-IV) accounted for 8.9% of the variance in observable behavioral activity (as measured by the Quotient Motion Scaled Score).

No significant relationship was found between self-reported symptoms of hyperactivity and observable impulsivity (as measured by BDEFS Self-Restraint, BAARS-IV Impulsivity, and BAARS-IV Hyperactivity) and the Quotient Impulsive Metric. Similarly, there was no significant relationship found between BDEFS Self-Restraint and BAARS-IV Impulsivity on the one hand, and the Quotient Motion Scaled Score, on the other. Moreover, no significant relationship was identified for self-reported symptoms of inattention (as measured by BDEFS Self-Organization/Problem-Solving and BAARS-IV ADHD Inattention) and the Quotient Distracted Metric [Attention State]). Finally, no relationship was found between BAARS-IV SCT and the Quotient Distracted Metric.

Interestingly, and although not originally hypothesized, a post-hoc analysis discovered a significant relationship between impulsivity (as measured by the BDEFS Self-Restraint) and the Quotient Inattention SS.

Validity and reliability of the Quotient ADHD System. Although the Quotient ADHD System (Pearson, 2014) purports to measure a participant's ability to control motor activity, sustain attention, and inhibit impulsive responses within developmentally appropriate expectations, for the most part, it did not correlate with the widely-accepted measures of ADHD used in this study, specifically most subscales of the BAARS-IV and BDEFS that measure core traits of ADHD, including impulsivity and inattention. In fact, the only subscale on a self-reported measure that correlated to observable behavior, in the form of motion, was ADHD Hyperactivity (BAARS-IV), with approximately 8.9% of the variance observed in the sample accounted for by ADHD Hyperactivity (BAARS-IV). There were no correlations found between self-reported subscales that measure aspects of inattention and impulsivity and the metrics that purport to measure these core symptoms of ADHD on the Quotient.

Measuring inattention. The ability to pay attention is quintessential while completing a CPT. The Quotient claims to measure a participant's ability to pay attention throughout the course of a 20-minute task. It measures inattention by tracking overall accuracy (omission and commission errors), the percentage of targets missed (omission errors), the percentage of incorrect hits to non-targets (commission errors), and response time (in milliseconds). Overall, accuracy and response time may suggest whether the participant was attentive or acted impulsively (Pearson, 2014). Yet, there was no significant relationship between any of the subscales of the self-reported measures

(the BDEFS and the BAARS-IV) and the observable measurement of inattention on the Quotient. One cause may be a discrepancy between the aspects of inattention explored in self-report measures and the attention span that is required to complete a CPT. Self-report measures may capture "real-world" inattention deficits, such as "forgetful in daily activities" or "having difficulty organizing tasks and activities" (BAARS-IV; Barkley, 2011a), whereas a CPT requires an individual to focus on a task for a short period of time, typically in a controlled environment with limited distractions. Although intuitive, the aspect of inattention measured by the Quotient does not correlate with ADHD-related inattention in the real-world, at least as measured by the self-report measures used here.

Measuring impulsivity. Generally, impulsivity is defined as "difficulty delaying gratification and regulating one's behavior, or acting without thinking." (Ramsay & Rostain, 2008, p. 5). Deficits related to impulsivity that are identified in self-report measures include "interrupt or intrude on others," "having difficulty waiting your turn," (BAARS-IV; Barkley, 2011a), "have a low tolerance for frustrating situations," and "make decisions impulsively" (BDEFS; Barkley, 2011b). On the Quotient, impulsivity is measured through commission errors, or when an individual responds too rapidly during a 30-second block. Since impulsivity is generally associated with hyperactivity, the current study explored the relationship between scales that examined self-reported and objectively-measured impulsivity and hyperactivity. None of the self-reported scales that measure impulsivity (BDEFS Self-Restraint and BAARS-IV ADHD Impulsivity) had significant relationships with the Quotient Impulsive Metric or the Quotient Motion SS. After all results had been computed, one additional analysis was conducted. Since the Impulsive Metric is included in the Inattention SS, it was proposed that self-reported

impulsivity may impact the Inattention SS. Conceptually, an impulsive style may make it difficult to focus on tasks that are either cognitive or behavioral. Interestingly, there was a significant relationship between self-reported impulsivity (BDEFS Self-Restraint) and the Quotient Inattention SS. This finding is odd, as there were no significant relationships between the two hypothesized metrics that are designated to measure impulsivity, the BDEFs Self-Restraint and BAARS-IV ADHD Impulsivity and the Quotient Impulsive Metric. Instead, the self-reported measure of impulsivity, the BDEFS Self-Restraint, had a significant relationship with the scaled measure that is comprised of the Impulsive Metric, the Attention SS. In total, the Attention SS is comprised of 13 attention metrics, including accuracy, omission errors, commission errors, attentiveness, impulsiveness, distracted, and disengaged. Observed impulsivity may better be explained by another subscale of the Attention SS, such as Commission Errors. Commission errors are considered incorrect hits to non-targets and measure impulsivity or inability to inhibit a response (Pearson, 2014).

Measuring hyperactivity. The present study found that self-reported hyperactivity/restlessness (as measured by the BAARS-IV ADHD Hyperactivity subscale) predicted observable behavioral hyperactivity (as measured by the Motion SS on the Quotient). These findings were consistent with the findings from a recent study that examined the relationship between the self-reported measure of ADHD, the CAARS, and the Quotient (Gastelle, 2018). Findings within that study revealed a significant relationship between self-reported hyperactivity/restlessness (as measured by the CAARS) and observed behavioral hyperactivity (as measured by the Motion SS). These consistent findings suggest that the Quotient may be most sensitive to hyperactive traits

of ADHD. Although "real world" traits of inattentiveness and impulsivity may be more difficult to observe and capture in a controlled environment, symptoms of physical and mental hyperactivity may be more transferrable between day-to-day life and completing a monotonous task in a controlled environment. The significant relationship may be attributed to the Quotient's infrared motion analysis system that is utilized to track head movement. It is also evident that the Quotient may not capture symptoms related to impulsivity and inattention. This study addresses the ongoing concern of how to objectively assess all core traits of ADHD to ensure accurate diagnosis.

Limitations

The present study has several limitations to consider, the first of which are the characteristics of the present sample. The sample includes predominantly White, college-educated individuals who presented for assessment and treatment after experiencing a significant level of impairment or distress in their lives. These individuals are either covered by a university-based health insurance plan or they have the financial means to self-pay and may, thus, be comprised of a relatively higher socioeconomic and educational levels than many individuals with ADHD. Consequently, the results of this study should be considered with caution when generalizing, as they may not accurately reflect the greater ADHD population. A referral bias may also be a limitation of this study because clinic-referred participants often experience greater symptomology and impairment than individuals who have not sought treatment. Additionally, screening for severe and chronic pathology (severe posttraumatic stress disorder, traumatic brain injury, severe and current substance use, and schizophrenia or other psychotic disorders) may limit the diagnosis and further understanding of ADHD with these comorbidities.

Another limitation is the use of archival data. Because the data were collected previously, only correlational conclusions may be drawn from these results and, therefore, no causality is implied or should be inferred. In addition, a control group was not utilized, which does not allow for a standard of comparison. A final limitation is the use of the self-report to gather data. Those with ADHD may not be the most accurate self-reporters and tend to underestimate personal symptoms, often due to a lack of self-awareness (Manor et al., 2012). Their awareness of dysfunction is subject to their own perceptions of experience.

Future Directions

The Quotient has recently been pulled from use in most clinical settings. Effective December 31, 2019, Pearson will cease offering the Quotient (Pearson, 2019). Nevertheless, implications from this study indicate the need for scientific rigor in the important matter of validating assessment instruments, including continuous performance tests that purport to objectively measure core symptoms of ADHD. Future studies should evaluate how adult ADHD self-report measures correlate with other CPTs. A particular focus should be placed on the CPT's ability to measure inattention and impulsivity.

Suggested self-report measures include the BFIS, the CAARS, and the BADDS. Additionally, future research could explore the relationship between other subscales of the BDEFS and BAARS-IV. Suggested objective measures include the TOVA, the GDS, the Conners CPT 3, and the QbTest. Future research displaying positive relationships between adult ADHD self-report measures and objective measures will further strengthen the validity and the reliability of CPTs. Furthermore, it will enhance the assessment and treatment of ADHD, particularly in adult populations.

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