IDENTIFICATION OF ATTENTION-DEFICIT/HYPERACTIVITY DISORDER IN CHILDREN WITH AN ORAL LANGUAGE DISORDER: THE DIAGNOSTIC UTILITY OF THE QUOTIENT/ADHD SYSTEM™ AND THE IMPACT OF EXECUTIVE FUNCTION AND WORKING MEMORY ON DIAGNOSIS

APPROVED BY SUPERVISORY COMMITTEE

To Ben, my husband and my best friend.

I am forever grateful for your

unending support, patience, and love.

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by

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IDENTIFICATION OF ATTENTION-DEFICIT/HYPERACTIVITY DISORDER IN CHILDREN WITH AN ORAL LANGUAGE DISORDER: THE DIAGNOSTIC UTILITY OF THE QUOTIENT/ADHD SYSTEM^{TM} AND THE IMPACT OF EXECUTIVE FUNCTION AND WORKING MEMORY ON DIAGNOSIS

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Common symptomatology in oral language disorders and attention-deficit/hyperactivity disorder, including inattention, hyperactivity, and behavior associated with impaired executive function, impacts the validity of diagnostic evaluations. Research demonstrates that the identification of these disorders can be dependent on evaluation setting and clinicians' field of training. Inaccurate diagnosis predicts inappropriate and/or inadequate intervention, and hence, impaired functioning across multiple domains. Assessment instruments to improve the evaluation of attention-deficit/hyperactivity disorder in the context of impaired oral language are needed. The present study explored the impact of comorbid attention-deficit/hyperactivity disorder on attention, movement, executive function, and working memory in children with an identified oral language disorder. Utility of the Quotient/ADHD System™, a continuous performance test with motion actigraphy, and the Children's Executive Functions Scale, a parent-report of executive function, for the accurate identification of an attention disorder in the context of impaired language was evaluated. The sample consisted of 51 children, between 6 and 13 years, with an oral language disorder; 30 child participants met diagnostic criteria for attention-deficit/hyperactivity disorder. Children with and without comorbid attention-deficit/hyperactivity disorder were compared on four domains: attention, movement, executive function, and working memory. Attention and movement were objectively measured with the Quotient/ADHD System™. Executive functioning was assessed using the subscale and Total scores on the Children's Executive Functions Scale. Verbal and visual-spatial working memory were evaluated separately with Digit Span and Spatial Span subtests of the Wechsler Intelligence Scale for Children, Fourth Edition, Integrated. Ingestion of prescribed stimulant medication was delayed until after testing. Results of analyses of variance revealed significant group differences in movement, overall executive functioning, and behavioral inhibition; differences in attention and working memory were not found. Logistic regression and discriminant function analyses supported the use of the Quotient/ADHD System™ and the Children's Executive Functions Scale for the identification of an attention disorder in this population. Exploratory analyses raise questions regarding attention-deficit/hyperactivity disorder subtypes and the not otherwise specified category. Findings have important implications for the evaluation of attention-deficit/hyperactivity disorder. Questions regarding the role of attentional mechanisms in oral language disorders and potential new adjunct interventions for improving language are highlighted.

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LIST OF ABBREVIATIONS

AACAP	American Academy of Child and Adolescent Psychiatry
ADD	Attention Deficit Disorder
ADHD	Attention-Deficit/Hyperactivity Disorder
ADHD-IA	Attention-Deficit/Hyperactivity Disorder, Inattentive type
ADHD-H/I	Attention-Deficit/Hyperactivity Disorder, Hyperactive/Impulsive type
ADHD-C	Attention-Deficit/Hyperactivity Disorder, Combined type
APA	American Psychological Association
BASC	Behavioral Assessment System for Children
BioBdx	Biobehavioral Diagnostics
CBCL	Child Behavior Checklist
CELF-IV	Clinical Evaluation of Language Fundamentals, Fourth Edition
CPT	Continuous Performance Test
C-CPT	Conners' Continuous Performance Test
C-TRS	Conners' Teacher Rating Scale
CEFS	Children's Executive Functions Scale
CLS	Core Language Score
CPQ	Connors' Parent Questionnaire
DSB	Digits Backward
DSF	Digits Forward

DSM	Diagnostic and Statistical Manual of Mental Disorders
DSM-II	Diagnostic and Statistical Manual of Mental Disorders, Second Edition
DSM-III	Diagnostic and Statistical Manual of Mental Disorders, Third Edition
DSM-III-R	Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Revised
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision
EF	Executive Functioning
ELD	Expressive Language Disorder
ELI	Expressive Language Index
G-CPT	Gordon Diagnostic System
IVA	Integrated Visual and Auditory CPT
K-SADS-P/L	Schedule for Affective Disorders and Schizophrenia for School Age Children, Present/Lifetime Edition
LD	Learning Disability
LI	Language Intervention
LLD	Language Learning Disability
M-MAT™	McLean Motion and Attention Test™
MPH	Methylphenidate
MTS	Motion Tracking System

NOS	Not Otherwise Specified
OLD	Oral Language Disorder
Quotient™	Quotient/ADHD System™
RELD	Receptive-Expressive Language Disorder
RLI	Receptive Language Index
SD	Standard Deviation
SIT-R	Slosson Intelligence Test-Revised
SSp	Spatial Span
SSpB	Spatial Span Backwards
SSpF	Spatial Span Forwards
TOVA	Test of Variables of Attention
WISC-IV	Wechsler Intelligence Scale for Children, Version IV
WISC-IV-I	Wechsler Intelligence Scale for Children, Version IV, Integrated
WM	Working Memory
WNV	Wechsler Nonverbal Scale of Ability

CHAPTER ONE
Introduction

STATEMENT OF THE PROBLEM

Research has shown that deficits attributable to an oral language disorder (OLD) often appear as problems in attention and impulsivity in children; rates of hyperactivity are high in this population as well. Moreover, the comorbidity rate of OLD and Attention-Deficit/Hyperactivity Disorder (ADHD) is substantially greater than expected. It has been hypothesized that this rate may be artificially inflated due to the extensive symptom overlap in these two disorders, and limitations of current assessment measures. Due to the psychosocial impact of OLD, ADHD, and their associated symptoms, accurate assessment procedures are imperative. Yet, research has demonstrated that identification of OLD and ADHD is often dependent on the evaluation setting. In speech/language clinics, symptoms of an unidentified attention disorder negatively impact performance on standardized language measures. Conversely, in psychiatric clinic settings, reported symptoms of inattention and impulsivity, and behavioral and social problems, are often attributed to ADHD, when an underlying language disorder may be responsible. Consequently, the need for an assessment measure to facilitate the diagnostic process of OLD and ADHD is clear.

Although the use of Continuous Performance Tests (CPT) as an objective measure of attention has proved to be useful in discriminating between ADHD children and their non-ADHD peers, sufficient research on the use of this instrument for the identification of ADHD when an OLD has already been identified is lacking. Furthermore, the CPT measure used in the current study, the Quotient/ADHD System™ (Quotient™), offers substantial advantages over other commercially available CPTs (e.g., Connors CPT (C-CPT), Test of Variables of Attention (TOVA), Integrated Visual and Auditory CPT (IVA)). To date, no research has examined the utility of this measure among children with an OLD or other learning disabilities (LD). An accurate ADHD diagnosis in children with an OLD is imperative so that appropriate ADHD treatment can be offered; without such treatment, children with an unidentified attention disorder will be limited in the benefit received from language services/intervention. Hence, this study examined the utility of the Quotient™ and other cognitive constructs in assisting clinicians in the diagnostic process of ADHD among children with an existing OLD.

A major component of the current study was the use of the Quotient™, a CPT that also measures movement with actigraphy recordings taken while the subject engages in the CPT task. Variables related to attention, impulsivity, and movement were evaluated in terms of their ability to accurately identify participants with a comorbid ADHD diagnosis in a sample of children previously identified as having an OLD. Furthermore, executive functioning was assessed, as well as verbal and visual-spatial working memory. Identification of disordered expressive and/or receptive language was based on results of a comprehensive psychoeducational/language evaluation completed by trained professionals employed by the Shelton School, a specialized private school for children with learning disabilities. ADHD diagnoses were based on a structured diagnostic interview completed with one or both parents. Due to the effects of stimulant medication on dependent variables, prescribed medication ingestion was delayed until the completion of testing.

CHAPTER TWO
Review of the Literature

ORAL LANGUAGE DISORDERS IN CHILDREN

Rationale for Studying OLD

Oral language is the means by which a child communicates and interacts with the world. Optimal language development and effective use of language is essential to academic achievement, family relationships, peer functioning, emotional development, and behavioral regulation (e.g., Botting & Conti-Ramsden, 2000; Hart, Fujiki, Brinton, & Hart, 2004; Silva, Williams, & McGee, 1987; Stevenson, Richman, & Graham, 1985). Language further contributes to a child's ability to process information, exercise self-control, and express needs in a socially acceptable manner (Botting, 1998; Riccio & Hynd, 1993). Clearly, impairment in language development has tremendous implications across domains of functioning.

A language impairment is defined as a delay in the acquisition and development of language skills that is not attributable to an acquired neurological condition, or to a cognitive or hearing impairment (Botting, 1998; Cantwell & Baker, 1991). Throughout the literature, various terms are used to refer to this condition including developmental language disorder, developmental dysphasia or aphasia, delayed language, language disorder, and phonological disorder, among others (see Toppelberg & Shapiro, 2000 for review). “Specific language impairment” is the prevailing label, but is often misused. According to the American Academy of Child and Adolescent Psychiatry (AACAP), the term “specific language impairment” refers to a language disorder defined according to a discrepancy between language skills and nonverbal intelligence. In the literature, rarely does the use of this term by authors accurately reflect diagnosis based on this standard. The wide range of terms used to seemingly refer to the same condition presents problems for the interpretation of research findings and for communication among professionals. Therefore, for the present study, the term oral language disorder (OLD) is used to refer to an impairment in expressive and/or receptive language.

Prevalence estimates of OLD vary depending on the setting, age, sampling method, assessment method, and diagnostic criteria utilized. Overall, prevalence rates range from 7% to 15% (American Psychological Association, 2000; Cohen, Davine, & Meloche-Kelly, 1989; Gibbs & Cooper, 1989; Love & Thompson, 1988). According to the American Psychological Association (APA; APA, 2000), language delays occur in 10 – 15% of children under age three, but by school age, prevalence rates drop to near 7%. In an epidemiological study of 7,218 kindergartners, prevalence of OLD was 7.4% (6% for girls, 8% for boys; n = 216) (Tomblin et al., 1997). Parents of the children identified as OLD by research assessment procedures were asked if they had prior knowledge (i.e., “had been told”) of their child’s language impairment. Of particular concern, only 29% of these parents reported having been informed that their child had such a problem; researchers did not specify how these parents gained such knowledge (e.g., taken their child to be formally evaluated, a teacher or professional had mentioned the possibility of a language impairment based on his/her observations, etc.). Furthermore, among the 71% of parents who were not aware of their child’s language impairment, it is unclear whether or not these parents had taken their child for formal evaluation previously, or if simply no one had ever suspected language problems (Tomblin et al.). These statistics point to the need for professionals, including those in the fields of speech/language pathology, psychiatry, and psychology, to have knowledge and increased awareness of OLDs. Moreover, professionals must work together towards the improvement of current assessment methods so that accurate diagnoses can be made, and as a result, treatment can be sought.

Signs and Symptoms of OLD

The APA (2000) refers to the category of disorders related to OLDs as “Communication Disorders;” this includes ELD, mixed RELD, phonological disorder, stuttering, and communication disorder not otherwise specified (NOS).

Clinical features of an ELD include limited speech, insufficient vocabulary for age, difficulty learning new words, trouble with word-finding, misuse of words, short utterances, simple grammatical structures, omission of parts of sentences critical to the overall meaning, unusual word order in spoken language, and in general, slowed language development. Children with a mixed RELD show evidence of comprehension deficits in addition to the aforementioned expressive problems. Impairments associated with receptive language are generally less apparent to teachers and parents, and thus, often go unidentified or are misidentified, usually as a behavior or attention problem. Receptive language problems manifest as apparent confusion, acting as if one did not hear or is not paying attention when spoken to, not listening, not following directions or following them incorrectly, and providing inappropriate or irrelevant responses to specific, direct questions. The behavioral manifestations of receptive deficits (e.g., not following directions, not listening) are also specific symptoms included in the diagnosis of ADHD, inattentive or combined types. Some researchers and professionals have made reference to a purely receptive impairment. However, according to the APA (2000), a pure receptive language disorder should not exist because the development of expressive skills is dependent upon the acquisition of receptive language.

A phonological disorder, commonly referred to as "developmental dyspraxia of speech," is a failure in the use of developmentally appropriate speech sound. This includes errors in the production of sound, use of sound for words, omission of sounds from a word, and substitution of sounds in words. Stuttering is a dysfunction in the fluency or timing of oral language. Signs include repetitions and/or prolongated words and/or syllables (APA, 2000). It is also important to note that, according to diagnostic criteria outlined in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR; APA, 2000), any of the above language difficulties must significantly interfere with academic achievement or social functioning to be considered a "disorder." Further, if mental retardation, a speech-motor or sensory deficit, or environmental deprivation is present, language problems must be in excess of those expected given those conditions.

There is considerable disagreement among professionals of varying backgrounds regarding the clinical utility of the DSM-IV-TR classification system for communication disorders given the wide variety of clinical presentations among children. For example, Cohen (2001) argued that the DSM-IV-TR classification system does not account for the variability in language dysfunction. Another commonly cited categorization of OLD is: (1) mixed RELD, (2) ELD, and (3) higher order processing disorders (e.g., pragmatics) (Rapin, 1996; Rapin & Allen, 1983). For the current study, children with predominately mixed receptive/expressive or predominately expressive OLD were included.

In addition to differences among diagnostic classification systems, methods espoused for the assessment of OLD are quite variable. The inconsistency in assessment methods is a substantial limitation of the OLD literature, making comparisons among studies difficult and communication among professionals confusing. The defining feature of communication disorders in the DSM-IV is evidence of language scores on standardized tests of language functioning/development that are substantially below one's identified level of nonverbal intellectual capability (i.e., nonverbal discrepancy or cognitive referencing). However, the size of the discrepancy is open to interpretation (APA, 2000).

There is substantial disparity among clinicians and researchers regarding the accuracy and utility of this discrepancy method. (Aram, Morris, & Hall, 1993; Lahey, 1990; Tomblin et al., 1997; Toppelberg & Shapiro, 2000). In fact, research consistently reveals that among children deemed to have an OLD based on a clinician's overall interpretation of formal assessment results, a high proportion fail to show a substantial discrepancy between nonverbal and language ability (Stark & Tallal, 1981; Tomblin & Zhang, 1999). This may be partially attributable to the finding that, in general, children with OLD show deficits in nonverbal cognitive ability as well (Leonard, 1998). Among professionals, Records and Tomblin (1994) found that practicing clinicians generally use performance on language measures ranging from the 10^{th} (age referenced standard score of 81) to the 16^{th} (age referenced standard score of 85) percentile as distinguishing OLD from normal performance. Furthermore, the AACAP cited limited empirical data to support the DSM Fourth Edition (DSM-IV) discrepancy-based definition of an OLD (e.g., Bishop, 1994; AACAP, 1998).

The AACAP's most recent practice parameters for the diagnosis and treatment of language disorders in children was written in 1998. The parameters acknowledge the limited utility of defining a specific discrepancy model for the diagnosis of a language disorder. In fact, based on the committee's review of the literature, the AACAP asserted that all children with age-discrepant language skills should be considered in need of intervention. However, the AACAP failed to make specific recommendations to address the limitations of the discrepancy-based model for diagnosis. Despite their acknowledgement of the limited validity and empirical support for this model the AACAP stated, "Though controversial…if a significant discrepancy exists between potential and performance that is not better accounted for by other factors, then a diagnosis of a language disorder may be made" (p. 55S). (Note: The AACAP failed to define "significant discrepancy.") Furthermore, although the AACAP asserted that children with age-discrepant language skills are in need of intervention, they also acknowledged that children with age-discrepant language skills may not meet a state's definition of LD (i.e., discrepancy of specific size). Given the lack of consistent diagnostic standards and the AACAP's practice parameters, for the present study, OLD participants demonstrated impaired performance on standardized tests of language, in the context of a comprehensive psychoeducational/language evaluation, by which a trained and licensed professional(s) deemed the impairment attributable to an oral language disorder. It is important to note that this method of evaluation is consistent with the AACAP's most recent guidelines for a "comprehensive diagnostic assessment" in the evaluation of oral language (AACAP, 1998).

Associated Sequelae of OLD

Paul (1992) asserts, "Students demonstrate what they know and what they have learned through language." In school age children, OLDs often present as problems learning to read, trouble learning and achieving at a level consistent with peers, and attentional difficulties. In fact, research consistently indicates that OLD children are at an increased risk for academic failure and being identified as LD (Riccio & Hynd, 1993). In an epidemiological study of 600 children (mean age of five) with an OLD, 6% were identified as LD. OLD diagnosis was made according to age-norms of a battery of standardized tests of language abilities, and LD diagnosis was based on performance in an academic area (e.g., reading, writing, or spelling) below that expected based on chronological age, educational history, and performance on nonverbal subtests of the Wechsler Intelligence Scale for Children (WISC). Five years later, of the first 300 original participants who presented for reevaluation 30% were identified as LD (Baker & Cantwell, 1990). Similarly, in a retrospective ten-year follow-up study of 20 preschoolers with OLD, the majority had been placed in LD classes or retained due to academic problems (Aram, Ekelman, & Nation, 1984).

In addition to academic problems, substantial research has pointed to the widespread social problems associated with an OLD (e.g., Conti-Ramsden & Botting, 2004; Hart et al., 2004; Redmond & Rice, 1998). Pragmatics is the ability to use language as a social tool in a way that supports interactions with others and learning. Without adequate development of pragmatic language skills, academic and social problems result (Chaban, 1996). It is likely that deficits in pragmatics are at least partial contributors to the impaired social functioning of OLD children. Deficient pragmatics is illustrated in the following dialogue:

"Speaker A: That's a Yankee's cap your wearing."

"Speaker B: No it's not. It's mine." (Chaban, 1996, p. 24)

Clearly, repetitive misunderstandings like this one will contribute to social withdrawal and/or peer rejection over time. In fact, in a group of 242 OLD children, followed longitudinally from age seven, 39% scored below average on measures of peer social competence and 36% were identified as at-risk for being a target of discrimination among peers at age 11. Pragmatic language deficits were most strongly related to the poor social outcomes in this group (Conti-Ramsden &

Botting, 2004). Research provides evidence that children with an OLD tend to fear social interaction and withdraw in social contexts. They are also rated significantly below normal peers on measures of likeability (i.e., peers enjoy being with the child, easily accepted into ongoing play) and prosocial behavior (i.e., helping others, sharing, offering comfort) (Fujiki, Brinton, Morgan, & Hart, 1999; Hart et al., 2004).

Studies of children with an OLD have consistently revealed high rates of behavioral and emotional problems. In a large-scale longitudinal study (*n* = 1,037) of language, cognitive functioning, and behavior problems, presence of a mixed RELD significantly predicted increased behavior problems at ages 7, 9, and 11, respectively (Silva et al., 1987). Parent ratings of behavior among five-year-old children with an OLD also indicated high rates of behavior problems, with 30% of the sample (*n* = 71) falling in the clinically significant range and 10% falling in the borderline range for behavior problems as reported on the Child Behavior Checklist (CBCL; Achenbach, 2001) (van Daal, Verhoeven, & van Balkom, 2007).

Among adolescents with a history of an OLD diagnosis, attention problems and social difficulties are common (Snowling, Bishop, Stothard, Chipchase, & Kaplan, 2006). In a longitudinal study of a group of kindergarteners with an OLD, at age 12.5, 43% met criteria for a psychiatric diagnosis, most commonly ADHD. Problems of these children persisted into young adulthood, evidencing higher rates of anxiety disorders, especially social phobia, and a trend was found toward an association between antisocial personality disorder and OLDs in males, compared to peers with typically developing language (Beitchman, Young, Jonson, & Wilson, 1997). Similarly, Brownlie and colleagues (2004) examined the outcomes of OLD children at age 19. After controlling for verbal IQ, demographic factors, and family variables, OLD males compared to controls had higher rates of conviction, arrests, and higher levels of parent reported delinquency (e.g., lying or cheating, steals at home). Among females, however, language impairment and aggressive/delinquent behavior was unrelated. Researchers hypothesized that the lack of association between these behavior outcomes and language functioning for females may have been a result of a limited sample size for females. However, it also seems likely that compared to females, males may be less likely to receive intervention services for the language problems, and more likely for externalized behavior resulting from the language impairment to be targeted. It seems probable that even despite intervention for what qualitatively may present as "behavior" problems, language problems will persist, contributing to increased frustration and further behavioral and/or emotional difficulties.

Clearly, in the case of a suspected OLD, a thorough evaluation is warranted, including an examination of social, behavioral, and emotional functioning. Yet, among speech-language pathologists who are typically sent the referrals for a suspected language disorder, evaluation for such psychiatric difficulties is outside the scope of their training and practice. Likewise, in the case of a suspected psychiatric or emotional problem, psychologists and psychiatrists have limited or no training in the assessment of OLDs, the very disorder that could be causing these seeming psychological problems. Unfortunately, in a psychological setting, it is likely that the behavioral, academic, emotional, and social problems among those with an unrecognized OLD are likely to be attributed to environmental factors, familial factors, or psychopathology. Yet, for some, these problems may just be the result of a chronic inability to express thoughts clearly, or to correctly understand what others are communicating.

ATTENTION-DEFICIT/HYPERACTIVITY DISORDER IN CHILDREN

Rationale for Studying ADHD

ADHD is one of the most commonly diagnosed psychiatric disorders in childhood, characterized by a persistent and developmentally inappropriate level of inattention, hyperactivity, and/or impulsivity (Accardo, Blondis, Whitman, & Stein, 2000; APA, 2000; Barkley, 1997a; Pennington & Ozonoff, 1996; Plizka & AACAP, 2007). Although debate continues regarding the diagnostic, assessment, and intervention procedures for this disorder, there is no question regarding the validity of this neurobehavioral condition and the significant impairment it has on the lives of children and their families. Recent epidemiological studies have indicated prevalence rates ranging from 4 to 12% in the general population and between 2 and 18% in school-age children (Brown et al., 2001; Rowland, Lesesne, & Abramowitz, 2002). Symptoms of ADHD impact family and social functioning, contributing to negative parent-child and peer interactions, and often include limited frustration tolerance, poorly modulated temper and mood, dysphoria, and low self-esteem (APA, 2000; Barkley, 1990; Brown, 2005). Poor academic achievement is also common among children with ADHD. In fact, research has shown that 25 – 35% of ADHD children have a coexisting language or learning disorder (Plizka & AACAP).

Among adolescents with ADHD, recent longitudinal data indicated that in approximately 1/3 to 1/6 of childhood cases, individuals report subthreshold symptoms as young adults, depending on level of symptom severity and education; however, in middle to late adulthood, symptoms reportedly increased to threshold level. This pattern may be attributable to a desire to avoid stigmatization in young adulthood, but later realization that in actuality, difficulties persist (L. Tamm, personal communication, September 2, 2008). It also seems possible that this pattern may be attributed to compensatory strategies learned by the patient to minimize the apparent impact of symptoms, but with changes in development (e.g., employment, marriage, parenting, etc.), such strategies are no longer sufficient and hence, symptoms reportedly increase (D. Liss, personal communication, September 30, 2008). Research has also indicated that the prevalence of ADHD in adulthood is in part attributable to the number of symptoms and level of impairment required for diagnosis (AACAP, 2007). Biederman and colleagues (2000) evaluated ADHD remission according to symptom decline and functional improvement in a sample of young adults (age 18 to 20) diagnosed with ADHD during childhood. Researchers evaluated participants for ADHD according to three definitions: (1) syndromatic remission (i.e., less than 8 of required 14 criteria), (2) symptomatic remission (i.e., less than five symptoms but impairment remains), and (3) functional remission (i.e., less than six symptoms and no impairment). Results indicated that 60% remitted (i.e., syndromatic remission), but only 10% were unimpaired by continued symptoms (i.e., met criteria for functional remission). Findings also revealed that symptoms of inattention declined at a slower rate and later age than hyperactive and impulsive symptoms. Researchers did not discuss differences in treatment history among participants or the possible impact of prior treatment on current symptoms. In a screen of 966 adults, 2.9% met full criteria for ADHD, including childhood onset, while 16.4% reported subthreshold symptoms (Faraone & Biederman, 2005; as cited in AACAP, 2007). In general, research has indicated that a substantial portion of individuals diagnosed with ADHD during childhood continue to experience symptoms during young adulthood, and importantly, symptoms continue to interfere with their functioning.

Continued deficits associated with ADHD have the potential to cause chronic emotional and behavioral problems, and as a result, lasting impairment. In fact, adults with ADHD have higher than expected rates of antisocial and criminal behavior, injuries and accidents, employment and marital problems, and health problems (Barkley, 1990; Barkley, Fischer, Smallish, & Fletcher, 2004; Plizka & AACAP, 2007); it should be noted that study samples included individuals with treated and untreated ADHD. Social problems associated with ADHD persist into adulthood, and most typically manifest as continued trouble keeping friends and having fewer friends (Barkley, Fischer, Smallish, & Fletcher, 2006).

Defining ADHD

Despite the tremendous body of research on ADHD in children, consistency in the diagnosis and assessment of ADHD in practice is lacking. This seems in part due to changes in diagnostic criteria/symptom threshold, but is more likely attributable to variable methods of evaluation. Furthermore, training among professionals in the diagnosis of ADHD is inconsistent, leading to misdiagnosis by some and lack of consensus among professionals of various backgrounds.

In 1902, what is known as ADHD today was referred to as a defect in "moral character" (Still, 1902). In the early 1960's, the name changed to "minimal brain dysfunction," after symptoms of restlessness, inattention, impulsivity, arousability, and hyperactivity were found in children following an epidemic of influenza (Pennington & Ozonoff, 1996). In 1967, the APA focused on the behavioral manifestation of ADHD, renaming the condition as "hyperkinetic reaction of childhood" in the second version of the DSM (DSM-II), otherwise referred to as "hyperkinetic impulse disorder." Throughout the 1960's and 70's, other names for this condition existed including "minimal brain damage" and "minimal cerebral injury;" those with hyperactivity were referred to as having "hyperkinesis," or "hyperactive child syndrome." In 1980, the focus changed from hyperactivity and impulsivity to inattention as the primary diagnostic feature; this was reflected in the diagnostic label "Attention Deficit Disorder (ADD)," with two subtypes: with or without hyperactivity, in the 3rd edition of the DSM (DSM-III).

Based on a seeming lack of empirical evidence to support such subtyping, in the revised version of the DSM-III (DSM-III-R), the APA renamed this general condition ADHD. Yet, once again, in DSM-IV (APA, 1994) subtypes reappeared (e.g., predominately inattentive (ADHD-IA), predominately hyperactive/impulsive (ADHD-H/I), and combined type (ADHD-C)), but the name remained ADHD. No changes were made to the label or subtypes in the text revision of the DSM-IV (DSM-IV-TR). Based on an evaluation of this nomenclature, the APA reaffirmed the need for labels to more specifically describe the symptoms present in an ADHD syndrome. Moreover, a recent factor analysis of teacher ratings of DSM-IV ADHD symptoms confirmed the existence of a two-factor model, consistent with inattentive and hyperactive/impulsive subtypes (Wolraich et al., 2003). Despite this research, studies often do not specify ADHD subtype, and the rating scales frequently used to identify individuals as ADHD for research purposes do not specify subtypes.

Further, lab-based evaluations of distinctions among ADHD subtypes are inconsistent. For instance, research has demonstrated that level of movement, assessed via actigraphs, differs significantly between ADHD and non-ADHD controls (Dane, Schachar, & Tannock, 2000). However, movement differences between ADHD subtypes (i.e., ADHD-IA and ADHD-C) were not present, contradicting DSM-IV criteria, which suggests that combined type should be characterized by greater levels of hyperactivity than inattentive type. Similarly, other studies utilizing a continuous performance task (CPT) (i.e., for the purpose of assessing inattention) have indicated more similarities than differences in ADHD-IA and ADHD-H/I (Baeyens, Roeyers, & Walle, 2006). These findings seem consistent with Nigg's (2001) assertion that the commonalities across definitions and subtypes are sufficient enough to warrant comparison of individuals of different subtypes (Nigg). Given the mixed findings regarding

ADHD subtypes, the current study aims to clarify the importance of subtype designation by analyzing data according to ADHD subtype (e.g., ADHD-IA, ADHD-H/I, or ADHD-C); such analyses are intended to be exploratory in nature and will be driven by the opportunity of sufficient sample size per group.

In addition to changes in subtyping, over the years, diagnostic criteria have also changed slightly in an effort to increasingly capture the heterogeneity of the behavioral manifestation and symptomatology of this childhood disorder. According to the DSM-IV-TR, the essential feature of ADHD is a persistent pattern of inattention, and/or hyperactivity/impulsivity. These behaviors must be more severe and frequent compared to peers of a similar age or developmental level, and must be present for at least the past six months. DSM-IV-TR criterions for diagnosis also assert that at least some symptoms must be present prior to age seven, and must interfere with the achievement of optimal functioning in two or more settings (e.g., symptoms should not be limited to the classroom environment).

Symptoms of inattention include making careless mistakes, not paying attention to detail, problems sustaining attention or difficulty persisting on a task to completion, not listening, not following instructions, trouble with organization, dislike or avoidance of tasks that demand concentration, often losing things, distractibility, and forgetfulness. Hyperactive symptoms include fidgeting and squirming, not remaining seated when expected, running or climbing excessively or in inappropriate situations, not being able to engage quietly in play activities, acting as if “drive by a motor” or “on the go,” and talking excessively. The final symptom domain, impulsivity, includes interrupting or intruding on others, blurting out, and having trouble waiting turns. Diagnosis requires six symptoms of inattention (i.e., ADHD-IA), six symptoms of hyperactivity and/or impulsivity (i.e., ADHD-H/I), or six symptoms of each category (i.e., ADHD-C). If prominent symptoms are present and causing impairment, but do not meet full diagnostic criteria, the diagnosis ADHD NOS is applicable (APA, 2000).

Unfortunately, there are no pathognomonic measures available to aid in the diagnosis of ADHD; rather, diagnosis is largely dependent on the reports and observations of parents, teachers, clinicians, and children themselves (Wolraich, 1999). Moreover, evaluation procedures vary widely among professionals and researchers. The most recent practice parameters for the evaluation and diagnosis of ADHD (Plizka et al., 2007) emphasized that a clinician should perform a detailed clinical interview with the parent, reviewing all symptom criteria and their duration, severity, and frequency; more details regarding ADHD assessment will be discussed in the following section.

Relevant to the purposes of the current study, the AACAP noted that neuropsychological testing, speech/language assessments, and computerized tests of attention and inhibitory control are warranted in an ADHD evaluation (Plizka et al., 2007). This is based on the frequent co-occurrence of language/learning disorders and ADHD (APA, 2000; Plizka et al.). In fact, the AACAP emphasized that symptoms of ADHD that are limited to contexts related to a LD (e.g., the classroom) are not symptoms of ADHD. They further stated that children with LD alone generally do not display the impulsive and hyperactive symptoms of ADHD. Despite the co-occurrence of OLD and ADHD, and the need for a thorough evaluation to distinguish between ADHD and a co-occurring or separate learning or language disorder, the APA (2000) makes no recommendations for the differential diagnosis of these conditions in the DSM-IV-TR.

COMORBIDITY OF OLD AND ADHD

Considerable research has demonstrated a high incidence of comorbid psychopathology in children with an OLD (Donahue & Cole, 1994; Riccio & Hynd, 1993). Among children with an OLD, the most frequently associated psychiatric diagnosis is ADHD (Beitchman, Hood, & Inglis, 1990; Prizant et al., 1990; Riccio & Hynd). It is important to consider, however, that OLD and ADHD diagnoses tend to be dependent on the setting. For instance, among children presenting with the previously described symptoms of OLD and/or ADHD in a speech/language setting, evaluators identified an OLD; however, given a similar cluster of symptoms in a psychiatric setting, ADHD was more likely diagnosed (Gibbs & Cooper, 1989; Love & Thompson, 1988).

Among children identified as having an OLD and/or referred for a suspected language problem, prevalence rates of comorbid ADHD range from 19% to 37% (Baker & Cantwell, 1990; Beitchman, Hood, Rochon, & Peterson, 1989; Benasich, Curtiss, & Tallal, 1993; Cantwell & Baker, 1991). In a study of 56 children (mean age 5.5) with an OLD diagnosis, 31% met ADHD criteria; compared to a conservative ADHD base rate of 4% (Pedigo, Scott, & Hughes, 2007), the incidence of ADHD among OLD children was quite high (Beitchman et al., 1989). Similarly, examination of 600 consecutive referrals to a speech-language pathology clinic, revealed ADD as the most common psychiatric diagnosis. Significant ratings of hyperactivity based on parent responses to the CBCL (Achenbach, 1991) and the Connors' Parent Questionnaire (CPQ; Conners, 2008) were also associated with an OLD (Benasich et al., 1993). This is noteworthy given clinicians tendency to conceptualize hyperactivity as a distinguishing feature of ADHD. Based on findings of Benasich and colleagues, hyperactivity may be associated with OLD in the absence of a diagnosable attention disorder; although, it seems likely that frequency and severity will differ with regard to OLD and ADHD.

Among children referred to a psychiatric clinic, OLD is quite prevalent, despite often going undetected. Studies have indicated that between 16 and 50% of children referred to a psychiatric clinic have an unidentified OLD (Cohen, Davine, Horodezky, Lipsett, & Isaacson, 1993; Cohen et al., 1989; Love &

Thompson, 1988). In a study of children admitted to a psychiatric inpatient facility (n = 40), 50% were diagnosed with a moderate to severe disorder in expressive and receptive language (Gualtieri, Koriath, Van Bourgondien, & Saleeby, 1983). In an evaluation of children referred for a psychiatric disorder with either an identified OLD or a previously unsuspected language disorder, those with an unsuspected OLD had the most serious externalizing behavior problems; children in both groups had symptoms of ADHD. It is important to note that of those with an unsuspected OLD, expressive speech problems were generally absent. Authors argued that in the absence of an articulation problem, externalizing behavior becomes the focus of parents', teachers', and clinicians' attention and the underlying expressive/receptive language deficit contributing to the behavior dysfunction was unrecognized (Cohen et al., 1993). Research further indicated that despite a diagnosis of an OLD, in the absence of articulation problems, few received speech/language services (Gibbs & Cooper, 1989).

One possible explanation offered for the poor identification of OLD in a psychiatric setting is that language problems impair a child's ability to comprehend or respond to verbal interactions, follow instructions, and complete tasks. In the absence of a language evaluation or lack of knowledge of the expressed symptoms of OLD, these language problems were generally misinterpreted as attentional difficulties (Rielly, Cunningham, Richards, Elbard, & Mahoney, 1999). Expressive language deficits in OLD are often manifested in situations that place demands on the child's cognitive resources. In a psychiatric evaluation setting, responses to questions can be simple, short sentences, or even a single word; thus, expressive language problems may not be evident (Vallance, Im, & Cohen, 1999).

A variety of hypotheses have been made regarding the high comorbidity of OLD and ADHD. Some asserted that language deficits may develop in children with ADHD as a consequence of deficits in impulsivity, hyperactivity, and inattention; while others claimed that OLD causes or underlies psychiatric disorders (Baker & Cantwell, 1987). More convincing, some argued that OLD and ADHD share a common etiology, possibly related to developmental deviations in brain development; thus, one did not cause the other, but they co-occured (Baker & Cantwell, 1990). In fact, in recent years, a prominent explanation for the overlap in OLD and attention disorders is that both are caused by delays in neurological development (Redmond, 2004). Researchers cited support for this hypothesis from studies indicating an association between performance on language measures, attention, and cognitive ability in early stages of development. Further support has come from studies indicating that ADHD children compared to normal controls were at increased risk for "markers" of an oral language disorder, including delayed onset of first words, delayed development in speaking phrases/sentences, and poor performance on verbal subtests of standardized measures (Cohen et al., 2000; Love & Thompson, 1988;

Purvis & Tannock, 1997). Tannock and Schachar (1996) argued that the executive dysfunction associated with ADHD accounted for the core symptoms of ADHD and for the development of language problems in these children.

Nature of Symptom Overlap

Based on a review of the literature, it seems possible that the high co-occurrence of OLD and ADHD may be attributable to overlapping symptomatology, limiting the internal validity of current evaluation and assessment procedures. Hence, the high co-occurrence could be artificially inflated as a result of misdiagnosis given current diagnostic standards and available assessment instruments. First, one must consider how language problems may appear as problems with attention and/or impulsivity/hyperactivity. OLD has implications for acquiring and applying verbal mediation strategies for the purposes of self-regulation; without the development and appropriate use of such strategies, behavior is at risk for being impulsive and poorly regulated (Benezra & Douglas, 1988; Douglas & Benezra, 1990). Memory problems associated with an OLD can lead to problems following complex directions, completing tasks, and abiding by specific rules (Siegel & Ryan, 1989).

A simple examination of the core symptoms of ADHD provides further insight into the language skills implicated in ADHD symptomatology (APA, 2000; Camarata & Gibson, 1999). Behavioral criterions for ADHD described as symptomatic of DSM-IV-TR communication disorders include: (a) doesn't seem to listen, (b) appearance of confusion, (c) difficulty organizing work, (d) easily distractible, (e) talks excessively, (f) difficulty waiting one's turn, and (g) interrupts others (APA, 2000; Tetnowski, 2004). Others have emphasized the impact of receptive language on listening, memory, and following instructions; expressive language deficits likely contribute to verbal impulsivity such as blurting out and talking out of turn (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003). Despite acknowledgement that "inattention must not be attributable to comprehension difficulties" in the discussion of ADHD criteria, the APA has not provided any differential criteria/recommendations to account for this symptom overlap and the resulting diagnostic confusion.

Although OLD evaluations often do not include an assessment of pragmatic language, diagnosis according to DSM-IV-TR criteria requires that "language difficulties interfere with…social communication." In reference to criteria for a mixed RELD, the symptom "poor or inappropriate conversational skills" also reflects the deficits in pragmatic associated with OLD (APA, 2000). Core symptoms of ADHD also have the potential for a substantial impact on pragmatics (Camarata & Gibson, 1999). Inattentiveness could manifest as pragmatic language problems in the following ways: (a) problems maintaining topic of conversation, (b) excessive pauses between sentences, (c) inadequate verbal responses, and (d) inadequate nonverbal responses due to inattention and distractibility causing one to miss cues and impaired focus on the conversational partner. Related to hyperactive/impulsive symptoms, fidgeting could be disruptive and interfere with the appropriate use of hand gestures. Furthermore, if a child is quite active, eye contact may be difficult to maintain. Other ways impulsivity could manifest as a pragmatic deficit are inappropriate turn taking in conversation and excessive talking, impairing the overall cohesion of the conversation.

In a review of research examining differences in pragmatic language in ADHD children compared to normal controls, Tannock and Schachar (1996) found that ADHD children exhibited substantially more problems in pragmatics. Pragmatic difficulties included: (a) excessive verbiage in a conversation, (b) reduced verbal output when a response requires planning or organization (e.g., giving directions), (c) difficulty introducing, maintaining, or changing conversation topics, (d) problems negotiating turn-taking in a conversation, (e) trouble related to the appropriate selection of words to express an idea, and (f) limited ability to adjust language to a specific context. Overall, research has indicated that pragmatic language could be a specific area of vulnerability in ADHD children.

Consideration of Barkley’s model of ADHD lends further evidence for the overlap in OLD and ADHD symptoms (Damico, Tetnowski, & Nettleton, 2004; Barkley, 1997a). This model of ADHD is based on a combination of language and other cognitive functions of the prefrontal cortex. According to Barkley (1997a), ADHD is due to a deficit in response-inhibition, and a core impairment in all subtypes of ADHD is a deficit in private, internalized speech, which is essential for self-regulated behavior (Damico et al., 2004; Westby & Watson, 2004). Thus, the development of internalized speech has a direct impact on one's ability to control and regulate behavior, possibly manifesting as impulsivity and overactivity in a child with OLD.

The overlap in OLD and ADHD symptom manifestation has clear implications for the assessment and accurate identification of these disorders. A clear understanding of this symptom overlap is needed so that internally valid tests and accurate diagnostic procedures can be developed. Clinicians must be able to better differentiate between the cognitive and behavioral phenotypes of OLD and ADHD to assure accuracy in diagnosis, and hence, provision of appropriate treatment.

Performance on Standardized Instruments

Standardized tests of language functioning include the Peabody Picture Vocabulary Test, Fourth Edition (PPVT-IV) (Dunn & Dunn, 2007), Test of Language Development, Versions 3 Primary and Intermediate (TOLD-P:3 and TOLD-I:3) (Hammill & Newcomer, 1997a, 1997b), and the Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-IV; Semel, Wiig, & Secord, 2003), among others; such tests are routinely used in the assessment of OLD. Despite their limitations, behavior rating scales such as, the Connors' Rating Scales (Conners, 2008), Brown Attention Deficit Disorder Scales (BADDS; (Brown, 2001), Behavioral Assessment System for Children (BASC; (Reynolds & Kamphaus, 2006), and CBCL (Achenbach, 2001), are frequently used for the diagnosis of ADHD, especially in research. Based on a review of performance of OLD and ADHD children on both standardized language tests and behavioral rating scales, it is clear that current measures are substantially limited in their ability to successfully differentiate between these disorders, or in some cases to identify the presence of a comorbid condition (i.e., OLD/ADHD). However, the use of the Quotient™, the measure evaluated in the current study, may address the limitation of using one of these single assessment measures (i.e., language tests and behavior scales) in isolation, supporting the likelihood of valid diagnosis.

Language and Academic Measures

Studies have consistently indicated that ADHD children perform poorly on measures of expressive language (e.g., Douglas & Benezra, 1990; Oram, Fine, & Tannock, 1999; Purvis & Tannock, 1997; Tannock, Purvis, & Schachar, 1993; Tannock & Schachar, 1996), thought to reflect underlying deficits in EF (Pennington & Ozonoff, 1996; Ylvisaker & DeBonis, 2000). EF deficits evident on measures of expressive language included (a) problems with organization, coherence, and verbal production of narratives (Purvis & Tannock, 1997; Tannock et al., 1993), (b) with verbal organization of sequential material (Tannock & Schachar, 1996), and (c) poor sentence formulation (Kim & Kaiser, 2000; Oram, Fine, & Tannock, 1999). ADHD children also demonstrated deficits on measures of receptive language (Lorch, Milich, & Sanchez, 1998; Lorch et al., 2000; Tannock et al., 1993). For instance, among ADHD children, problems comprehending causal relationships in verbal stories were attributed to an ineffective use of the structure of the story to guide an organized recall of story events.

Limited research has examined the performance of OLD children versus those with a comorbid ADHD diagnosis (i.e., OLD/ADHD) on language measures. Oram and colleagues (1999) compared the performance of OLD/ADHD (n = 28) children to those with ADHD only (n = 25) and non-ADHD controls (n = 24) on standardized language measures. ADHD diagnoses were based on parent and teacher semi-structured interviews and completion of behavior rating scales. All children were assessed by a certified speech-language pathologist for an OLD; diagnosis was defined as age-discrepant performance on language measures (i.e., 1.5 standard deviation below the mean on one composite or total area or 1 standard deviation below the mean on two or more of these scores). ADHD and non-ADHD controls performed similarly, but better than

ADHD/OLD children on most language measures examined. However, ADHD children performed significantly worse than normal controls on language tasks involving working memory, planning, organization, and word structure. Performance on subtests of planning, organization, and word structure, however, was not significantly different among ADHD and ADHD/OLD participants. Furthermore, both ADHD and ADHD/OLD groups performed at least within the borderline range on the test assessing working memory (i.e., remember a target word while making a sentence using the word). Researchers interpreted findings as indication that on certain language tasks, performance deficits may have been attributable to ADHD. Further, when considering the possible influence of these deficits on ADHD intervention (e.g., cognitive behavioral treatment), the importance of language findings among ADHD children is noted. Findings also point to the importance of interpreting test results in light of other data so accurate diagnoses result.

Javorsky (1996) examined the performance of children at an acute psychiatric hospital (i.e., inpatient or partial) on a battery of academic and language measures. At the time of admission, the Diagnostic Interview Schedule for Children (DISC) (Costello, Edelbrock, Kalas, Kessler, & Klaric, 1982) was used for all psychiatric diagnoses; 76% of children were diagnosed with an affective disorder (i.e., dysthymia and major depression) and 23% were diagnosed with a disruptive behavior disorder (i.e., oppositional defiant and conduct disorders). ADHD diagnoses were based on DISC interview and collaboration with the treatment team (i.e., clinical psychologist, social worker, special education specialist, psychiatric nurse, and activity therapist) via staff observations and completion of the Conner's Teacher Rating Scale (C-TRS) (Conners, 1973). Only children with ADHD diagnosis at the time of admission and at the time of discharge, per a reevaluation by the child psychiatrist, were included in the study.

Child participants were also evaluated for an existing "language learning disability" (LLD) at the time of hospital admission. LLD diagnosis was based on a discrepancy between performance on measures of decoding and listening comprehension. Children who scored less than a standard score of 85 on Word Attack (i.e., a measure of decoding) from Woodcock Johnson Psychoeducational Battery – Revised (WJPB-R; Woodcock & Johnson, 1989) and greater than an 85 on the Listening Comprehension subtest (WJPB-R) were identified as "LLD" (Javorsky, 1996). This method of diagnosis is questionable. For instance, a child with an 84 on Word Attack and an 86 on Listening Comprehension would be identified as LLD based on this diagnostic procedure, when such a difference could be attributable to measurement error. Furthermore, it is probable that factors related to psychiatric status (e.g., oppositionality, low energy, apathy, etc.) could greatly affect test performance, impacting the reliability of the LLD diagnosis. If children were evaluated for a LLD after psychiatric stabilization and symptom reduction, one could place more confidence in results of the study. Thus, LLD diagnosis is questionable and a limitation; this has implications for the internal validity of results. The current study aimed to improve upon this research with the use of a comprehensive psychoeducational/language assessment completed by professionals trained in the evaluation of language and learning disorders, and valid diagnostic procedures.

Following diagnostic assessment, child participants were assigned to a study group: LLD (n = 14), ADHD (n = 26), ADHD/LLD (n = 18), or neither (i.e., no LLD or ADHD diagnosis, but a psychiatric diagnosis) (n = 38). It is important to note that children in the LLD, ADHD, and ADHD/LLD groups carried a comorbid affective or disruptive behavior diagnosis at the time of evaluation. Group performance on measures of academics and language were evaluated using multivariate analyses of variance (MANCOVA) with special education placement, gender, and psychiatric group membership (i.e., affective or disruptive behavior) as covariates (Javorsky, 1996).

On all academic tests (i.e., academic clusters on the WJPB-R), ADHD/LLD children scored lower than children with ADHD and those with neither disorder; no differences were observed between the ADHD and neither groups or between ADHD/LLD and LLD groups. This seems to suggest that academic difficulties are attributable to LLD. On the Test of Language Competence-Expanded Edition (TLC-EE) (Wiig & Semel, 1988), a measure of expressive and receptive oral language abilities, no group differences in composite scores existed, but all children scored in the low average to below average range. Also, on a measure of receptive vocabulary, the PPVT-Revised (PPVT-R) (Dunn & Dunn, 1981) groups did not differ (Javorsky, 1996). Javorsky interprets these findings as an indication of the impact of psychiatric symptoms on language abilities. On specific tests of syntactic abilities (i.e., language structure and rules) and phonology, the ADHD/LLD group's performance did not differ from that of the LLD group, but was lower than the ADHD and neither groups. Given the similarities and differences among these groups, it seems likely that performance variability is attributable to language-based differences.

In general, ADHD/LLD and LLD children did not differ in academic and language performance. Given the common language-based weakness in the children comprising these groups, Javorsky (1996) asserted that the basic language abilities of these groups are similar. As highlighted earlier, there is great similarity between ADHD symptoms and the behavioral manifestation of an oral and/or expressive language-deficit. Hence, based on parent report of such symptoms in a speech/language clinic setting, the language LD will likely be identified; however, as the results of Javorsky indicated, without additional evaluation specific to ADHD, this comorbid diagnosis will be missed. Thus, results point to the need for additional testing procedures, such as the use of lab-based continuous performance tests, to assists clinicians in identifying a child's need for further evaluation, specific to ADHD.

Another possible explanation for findings regarding ADHD children's performance on language and academic tasks is the impact of the actual testing procedures and measures. In fact, Barkley (1990) asserted that for children with ADHD, standardized tests of language, intellect, and academic achievement consistently underestimate their true ability or skill level due to the demands of such tests on vigilance and sustained attention. Similarly, Redmond (2004) noted that language tests place demands on non-language cognitive functions including sustained attention, impulsive control, working memory, and planning/organization. Thus, he asserted that for children with ADHD, weaknesses in some areas of language testing may be more attributable to ADHD than OLD. Tetnowski (2004) also reported that standardized language tests tax the very deficits that define ADHD; these included limited attention to detail, problems listening, trouble organizing tasks, avoidance/dislike of tasks that require sustained mental effort, distractibility, and blurting out. Thus, the appearance of a comorbid OLD in an ADHD child could be an artifact of the nature of the language assessment (e.g., demand for sustained attention) rather than a true language disorder. Moreover, in the case of children with an unidentified attention disorder, an OLD could be diagnosed while the true disorder underlying these deficits remains undetected. Overall, it seems that researchers agree that despite being designed to assess a weakness in language, among ADHD children, poor performance on standardized tests of language ability could be a reflection of problems related to ADHD rather than to an OLD, or of problems related to ADHD in addition to OLD.

Behavioral Measures

Just as the validity of tests used routinely in the diagnosis of OLD may be threatened by the presence of ADHD, the same is true of the behavioral measures consistently used in the ADHD diagnostic process. Despite the proven reliability of standardized behavioral questionnaires and the empirical derivation of ADHD cut-off scores, the construct validity of such measures for ADHD specifically is questionable due to the presence of symptoms of inattention, impulsivity, and hyperactivity across disorder groups (Pennington & Ozonoff, 1996). In an examination of broadband behavior rating scales and checklists (e.g., CBCL and BASC) to discriminate between ADHD children and non-ADHD peers, results of a meta-analysis did not support the use of such measures to screen or diagnose ADHD. Furthermore, due to weaknesses in research methodology (e.g., lack of psychiatric control group), it is difficult to determine the efficacy of rating scales specific to ADHD symptoms for the differentiation of children with ADHD versus other psychiatric diagnoses or LD (Brown et al., 2001). Teacher ratings are also highly susceptible to the halo effect (i.e., one behavior affects perception of another behavior), limiting the validity of teacher-report versions of rating scales (Nass, 2006).

Relative to the current study, clinicians' failure to consider the possible impact of language disorders in the interpretation of results of behavioral/emotional questionnaires included in a psychiatric evaluation is a significant concern (Redmond, 2002). As indicated in the prior discussion of the symptom overlap in OLD and ADHD, children with an unidentified OLD may be at risk for misdiagnosis of ADHD, when symptoms are actually language based. In fact, Redmond claimed that among children with an identified or unidentified OLD, utilization of such scales has been associated with a high likelihood of over identifying emotional and/or behavioral problems.

In a review of five commonly used psychiatric checklists (i.e., Louisville Behavior Checklist-Revised, Revised Behavior Problems Checklist, CBCL - Teacher Report Form, BASC, and Connors' Rating Scales Revised), only two had scales related to learning or intellect, and none had scales specifically for speech/language problems. Despite this, every scale had speech language items including "can't talk," "doesn't speak clearly," "doesn't respond to questions," "uses words like 'yesterday' incorrectly," "incoherent speech," "speech problems," "does not seem to listen," and "begins conversations inappropriately." These language items generally appeared on subscales designed to measure symptoms of ADHD (Redmond, 2002).

Based on the evaluation of the accuracy of teacher ratings of hyperactivity and ADHD symptoms, researchers asserted that teachers are likely to rate OLD children as high on symptoms of ADHD, especially inattention and hyperactivity (Abikoff, Courtney, Pelham, & Koplewicz, 1993). Similarly, Redmond and Rice (1998) examined teacher evaluations of children with an identified OLD using the CBCL (Achenbach, 1991). Significant differences in internalizing, social, and attention problems were found between OLD and normal age-matched control children. Of importance, when three linguistic items (i.e., "has difficulty following directions," "refuses to talk," and "speech problems") were removed from the teacher rating scales, group differences were nonsignificant, with the exception of differences in attention problems. Questions regarding the specific cause of these attention problems (i.e., an attention disorder, impact of an OLD on apparent classroom behavior), however, remain unanswered.

Thus, if such scales are routinely used in the diagnostic process without a working knowledge of the limitations of these measures for OLD children, or with a careless approach to test interpretation, behavior rating scales are likely to over represent social, emotional, and behavior problems in OLD children. Nass (2006) asserted that a history and interview by a trained clinician is the "cornerstone" of ADHD assessment. More specifically, DSM-criteria-based structured and semi-structured interviews, most often conducted with a parent(s), are the most reliable clinical assessment tools for an ADHD diagnosis (Nass).

Yet, due to their time-consuming nature, such interviews are rarely used in clinical settings and often under-utilized in research.

Clearly, this review identifies the potential for misdiagnosis with the use of typical measures of language and ADHD symptoms, particularly as it relates to the differential or comorbid diagnosis of OLD and ADHD. Given the increasing prevalence of ADHD in recent years, clinicians and researchers have worked to develop other means for *objectively* assessing ADHD's core symptoms of inattention, impulsivity, and hyperactivity. Furthermore, due the high comorbidity of ADHD and OLD, some have evaluated the utility of such objective measures to aid in the differential diagnosis process. Such measures have focused largely on the constructs of attention and impulsivity, almost at the exclusion of hyperactivity. It seems probable that given the general absence of language, the use of such measures may be able to aid in the identification of ADHD symptoms among children with an. Children with an OLD, but unrecognized ADHD, will likely not receive treatment appropriate for ADHD, and untreated deficits attributable to ADHD will almost certainly impact the success of language-based intervention as well. Hence, examination of the potential role of objective measures of attention, impulsivity, and hyperactivity for this population is warranted.

ATTENTION DEFICITS IN OLD AND ADHD

The Construct of Attention

The APA (2000) defined attention as, “the ability to focus in a sustained manner on a particular stimulus or activity,” and asserted that a disturbance in attention “may be manifested by distractibility or difficulty finishing tasks or concentrating on work” (p.820). This definition seems to indicate that attention is a unitary construct; yet, it is actually a complex construct comprised of multiple cognitive processes, including focusing, sustaining attention/vigilance, inhibition (i.e., selective attention), and shifting attention (Riccio, Reynolds, Lowe, & Moore, 2002). In addition, attention must be considered in light of processing speed, the rate at which an individual takes in information from the environment (i.e., input), processes the information (i.e., processing), and then does something with the information (i.e., output) (Greenaway, 2004). Greenaway claimed that separating attention from processing speed is challenging, and in fact, some use processing speed as a reliable measure of attention (Mialet, Pope, & Yurgelun-Todd, 1996; van den Bosch, Rombouts, & Van Asma, 1993). Teicher and colleagues (1996) found that variability in response time, assumed to reflect a difference in processing speed, demonstrates adequate sensitivity and specificity in differentiating children with impaired attention from normal controls. Findings of slower response time and increased response variability in ADHD children were consistent with those of Stins and colleagues (Stins et al., 2005). Furthermore, these results were consistent with research that revealed impaired processing speed in ADHD children compared to non-ADHD control peers (e.g., Calhoun & Dickerson, 2005; Dickerson & Calhoun, 2007; Shanahan et al., 2007).

Objective Measurement of Attention

Due to the complexity of attention, adequate and accurate assessment of this construct is challenging. The continuous performance test (CPT) is one means for evaluating attention, and to a lesser degree, impulsivity. In fact, CPTs are one of the most popular assessment tools to evaluate sustained attention or vigilance, and are often used as a standardized measure to corroborate an ADHD diagnosis (Nass, 2006; Nichols & Waschbusch, 2004; Riccio et al., 2002). Despite their widespread use, some have suggested that if used at all, these lab-based measures should have a limited role in the evaluation of ADHD (Demaray, Schaefer, & Delong, 2003). Prior to an examination of studies on the utility of the CPT for the assessment of the attention problems characteristic of ADHD, it is important to review the variety of CPT paradigms, scoring variables, and specific limitations of the CPT instruments most commonly used in clinic settings (see Table 1 for review of commonly used commercial CPTs).

In general, the CPT is characterized "by the rapid presentation of continuously changing stimuli with a designed target stimulus or target pattern" (Riccio et al., 2002, p. 241). The use of CPTs has focused largely on assessing attention in ADHD, brain damaged, schizophrenic, depressed, and LD populations (McGee, Clark, & Symons, 2000). Despite the same nature of the CPT tasks, there are a variety of CPT paradigms used in research and clinic settings (Riccio et al.). For instance, several require the examinee to respond to a single letter or to a specific sequence of letters (e.g., CPT-X, CPT-AX, CPT-AA) (Collings, 2003; Schachar, Logan, Wachsmuth, & Chajczyk, 1988). It seems likely that CPT paradigm may be a threat to the internal validity of such instruments.

In an examination of the effect of paradigm on CPT performance, Schachar and colleagues (1988) evaluated the impact of three CPT paradigms (i.e., CPT-A, CPT-AX, and CPT-AA) on performance accuracy and response time in an effort to assess for the presence of a sustained attention deficit in hyperactive children. Children with an attention deficit disorder with hyperactivity (ADDH; n = 18) were compared to children with conduct disorder (n = 15), mixed conduct disorder and ADDH (n = 26), emotional disorder (i.e., criteria met for separation anxiety, overanxious, affective, phobic, obsessivecompulsive, or somatization disorder; n = 18), a learning disability (LD; n = 22), and normal controls (n = 15). ADDH, conduct, and emotional diagnoses were based on symptom information gathered during a semi-structured parent interview completed by a child psychiatrist; parent report was compared to DSM-III symptom criteria. A diagnosis of ADDH was made if a child had at least three inattention symptoms, three impulsivity symptoms, and two hyperactivity symptoms, in addition to a history of these symptoms prior to age six. Procedure for LD diagnosis was unclear; researchers cited administration of a psychoeducational battery of intellectual and academic tests, but did not state how results from this testing were used for the designation of LD. Hence, due to limitations in group assignment procedure and its impact on group comparisons, discussion will focus on CPT-specific results.

Findings indicated that for all groups, performance deteriorated over time. More specifically, with increasing time on task, performance (i.e., percent of correct detections) on the AX and AA versions deteriorated more than the A version. Also, independent of group assignment, results revealed significant differences in mean response time across paradigms (i.e., faster response time on the AX version and slowest on the A version), fewer omission errors on the A version, and more commission errors on the AA than on the AX or A versions. Researchers asserted that findings of performance variability across CPT version was an indication that attention can be an artifact of measurement related factors

(Schachar et al., 1988). This is an important consideration for the interpretation of CPT results and contributes to the inconsistency among CPT research.

In addition to a single letter or sequence of letters, other CPT stimuli include: (a) a number (e.g., Gordon, 1991), (b) a picture or object (e.g., TOVA, 2007) , (c) a word (Earle-Boyer, Serper, Davidson, & Harvey, 1991), (d) two digits in a series of numbers or two letters in a series of letters are the same in two consecutive stimuli presentation (e.g., 13, 13) (Cornblatt, Lenzenweger, & Erlenmeyer-Kimling, 1989), or (e) where color and letter are critical features (e.g., an orange T followed by a blue S) (e.g., (Garfinkel & Klee, 1983). Of particular relevance for the current study, is the use of alphabet letters as target and non-target stimuli in the Connors CPT (C-CPT; Conners, 1995), a CPT available for commercial purposes and widely used in the clinic setting. Due to the nature of the stimulus, the validity of this instrument for use in LD populations is questionable. The wide variety of CPT paradigms used among researchers represents a significant limitation to the body of CPT research; such variability in CPT target stimuli, and in some cases, the type of stimuli, limits comparisons among studies.

In addition to variable stimuli, CPTs also differ in time between stimulus presentation, duration of stimulus presentation, and display of time on task on the screen (e.g., Beale, Matthew, Oliver, & Corballis, 1987; Riccio et al., 2002; Rueckert & Grafman, 1996). Among children with an attention disorder and hyperactivity (ADDH), research has indicated that the rate of stimuli presentation has a unique effect. More specifically, for these children, performance was less accurate at both fast (one second) and slow (four seconds) stimulus presentation rates (i.e., stimuli change quickly or slowly) (Chee, Logan, Schachar, Lindsay, & Wachsmuth, 1989). A logical assumption could be that the shorter stimulus duration places greater demands on the attentional system because a subject must attend and respond before the next stimulus appears, hence requiring faster response time. As previously cited, processing speed is a known cognitive weakness associated with ADHD; thus, shorter stimulus duration likely increases the test's sensitivity in detecting attention problems. Conversely, slower presentation of stimuli may result in increased boredom with the task, and hence, increased distractibility resulting in less accurate performance.

The Quotient™ (BioBehavioral Diagnostics, BioBdx, 2007) is the CPT used in the current study (see Table 2 for a review of all Quotient™ studies). It is a fifteen-minute computerized task that provides a quantitative, objective assessment of the three core symptoms of ADHD, inattention, impulsivity, and movement. It measures the capacity of a child to sustain attention (i.e., respond to target stimulus) while inhibiting both movement and responses to non-targets. (Note: The measurement of movement will be discussed in depth in a later section.)

For the age range of participants in the current study (6 – 13 years), Quotient™ visual stimuli are two different stars, an eight-point star (target) and a five-point star (non-target). Stimuli are presented in random sequence and in randomly changing positions on the computer screen, for 200 milliseconds at a time. Of particular importance, the target stimuli are shapes, not numbers or letters; hence, it is assumed that the internal validity of results are not threatened by the presence of dyslexia, or another LD (BioBdx, 2007). Martin Teicher, the developer of the Quotient™, has emphasized that the randomly changing positions of the stimuli make the task more difficult by demanding that the child attend to the entire screen and constantly redirect their attention; the Quotient™'s sensitivity to attention problems is thereby increased reportedly (Greenaway, 2004). Furthermore, the use of a non-stationary target places an additional demand on attention resources, thereby, reportedly increasing the propensity to respond impulsively (BioBdx).

Scoring variables calculated by the Quotient™ (see Table 3) offer a substantial advantage over the results provided by other CPTs commonly used in clinic settings, including the TOVA (TOVA, 2007), C-CPT (Conners, 1995), and IVA (Sandford & Turner, 1995). In general, CPT scores include the number of correct responses, omission errors, and commission errors, used as indications of accuracy, inattention, and impulsivity, respectively. However, studies have indicated that omission and commission errors are highly correlated, and thus, should not be used as separate indices of inattention and impulsivity (Halperin, Wolf, Greenblatt, & Young, 1991; Halperin et al., 1988; Teicher, Lowen, Polcari, Foley, & McGreenery, 2004). Although the Quotient™ evaluates errors of omission and commission, it also provides measures of attention, distraction, and impulsivity that are uncorrelated (Teicher et al., 2004).

Unlike any other CPT, the Quotient™ measures the process of attention and fluctuations in attention state over time. For every thirty seconds of the test, an examinee's performance is designated as attentive, distracted, impulsive, or random, based on the percentage of responses to targets and non-targets. This measurement is of particular importance for ADHD given the fluctuations in attention that cause many of the symptoms observed in this disorder (Teicher et al., 2004). Based on an analysis of these thirty-second blocks, figures for the number of shifts in attention state, and percentage of time spent on task, distracted, and impulsive can be easily calculated (see Table 3).

Unlike the high correlation between errors of omission and commission, research has demonstrated that percent of time spent in any one attention state is not correlated with the percent of time spent in another attention state (Teicher et al., 2004). Compared to errors of omission and commission, percent of time spent on task was significantly different between ADHD children and normal controls (Teicher et al., 2004). More specifically, Teicher and colleagues (2004) found that on a fifteen minute CPT task, divided into 30-second epochs, healthy controls (n

= 8) were on task (i.e., high accuracy with few, if any, errors of omission or commission) during 82.4% of 30-second epochs while participants identified as ADHD-C type participants (n = 60) were on task for 42.6% of the thirty-second epochs. Findings are consistent with results of a meta-analysis that also found that ADHD children spend significantly less time on task in a classroom setting compared to their non-ADHD peers (Kofler, Rapport, & Alderson, 2008).

Teicher and colleagues (2004) also evaluated CPT performance according to fluctuations in attention state across the task (i.e., Quotient™ variable "number of shifts"; see Table 1). Compared to normal controls, ADHD children made significantly more attention shifts (e.g., on task to impulsive) throughout the task. It was argued that the variable "number of shifts" provides quantitative and qualitatively specific information on attention problems, further enhancing the utility of this measure. Findings regarding fluctuations in attention across the task are consistent with results of a meta-analysis of observational classroom studies, which found that across studies, ADHD children are more variable in their attention (Kofler et al., 2008). As mentioned, processing speed is weak in ADHD and is also limited in LD and OLD (e.g., Miniscalco, Hagberg, Kadesjo, Westerlund, & Gillberg, 2007; Shanahan et al., 2007); hence it is important that CPT data on response latency and variability be considered in an evaluation of attention problems. In general, the Quotient™ provides numerous advantages over other CPT measures related to stimuli format and data analysis (see Table 1).

CPT Performance in OLD and ADHD

The primary aim of the current study was to determine the clinical utility of the Quotient™ to identify ADHD children, diagnosed according to DSM-IV-TR criteria, in a sample of children with an identified OLD, also known to be associated with symptoms of inattention and verbal impulsivity. Given the reviewed limitations of the use of behavior rating scales among OLD children, it seems probable that the use of a lab-based measure for the evaluation of ADHD in this population specifically can be useful. In general, with respect to the clinical utility of the CPT for ADHD, it is important to review three areas of research: (a) convergent validity, (b) predictive validity, and (c) discriminant validity.

Convergent Validity

An examination of convergent validity of the CPT involved a review of studies evaluating the association between validated measures of ADHD behaviors such as rating scales and observational methods and CPT performance (Nichols & Waschbusch, 2004). In general, findings of convergent validity are mixed. Some research has found that CPT scores of inattention and impulsivity correlate highly with parent ratings of behavior (Nigg, Hinshaw, & Halperin, 1996). Teacher report of externalizing behavior was also significantly correlated with response variability and omission/commission errors on a CPT (Klee & Garfinkel, 1983; McGee et al., 2000). Other studies however, did not find a significant correlation between parent/teacher behavior ratings and CPT performance (Edwards et al., 2007; Halperin, Greenblatt, Sharma, & Schwartz, 1991). It should be noted that in these latter studies, the sample was comprised of normal children. Research that demonstrated a positive correlation between behavior rating and CPT performance involved samples of ADHD children and children of other psychiatric diagnostic groups. Perhaps the discrepancy in findings is attributable to a difference in severity of both ratings and test performance.

Predictive Validity

Nichols and Waschbusch (2004) conceptualized the issue of predictive validity as whether CPT measures can be used as an indicator of treatment response in ADHD children. Studies have consistently revealed that CPT performance improves following methylphenidate (MPH) administration (Byrne, Bawden, DeWolfe, & Beattie, 1998; Losier, McGrath, & Klein, 1996; Nigg et al., 1996). In an earlier study utilizing the Quotient™, results demonstrated the effects of various dosing regimens of methylphenidate (MPH) on task performance (Teicher et al., 2003). Other studies on the Quotient™ have also supported its predictive validity (Teicher, Polcari, & McGreenery, 2008; Teicher et al., 2004). In the 2008 study, the MPH dose that produced the best clinical outcome according to parent report was also the dose associated with the best improvement in Quotient™ performance. Furthermore, in the earlier 2004 study, among ADHD participants, MPH ingestion resulted in increased time on-task, and reduced time characterized as distracted, impulsive, or randomly responding. It should be noted that the Quotient™ is currently involved in multi-site research for FDA approval for the dosing of stimulant medication in children with ADHD.

Discriminant Validity

The question of discriminant validity is related to whether or not a CPT can accurately distinguish children with ADHD from other children. In general, research has indicated that the CPT can effectively distinguish ADHD children from normal controls (e.g., Doyle, Biederman, Seidman, Weber, & Faraone, 2000; Grodzinsky & Barkley, 1999; Nigg et al., 1996). In a meta-analysis of twenty-six studies of CPT performance in ADHD children, reaction time on this lab-based measure reliably differentiated children with ADHD from normal control children; shorter stimulus presentation time increased the accuracy of this variable in distinguishing children (Losier et al., 1996). Results are consistent with the more recent findings of Swaab-Barneveld et al. (2000). Similarly, in a study utilizing the Quotient™, Teicher and colleagues (1996) found that response latency and variability were significantly slower and more variable for ADHD children (n = 18) compared to normal controls (n = 11). Despite the consistency between this finding and results of other CPT research, the small group size is a limitation, and thus, should be replicated in future research with increased group size. Research has also found that the occurrence of increased errors near the end of the task is more common in ADHD (Trommer, Hoeppner, Lorber, & Armstrong, 1988). This may be due to the weakness in sustained attention, and the increased demands on attentional resources due to the effects of fatigue and reduced concentration as the task increases in length.

Studies have examined the ability of the CPT to distinguish between ADHD and other psychiatric or learning conditions. For instance, results of a chi square analysis indicated that the presence of a score 1.5 SD greater than the age and sex-adjusted mean on any one TOVA variable (i.e., omission errors, commission errors, response time, variability, or multiple responses) correctly identified 80% of participants with ADHD, and 72% of the sample without ADHD (OTHER). Disorders present among participants in the OTHER group included Oppositional Defiant Disorder (ODD), LD, Major Depressive Disorder (MDD), and an adjustment disorder. ADHD participants differed most significantly from the OTHER group on omission errors, response time, variability, and number of multiple responses (Forbes, 1998). It should be noted, however, that findings are inconsistent with those of Halperin and colleagues

(1992) who evaluated the specificity of inattention and impulsivity for ADHD, as assessed by a CPT. Participants for their study were recruited from an outpatient psychiatry clinic and consisted of unmedicated referrals; authors did not specify comorbid psychiatric diagnoses. Among child participants (ages 6.5 – 13), groups included ADHD (n = 31), non-ADHD psychiatric controls (n = 53), and normal controls (n = 18). Psychiatric diagnoses, including ADHD, were based on clinician completion of a 70-item scale of DSM-III-R items for ADHD, ODD, avoidant disorder, major affective disorder, and dysthmia; items were rated as present or absent. Information used to complete the questionnaire was based on parent completion of the CBCL, teacher completion of the C-TRS, and a series of clinical interviews conducted with parent and child. Diagnoses were generated using a DSM-III-R based computer algorithm.

Results of Halperin and colleagues (1992) indicated that ADHD and non-ADHD patient groups were inattentive compared to normal controls, but were not distinguishable from each other, based upon attention. For impulsivity, ADHD participants were significantly more impulsive than normal controls; significant differences in impulsivity did not exist between ADHD and non-ADHD patients and between controls and non-ADHD patients. Researchers interpreted these findings as an indication that inattention may characterize a variety of childhood psychiatric disorders. Findings are consistent with impulsivity as a symptom of childhood ADHD, but the pattern of findings related to impulsivity is less clear in terms of its specificity for ADHD.

The current study aimed to examine the efficacy of the Quotient^{TM} for detecting symptoms of ADHD among children with an OLD. If results indicate that the Quotient^{TM} is sensitive to group differences in attention and movement, the utility of this instrument for diagnostic purposes among children with an OLD can be clarified. Findings of previous studies, similar in design, have provided inconsistent support for the utility of the CPT in differentiating diagnostic samples of ADHD, LD, and in some cases, comorbid ADHD/LD children (Barkley & Grodzinsky, 1994; Grodzinsky & Barkley, 1999; Rielly et al., 1999). However, lack of consistency may be attributable to methodological weakness, especially regarding diagnostic procedure and measurement choice.

In an exploratory study of the positive and negative predictive power of the Gordon Diagnostic System CPT (G-CPT; Gordon, 1991), differences in omission scores did not distinguish ADD+H, ADD-H or LD groups. LD and normal controls did not differ significantly on omission or commission errors, but commission errors distinguished ADD groups from others (LD and normal controls). Analyses for the predictive power of this instrument indicated that it was not useful in discriminating among ADD subtypes, but suggested that an abnormal score could be reasonably indicative of the presence of an attention disorder (Barkley & Grodzinsky, 1994).

Findings of Barkley and Grodzinsky (1994) did not provide clear support for the use of the G-CPT for the prediction of ADHD or differentiation among ADHD subtypes; however, results may have been partially attributable to study weaknesses. A substantial limitation was the method utilized for the designation of LD. Specifically, LD diagnosis was based on referral for a learning problem, current enrollment in an academic program for LD children, or teacher complaints of academic delay. Given the academic problems associated with ADHD, emotional, and behavioral disorders, basis for LD designation may have been unrelated to the actual presence of an LD. However, for those with a true LD, the G-CPT's use of numbers as target and as non-target stimuli and distractors presented a confound for the evaluation of attentional problems. Also, unlike other CPT instruments, on a portion of the G-CPT, a correct response is reinforced by a flashing light on the screen and the number of points is visible on the screen. These reinforcements are possible threats to internal validity and limit comparison of findings to other CPT studies.

Similar to Barkley and Grodzinsky (1994), Rielly and colleagues (1999) examined the sensitivity, specificity, predictive utility, and likelihood ratios of the G-CPT in identifying ADHD in a sample of 99 school-age boys with a historical diagnosis of a language disorder. However, unlike the findings of Barkley and Grodzinsky (1994), results indicated that given a normal test score on the G-CPT, there was a high probability (87.9%) that a subject *did not* have ADHD (Rielly, Cunningham, Richards, Elbard, & Mahoney, 1999). Researchers interpreted this finding as an indication of the utility of this measure in ruling out an ADHD diagnosis in a clinic population of language impaired boys (Rielly et al.). However, results must be considered in light of study limitations. A substantial threat to the internal validity of results is the questionable accuracy of the procedure for identification of a language disorder. Language disorder diagnosis was made at preschool age (mean age at time of study was 8), by providers of diagnostic services at the Child and Family Centre of Hamilton Health Sciences Centre, and investigators did not perform any additional testing to confirm the current presence of a language disorder. Furthermore, ADHD diagnosis was based on teacher *or* parent rating of eight of fourteen ADHD symptoms as stated on the Disruptive Behavior Disorders (DBD) Rating Scale; the presence of symptoms according to an age criterion was not acknowledged. This method of diagnosis is a further methodological limitation. Hence, results need to be replicated when group assignment and diagnostic procedures are modified to strengthen internal and external validity. Further, given the aforementioned limitations of the G-CPT, results should also be replicated with the use of another CPT that is not confounded by the presence of reinforcers (e.g., visible score, flashing light upon correct response, etc.). With regard to group assignment and measurement, the current study aimed to improve upon these previous studies (e.g., Barkley & Grodzinsky, 1994; Rielly et al.) in an effort to further examine the possible utility of a lab-based measure in the evaluation of ADHD among those with language deficits.

As previously mentioned, all children in the current sample were diagnosed with an OLD based on a comprehensive assessment procedure by licensed speech-language pathologist(s) and educational diagnostician(s). Moreover, in the current study, ADHD diagnosis was based on parent responses to a semi-structured diagnostic interview according to DSM-IV-TR criteria, rather than responses to a self-report measure, which as indicated earlier, has limited validity for children with learning and/or language issues especially. Hence, although there is some inconsistency in the literature, sufficient evidence has indicated that CPTs can play a potentially important role in the diagnosis of ADHD; this is especially important when comorbid conditions such as OLD may reduce the validity of parent and teacher reports. The inclusion of such a lab-based measure may contribute to the overall incremental validity of an assessment battery for children with symptoms of ADHD.

Of particular importance for the contribution of the current study to the literature is that despite the cited value of the Quotient™ compared to other CPTs, no studies have examined Quotient™ performance among OLD, or LD, children. Also, it should be noted that studies of CPT performance among ADHD children have not consistently evaluated performance according to ADHD subtype; rather, generally speaking, all ADHD children are included in one group. Given that hyperactivity is a defining feature of the hyperactive/impulsive ADHD subtype, it is important to consider subtype when evaluating the utility of such lab-based instruments. The following discussion of hyperactivity in OLD and ADHD highlights the potential usefulness of lab-based measures, such as the Quotient^{TM}, for the evaluation of ADHD.

MOVEMENT IN OLD AND ADHD

Hyperactivity in OLD and ADHD

Research has consistently indicated a strong association between OLD and parent/teacher report of hyperactivity (e.g., Cohen et al., 1993; Cohen et al., 1998; Stevenson, 1996); however, reports of hyperactivity were not clinically significant (Botting & Conti-Ramsden, 2000; Stanton-Chapman, Justice, Skibbe, & Grant, 2007). As mentioned previously, in the case of ADHD, hyperactivity is one of the defining diagnostic features of the hyperactive/impulsive subtype and a characteristic of the combined subtype (APA, 2000). Also, regardless of subtype, research has demonstrated a strong association between inattention and hyperactivity in ADHD children (Halperin, Matier, Bedi, Sharma, & Newcorn, 1992; Teicher et al., 2004). The DSM-III-R Advisory committee examined the sensitivity, specificity, and odds ratios of ADHD diagnostic criteria (Spitzer, Davies, & Barkley, 1990). Odds ratios for hyperactive symptoms (e.g., fidgets or squirms, has difficulty remaining seated) indicated considerably higher discriminating power than items of inattention and impulsivity. Moreover, face valid items of inattention (e.g., doesn't listen, doesn't follow directions, and easily distracted) demonstrated low specificity for ADHD compared to other behavior disorders. Halperin and colleagues (1992) asserted that although commonly used parent and teacher rating scales have substantial ecological validity for assessing "ADHD-like symptoms," they are limited in their specificity of symptoms for ADHD. The Quotient™, however, is a means for not only assessing inattention and impulsivity, like other commercially available CPTs, it also provides an objective assessment of movement, or hyperactivity.

Objective Assessment of Motion

The use of wristband actigraphy monitors for the assessment of hyperactivity and movement differences among psychiatric disorders dates back to the late 1970's (Bhrolchain, Brown, & Harris, 1979; Fleiss, 1972; Kendall & Gourlay, 1970; Teicher, 1995). In the early 1980s, research demonstrated that objective measurement of movement in a classroom setting can assist with the identification of ADHD (Porrino, Rappoport, Behar, Ismond, & Bunney, 1983; Porrino, Rappoport, Behar, Scerry et al., 1983). Studies have continued to demonstrate support for the objective measurement of movement in ADHD evaluations (i.e., ADHD versus non-ADHD) (Dane et al., 2000; Teicher, 1995).

As previously reviewed, Halperin and colleagues (1992) examined CPT performance in ADHD (n = 31), non-ADHD psychiatric children (n = 53), and normal controls (n = 18); their examination also included an assessment of activity differences among groups, using solid state actigraphy measures (waist actigraphy devices). Results indicated that ADHD children were uniquely characterized by hyperactivity; however, non-ADHD patients and normal controls did not differ from each other on activity. It should be noted that results referred to the entire ADHD sample, despite differences in activity among ADHD subtypes according to *current* diagnostic criteria. Halperin and colleagues (1993) interpreted findings as an indication that hyperactivity may be a unique feature of childhood ADHD, where other "ADHD" symptoms (i.e., inattention based on CPT findings) may be nonspecific for this disorder. In a similar study, however, children with ADHD and other psychiatric diagnoses (e.g., anxiety and disruptive behavior) differed in activity level, but differences did not reach statistical significance. Researchers hypothesized that differences between this study and the aforementioned study may be attributable to power differences (Halperin et al., 1993). Overall, findings speak to the possible utility of an objective movement measurement in distinguishing ADHD children from both other psychiatric and non-patient groups.

The Quotient^{TM}, unlike any available CPT measure on the market, provides quantitative information on a child's movement throughout the duration of the test. Furthermore, the Quotient^{TM} movement analysis offers unique advantages over the use of actigraphy, analyzing movement data according to a variety of dimensions (see Table 3). The Quotient^{TM} captures movement data fifty times per second through the use of a Motion Tracking System (MTS; described in more detail in the Methods section). Hence, unlike all other CPTs, the Quotient^{TM} gathers data on one of the most discriminative feature of ADHD, activity (BioBdx, 2007).

Teicher and colleagues (1996) used the TOVA as a CPT measure and an infrared motion tracking system (MTS) (the same MTS as that utilized in the Quotient^{TM}) to determine if this lab-based measure of attention and movement had significant power to distinguish between ADHD (n = 18) and non-ADHD control children (n = 11); children with a "severe LD" were excluded. Movement was assessed according to several variables (see Table 3; details of results for CPT performance and method previously discussed). ADHD children evidenced a greater amount and range of movement while responding to the CPT, and less complex movement compared to normals. Variables age, spatial complexity, accuracy, and response rate (see Table 3) in a discriminant analysis indicated that ADHD children could be differentiated from non-ADHD children (i.e., 16 of 18 children with ADHD correctly classified and 11 of 11 non-ADHD controls correctly classified). Moreover, results also indicated support for these variables in differentiating among ADHD subtype; six of eight ADHD-IA, four of four ADHD-H/I, and six of six ADHD-C were correctly classified. Prior Quotient™ studies also demonstrate statistically significant differences in the number of microevents (see Table 3), spatial complexity, and overall attention and activity of nonmedicated and medicated ADHD children (Heiser et al., 2004; Teicher et al., 2008).

Overall, research has demonstrated the potential usefulness of an objective movement measurement to aid in making a valid diagnosis for ADHD (see Table 2 for review of Quotient™ studies). Of particular importance for the current study is consistent evidence that OLD children are reported to demonstrate hyperactivity, but generally, not to the degree of an ADHD child. Hence, given the shared symptoms of OLD and ADHD, and the high comorbidity rates for these two disorders, it seems logical that among children with OLD, an objective assessment of hyperactivity to facilitate accurate differential diagnosis is warranted. To the author’s knowledge, no studies have examined activity differences in ADHD and OLD or in ADHD and LD populations. In the current study, the Quotient™ was the instrument used to assess movement differences in OLD and OLD/ADHD groups.

EXECUTIVE FUNCTIONING IN LANGUAGE AND ADHD

The Construct of Executive Functioning

In addition to an examination of core ADHD symptoms among OLD and OLD/ADHD children, the current study also evaluated these groups according to other cognitive constructs known to be impaired, including EF and WM. EF refers to a variety of cognitive operations involved in organizing, regulating, and planning behavior to achieve a specific goal or objective. For goal attainment, one must initiate, plan, shift attention, organize, inhibit inappropriate action or thoughts, and sustain a specific behavior until success is achieved (Pennington & Ozonoff, 1996; Westby & Watson, 2004). Denkla (1996) emphasized the complex nature of EF, referring to it as a “domain,” not a “unit.” A recent meta-analysis of 83 studies utilizing EF measures supported Denckla’s (1996) view (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Results revealed four separate EF factors: (a) response inhibition and execution, (b) shifting sets and/or tasks, (c) interference control, and (d) working memory. Given the multi-faceted nature of this construct, the internal and external validity of EF tests have been purported to be weak (Denkla, 1998, 1996). Yet, in general, EF dysfunction has demonstrated significant convergent and discriminant validity in childhood developmental psychopathology (Pennington & Ozonoff).

Executive Functioning and Language

Researchers asserted that language plays a critical role in EF (Denkla, 1998, 1996; Singer & Bashir, 1999). EF has been described by some as "all about the connection between human verbal abilities and actual behavioral regulation" (Hayes, Gifford, & Ruckstuhl, 1996, p. 300). Major impairments in communication thought to reflect EF deficits include pragmatic language problems, problems in the organization of conversational discourse, inefficient word retrieval, and impaired strategic thinking (Ylvisaker & DeBonis, 2000). In fact, Singer and Bashir claimed that language deficits alone do not account for the academic problems in children with OLD. Rather, the involvement of EF processes in producing oral and written explanations, communicating mastery of academic material effectively, and expressing what one knows and thinks, are at least partially accountable for the poor academic achievement associated with OLD. Language also mediates the process of focusing attention. Of importance, self-inhibition is carried out partially by the regulation of one's attention; hence, language cannot be separated from the process of behavior inhibition (Baird, Stevenson, & Williams, 2000; Fischler, 1998).

Executive Functioning and ADHD

Not only are EF deficits associated with OLDs, such impairments are also common to ADHD. According to Barkley (1990), ADHD is defined by "developmental deficiencies in the regulation and maintenance of behavior by rules and consequences…giving rise to problems with inhibiting, initiating, or sustaining response to task…and adhering to rules…" (p. 71). The inhibition hypothesis of ADHD, espoused by a number of current researchers (e.g., Barkley, 1997a; Brown, 2005), attributes cardinal symptoms of ADHD including hyperactivity, distractibility, and impulsivity to EF deficits. Based on this theory, impairments in specific executive functions (i.e., WM, self-regulation of affect, motivation, and arousal, speech internalization, and analyzing/synthesizing behavior) create the attention problems (e.g., poor sustained attention) symptomatic of ADHD. Language is an area of evidence that provides support for this view. ADHD children talk more than non-ADHD children, make more vocal noises, blurt out verbally, and disrupt and intrude on conversations (Barkley, 1997b). On neuropsychological tests of EF, children with ADHD have demonstrated impairment relative to controls (Doyle et al., 2000; Willcutt et al., 2005). Overall, there is agreement and empirical support for the role of utilizing

EF measures in the assessment of ADHD (Nigg, 2001; Pennington & Ozonoff, 1996; Willcutt et al.; Wu, Anderson, & Castiello, 2002).

Given the multifaceted nature of EF and the wide variety of measures purported to assess EF, Molho and Silver (1997) attempted to explore the assessment of child EF according to responses on a parent-report measure of EF, the Children's Executive Functions Scale (CEFS; Silver, Kolitz-Russel, Bordini, & Fairbanks, 1993). They aimed to evaluate this instrument according to its ability to distinguish ADHD from non-ADHD children. Researchers also examined the association between results on the CEFS and performance on traditional neuropsychological measures. Scores on the CEFS and on neuropsychological measures revealed ADHD children as significantly more impaired in EF; CEFS scores were not sensitive to age differences. Discriminant analyses further demonstrated the utility of the CEFS, in isolation; CEFS Total Score accurately identified ADHD in children 90.4% of the time. Research has also demonstrated the utility of this measure for assessing EF deficits associated with traumatic brain injury in children (Goulden, Silver, Harward, & Levin, 1997). Overall, findings support further study of this measure in populations known to have deficient EF, such as children with an OLD.

Executive Functioning and Comorbid OLD and ADHD

The high percentage of ADHD children who exhibit problems in language processing has been thought by some to be attributable to the significant demands interpersonal communication places on EF (Brown, 2005; Tannock & Schachar, 1996). Despite the highly comorbid and overlapping nature of OLD and ADHD, and evidence of EF impairments in both individually, studies of EF deficits in comorbid OLD and ADHD are lacking. Despite the lack of studies on EF impairments in the case of comorbid ADHD/OLD, an examination of EF deficits in this study's sample may point to the utility of an EF parent-report measure, previously proven to aid in the identification of ADHD, in making an accurate diagnosis of ADHD among children with OLD.

WORKING MEMORY IN LANGUAGE AND ADHD

The Construct of Working Memory

As previously mentioned, WM is also an area of weakness associated with both OLD and ADHD. WM is defined as "a cognitive processing resource of limited capacity that allows for the temporary storage of information while simultaneously processing the same or other information" (Lui & Tannock, 2007).

WM is a primary area of EF implicated in theories of ADHD (e.g., Barkley, 1997b; Brown, 2005; Cohen et al., 2000; Kempton et al., 1999) and is also critical to theories of language processing (Westby & Watson, 2004; Williams, Stott, Goodyer, & Sahakian, 2000). In fact, a meta-analysis of EF batteries indicated WM as a primary factor, and distinguished between verbal and nonverbal WM (Willcutt et al., 2005). Furthermore, deficits in WM have substantial consequences for learning and academic progress (Gathercole & Alloway, 2006).

The Baddeley and Hitch model, originally developed in 1974, remains the most influential model of WM today. The model identified four components of WM: (a) the phonological loop, (b) visuospatial sketchpad, (c) central executive, and most recently, (d) the episodic buffer (Baddeley, 1996, 1999, 2003). Although a full discussion of this model is beyond the scope of this study, a brief description of each component highlights the applicability of this model for an examination of WM in OLD and OLD/ADHD.

The phonological loop includes a system for temporary storage of information and a "subvocal rehearsal system" that serves to maintain the stored information. The visuospatial sktechpad serves the function of integrating visual, and possibly kinesthetic, information into a representation that can be temporarily stored and manipulated. According to Baddeley (2003), the visuospatial sketchpad is less central to language development/impairment than the phonological loop. The central executive is assumed to be responsible for the attentional demands of working memory; it retrieves information from storage (i.e., phonological loop and visuospatial sketchpad), reflects on the information, and manipulates or modifies the information as needed for accurate output (Baddeley, 1996). The central executive controls the fourth WM component, the episodic buffer, which provides information to and retrieves information from long-term memory (Baddeley, 1999).

Theoretical models have consistently identified two distinct processes of WM; one involving the storage of information and the other involving the manipulation of information (Lui & Tannock, 2007). The Baddeley model further separates the storage component into distinct subunits that maintain either verbal or visual-spatial information, the phonological loop and the visuospatial sketchpad, respectively. It is important to recognize the structure and development of WM in light of child cognitive development. In a sample of children, ages four to fifteen, digit and block recall tasks from the Working Memory Test Battery for Children (Pickering & Gathercole, 2001) were administered to assess the phonological loop and visuospatial sketchpad, respectively; central executive was assessed via backwards versions of these tasks. Results indicated that from age six, three distinct but correlated factors, the phonological loop, visuospatial sketchpad, and central executive, corresponding to the Baddeley model, existed and provided a good fit for the data (Gathercole, Pickering, Ambridge, & Wearing, 2004). Findings were replicated in a later study (Gathercole & Alloway, 2006). Given the consistency of these findings, the widespread acceptance of the Baddeley model, and the age range of the current sample, this model served to inform the selection of WM tasks for the current study.

Working Memory, Language, and ADHD

In recent years, researchers have examined the role of WM in children with an OLD, and have recognized the pivotal role it plays in tasks requiring higher-level language processing (Marton & Schwartz, 2003; McInnes, Bedard, Hogg-Johnson, & Tannock, 2007; Montgomery, 2003). Gathercole and Alloway (2006) reported consistent impairments in verbal short-term memory and verbal WM in children with OLD. Such impairments contribute to the learning difficulties of these children.

Baddeley has claimed that the acquisition of language relies heavily on the adequate functioning of the phonological loop (Baddeley, Gathercole, & Papagno, 1998). Relative to language development, the phonological loop stores temporary sound patterns, critical for learning new words, while a more permanent memory representation is formed. This is consistent with evidence of delayed vocabulary development in OLD (Adams & Gathercole, 1995; Baddeley et al., 1998). Impaired performance of children with an OLD on non-word repetition tasks have also been attributed to dysfunction of the phonological loop (Adams &

Gathercole, 2000; Baddeley, 2003; Gathercole & Baddeley, 1990). Studies have consistently identified the discriminative validity of non-word repetition tasks, compared to more traditional language measures, in distinguishing between samples of OLD and non-OLD control children (Dollaghan & Campbell, 1998; Weismer et al., 2000).

Despite consistent differences on non-word repetition tasks, OLD and control children have not consistently shown differences on verbal working memory tasks with limited demands on language (e.g., Digit Span, Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003); inconsistency in this research may be attributable to the use of tests with outdated norms (e.g., Martinussen & Tannock, 1996; Marton & Schwartz, 2003; Williams et al., 2000). With regard to visual-spatial WM and OLD, findings have also been mixed (e.g., Cohen et al., 2000; Martinussen & Tannock; Williams et al.). It is possible that inconsistencies are attributable to the variety of tasks used to assess this construct. (Note: see Tables 4 and 5 for review of studies on verbal and visual-spatial WM, respectively.)

Just as theory has suggested that impaired WM is associated with OLD, Barkley's EF model of ADHD identified verbal and visual-spatial WM as primary deficits. However, with regard to verbal WM, empirical studies have not supported this claim consistently. In a meta-analysis of studies comparing ADHD children to non-ADHD controls on measures of verbal working memory, ten of the thirteen studies reviewed failed to find a significant difference (Pennington & Ozonoff, 1996). Other studies, however, have indicated that the presence of ADHD is associated with deficits in verbal working memory (e.g., Jonsdottir et al., 2005; Martinussen & Tannock, 1996).

Similar to verbal working memory, results of studies examining deficits in visual-spatial WM among ADHD children have also been inconsistent. For instance, results of two meta-analyses of visual-spatial working memory indicated significant group differences between ADHD and non-ADHD child participants (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Willcutt et al., 2005). However, there are studies that have failed to identify deficits in visual-spatial WM in children with ADHD (e.g., Martinussen & Tannock, 1996). Like in the research on OLD and WM, differences in findings may be attributable to variation in the working memory tasks. Moreover, of the studies reviewed, researchers failed to note the use of stimulant medication among participants; yet, research has consistently indicated improved performance of ADHD children on verbal and visual-spatial WM measures when taking stimulant medication (Bedard, Jain, Johnson, & Tannock, 2007; Bedard, Martinussen, Ickowicz, & Tannock, 2004; McInnes et al., 2007). Hence, inconsistent findings may be attributable to differences in stimulant use among study samples. It should also be mentioned that few studies have examined the WM deficits in children with comorbid language and attention problems. Of the studies reviewed, deficits in verbal working memory were attributed to the presence of a language disorder (e.g., Cohen et al., 2000; Jonsdottir et al., 2005; Williams et al., 2000), and comorbid ADHD diagnosis did not appear to significantly affect visual-spatial WM (e.g., Martinussen & Tannock, 1996).

In sum, although the research on WM is vast and the studies cited in this review is not comprehensive, throughout the literature, researchers have commented on the lack of consistency in studies of WM in OLD and ADHD. This is clear from the current review and points to the need for further research in this area. Prior to the pursuit of such research, however, it is important that the limitations of the current literature be considered and addressed. In addition to the aforementioned limitation involved with the use of stimulant medication and variety of WM tasks, other limitations of available literature include: (1) the utilization of a novel, non-standardized visual-spatial WM task, (2) poor performance secondary to low motivation, susceptibility to distraction or interference, and (3) the presence of unidentified language based difficulties in ADHD children (Barnett et al., 2005; Martinussen et al., 2005). Such limitations have implications for the interpretation of results and comparison of findings among studies. Thus, in an effort to clarify the nature of WM deficits associated with ADHD, the current study improved upon these limitations by accounting for the presence of OLD, using standardized, widely-used measures of both verbal and visual-spatial WM, and administering WM measures when stimulant medication was delayed until the completion of testing

CHAPTER THREE

Rationale, Aims, and Hypotheses

RATIONALE

This literature review has examined the substantial symptom overlap in OLDs and ADHD. Given the implications of these disorders for academic, social, and emotional/behavioral functioning, accurate diagnosis and assessment must be of primary concern for professionals. Yet, it appears that the identification of these disorders is sometimes dependent on the evaluation setting (e.g., psychiatric versus speech/language clinic) and the specific measure(s) utilized in the evaluation (e.g., behavior rating scales, sustained attention on standardized test of language or intelligence). Due to the impact of an unidentified attention disorder on the potential benefits received from speech/language therapy services, it is imperative that clinicians accurately identify the presence of ADHD in children with identified oral language problems such that appropriate treatment can be offered.

This examination of the literature also highlighted the usefulness of the CPT for detecting ADHD, and for discriminating between ADHD and non-ADHD children. Based on the research reviewed, it appears that attentional problems common to OLD may or may not be a reflection of an underlying attention disorder. Despite the demonstrated utility of the CPT for the evaluation of attention problems associated with ADHD, few studies have examined the usefulness of this objective measure to assist in the evaluation process for ADHD in children previously identified as having an OLD. Of the studies completed, however, flaws in the design and methodology limit the internal and external validity of findings. Moreover, despite cited advantages of Quotient™ compared to other commercially available CPTs, no studies have examined Quotient™ performance among children with an LD or more specifically, children with an OLD. In addition, despite documented "subthreshold" hyperactivity in OLD children, to date no studies have evaluated movement differences in OLD and OLD/ADHD; the Quotient™ provides an objective assessment of movement. Given that symptoms of "ADHD" in children with an OLD may be the consequence of a language impairment rather than a true reflection of ADHD, it seems probable that a "language-free," objective measure of the core symptoms of ADHD (i.e., inattention, impulsivity, and movement) can accurately detect the presence of ADHD in a child with comorbid OLD/ADHD. Identification of such a measure could contribute to a more reliable and valid diagnostic process for ADHD when language problems are present.

This review has also examined the available literature on deficits in EF and WM common to both OLD and ADHD. Overall, such research for comorbid OLD/ADHD is limited and findings are contradictory. Also, among these populations of children, the use of a parent-report measure to assess EF is lacking, and the use of standardized visual-spatial WM measures are rare. Hence, additional research to characterize the nature of EF and visual-spatial WM deficits associated with OLD and comorbid OLD/ADHD is needed. Such information can further enhance the validity of the diagnostic process, and ultimately provide information regarding the design and implementation of interventions for these children.

AIMS AND HYPOTHESES

In an effort to contribute to the literature regarding the assessment of ADHD among children with an OLD, the current study examined differences in attention, impulsivity, and movement between OLD and OLD/ADHD children, and evaluated the utility of the Quotient^{TM}, an objective measure of ADHD symptoms, to successfully discriminate between children with an OLD only and those with a comorbid OLD/ADHD diagnosis. Furthermore, a parent-report measure of EF known to distinguish ADHD and non-ADHD children, and standardized measures of verbal and visual-spatial WM were used to evaluate the impact of a comorbid ADHD diagnosis on these areas of cognition. In sum, this study addressed the following aims and evaluated the respective hypotheses:

Aim I

Quotient™ performance was evaluated to examine the effectiveness of this instrument for assessing differences in attention, impulsivity, and movement in OLD and OLD/ADHD groups of children when language demands are absent.

Hypothesis 1a

With respect to the ADHD core symptom inattention, it was hypothesized that scores for response accuracy, errors of omission, errors of commission, response latency, and response variability would be more impaired for OLD/ADHD children than for children in the OLD group, as measured by performance on the Quotient™.

Hypothesis 1b

Given that attention is a process and fluctuates over time, it was hypothesized that compared to OLD children, Quotient™ performance of OLD/ADHD children would be characterized by a greater number of number of attention shifts, lower percentage of time on task, greater percentage of time spent in a distracted state, and a greater percentage of time spent in an impulsive state.

Hypothesis 1c

With respect to the ADHD core symptom hyperactivity, it was hypothesized that OLD/ADHD children would evidence more frequent movement, move a further distance and greater area, and exhibit less complex movement than OLD children as measured by the following Quotient^{TM} variables: immobility duration, movements, temporal scaling, displacement, area, and spatial complexity.

Hypothesis 1d

With respect to overall indications of ADHD based on Quotient^{TM} performance, it was hypothesized that compared to children with an OLD, OLD/ADHD children would demonstrate poorer overall attention, movement would be greater and more characteristic of individuals with ADHD, and overall performance would be more indicative of ADHD as measured by the following Quotient scaled scores: Inattention, Motion, and Global ADHD.

Aim II

This study aimed to characterize the nature of EF impairments in comorbid OLD/ADHD compared to OLD.

Hypothesis 2

It was hypothesized that compared to children with an OLD, children with comorbid OLD/ADHD would evidence significantly greater impairment in EF as evidenced via higher scores on the CEFS Total score and on individual CEFS subscale scores. More specifically, it was predicted that based on parent-report, the behavior of children with OLD/ADHD would be less socially appropriate (i.e., Social-Appropriateness), less inhibited (i.e., Inhibition), marked by greater difficulties with daily problem-solving (i.e., Problem Solving), more trouble initiating goal-directed behavior (i.e., Initiative), and more difficulty completing tasks that require planned sequences of movement (i.e., Motor-Planning).

Aim III

The present study evaluated differences in WM in children with OLD and comorbid OLD/ADHD.

Hypothesis 3

It was hypothesized that OLD/ADHD children would demonstrate significantly poorer visual-spatial working memory (i.e., lower scaled score) than OLD children as measured by performance on the Spatial Span Backwards (SSpB) subtest of the Wechsler Intelligence Scale for Children, Fourth Edition, Integrated (WISC-IV-I).

Aim IV

Previous Quotient™ research has demonstrated the utility of Quotient™ variables response accuracy, head spatial complexity, and response variability for distinguishing children with ADHD from non-ADHD controls (Teicher et al., 1996). In an effort to improve the assessment process for ADHD among language impaired children, this study evaluated the clinical utility of these same Quotient™ variables for accurately identifying ADHD in a sample of children with OLD.

Hypothesis 4a

It was hypothesized that Quotient™ variables response accuracy, head spatial complexity, and response variability would accurately distinguish OLD/ADHD children and OLD children.

Hypothesis 4b

It was hypothesized that Quotient™ variables identified as differing significantly between OLD and OLD/ADHD participants (per evaluation of hypotheses 1a, 1b, 1c, and 1d) would accurately predict the presence of ADHD in language impaired children.

Aim V

Given the cited utility of the CEFS for differentiating ADHD and non-ADHD children, this study aimed to determine the utility of this measure, as an assessment of executive function, in detecting ADHD when an oral language disorder is present (OLD/ADHD).

Hypothesis 5a

It was expected that degree of executive functioning impairment, as measured by the CEFS subscale and total scores, would accurately distinguish OLD and OLD/ADHD children.

Hypothesis 5b

It was hypothesized that consideration of inattention, impulsivity, and movement, as measured by the Quotient^{TM}, *and* executive functioning, as measured by the CEFS, would increase the accuracy of diagnostic classification (i.e., OLD versus OLD/ADHD) over that of either test alone..

CHAPTER FOUR
Methodology

PARTICIPANTS

Participants in the current study were recruited from a group of children enrolled in a language intervention (LI) program at the Shelton School, a specialized private school for children with learning disabilities, in Dallas, Texas. All children enrolled in the LI program were identified as having an oral language disorder (OLD) per results of a comprehensive psychoeducational/language evaluation completed at the time of admission to the Shelton School. Evaluations were performed by experienced speech-language pathologists, licensed psychologists, and educational diagnosticians; assessments included measures of verbal and nonverbal cognitive ability, short-term and working memory, reading comprehension, decoding, expressive and receptive language, auditory processing, and articulation.

Within the Shelton LD classification system, children are assigned to a category based on a specific profile of scores on standardized tests of the aforementioned areas of functioning. All children enrolled in the LI program were assigned a Pattern 6 (i.e., a predominant Oral Language Disability or Dysphasia). A Pattern 6 categorization reflects the following profile of skills: (a) low average (85 – 89) or below average (< 85) verbal IQ, (b) below average (< 85) skills in auditory processing, processing speed, visual perceptual ability, reading comprehension, spelling, and/or handwriting, and (c) average reading rate and accuracy (85 – 115). Most importantly for the purposes of this study, performance on measures of receptive and expressive language was below average. In addition to a Pattern 6 designation, to be included in the LI program, specific exclusion criteria could not be met.

Exclusionary Criteria for LI Program

- Children under three years of age.
- Children not diagnosed with an OLD per comprehensive psychoeducational/language evaluation completed by licensed and trained professionals employed by the Shelton School.
- Participants could not be diagnosed with autism.
- Although participants could have clinically significant scores on the Clinical Scales of the Behavioral Assessment System for Children, 2nd edition, Parent Rating Scales (BASC-2 PRS; (Reynolds & Kamphaus, 2006)), behavioral and/or emotional problems could not be *primary*.
- For admission to the LI program, participants could not have a prior, *primary* diagnosis, per parent report, of Oppositional Defiant Disorder, Disruptive Behavior Disorder, Conduct Disorder, an anxiety disorder, or a

mood disorder.

All children enrolled in the LI program were eligible for participation in the current study if the following inclusion and exclusion criteria were met.

Inclusionary Criteria for the Current Study

- Age 6 through 13 years old.
- Primary oral language disorder (OLD) and subsequent enrollment in the LI program at the Shelton School.
- For children in the OLD/ADHD group, diagnosis of Attention-Deficit/Hyperactivity Disorder (ADHD), as determined by investigators in the current study, per parent(s) report to the Schedule for Affective Disorders and Schizophrenia in School Age Children, Present and Lifetime (K-SADS-P/L) (J. Kaufman et al., 1997).
- If child was prescribed stimulant medication, s/he delayed medication until after testing.
- Ability to understand, assent to, and complete all parts of the study.
- Ability to follow directions on a task of sustained attention (i.e., the Quotient™) determined by the child's demonstration of understanding and observed behavior during completion of the Quotient™ practice test.

Observations that indicated a lack of understanding of test directions included: (a) not responding to the target stimuli, (b) responding incorrectly to stimuli, (c) responding to stimuli in a seemingly random fashion, (d) an inability to explain the instructions orally, or (e) an inability to demonstrate what to do when the target or non-target appeared on the screen.

Exclusionary Criteria for the Current Study

- Shelton students not enrolled in the LI program at the time of testing.
- History of head injury or neurological disorder, such as a seizure disorder.

MEASURES

LI Program

As noted, study participants were enrolled in the LI program at the Shelton School. OLD diagnoses (and related cognitive and language testing) were made prior to the investigator's involvement in research with this population of children. Cognitive and language measures are readministered annually for LI program evaluation and progress testing. The following cognitive and language measures were selected for preliminary analyses in the current study.

Nonverbal cognitive ability

The Weschler Nonverbal Scale of Ability (WNV; Weschler & Naglieri, 2006) is an individually administered standardized measure of general ability based on performance on only nonverbal tasks; hence, the need for receptive and expressive language is largely eliminated. The WNV was administered according to standardized procedure to all LI participants at the time of admission to the Shelton School. Ability scores for LI participants are based on two subtests, as specified in the WNV technical manual. For children under age eight, WNV ability score is based on the subtests Matrices and Recognition; ability score for children over age eight is comprised of performance from the Matrices and Spatial Span subtests.

The Matrices subtest requires the examinee to select a colored geometric shape that completes a relationship among parts of a figure based on spatial and analogical reasoning. The Recognition subtest involves short-term memory for visual-spatial designs; it requires the examinee to view a stimulus for three seconds and then choose an identical stimulus among a row of similar figures. Spatial Span (SSp) is a measure of visual-spatial working memory and requires the examinee to reproduce a sequence of tapped-block in the same and reverse order as that demonstrated by the examiner. This subtest was also used in the current study as a measure of visual-spatial WM, administered at a separate time; the details of this subtest will be discussed in the section describing working memory measures for the current study. In addition to specific abilities assessed by individual subtests, research indicates that Matrices, Recognition, and SSp are good indicators of "general ability" (Naglieri, 1997; Weschler et al., 2004).

The WNV yields T-scores with an average of 50 and standard deviation of 10 for all subtest scores; the full scale score is based on the sum of T-scores, which is translated to a Full Scale standard score (mean = 100; SD = 15). The normative sample included 1,323 examinees age 4.0 to 21:11, and is based on a national U.S. sample, stratified according to demographic variables (i.e., education level, age, sex, race/ethnicity, and geographic region). Reliability coefficients for the Full Scale Score (based on administration of two subtests) range from .87 to .92 for the age groups included in the current study; internal consistency coefficients of subtests for a special group of individuals with a language disorder are similar. Test-retest reliability was calculated for age groups 4.0 – 7:11 and 8.0 – 21:11, with retest intervals ranging from 10 to 31 days and 10 to 52 days, respectively. Coefficients indicate adequate stability in performance over time; however, it should be noted that mean retest scores across ages are higher than at initial testing.

In terms of validity, test authors assert that content validity was ensured during the actual creation of the measure with effort made to create items and ensure subtests varied in demands on the examinee (e.g., memory, visual-spatial thinking) and hence, assessed general ability. Research has examined the criterion and construct validity. Construct validity was evaluated via intercorrelational examinations among WNV subtests; all correlations were moderate to high. Confirmatory factor analytic studies were conducted using a single factor, to replicate the general ability factor; separate analyses were performed for the two age groups (i.e., 4.0 – 7:11 and 8:0 – 21:11). Results indicated that each subtest measures a unique ability and all subtests load onto a single factor. Criterion validity was assessed via an examination of WNV scores in comparison to performance on other measures designed to evaluate similar constructs. In general, correlations between the WNV Full Scale IQ (based on administration of two subtest) and WPPSI-III IQ scores indicate assessment of a similar construct (e.g., r = .68, WNV Full Scale with Performance IQ score; r = .67 WNV Full Scale and WPSSI-III FSIQ) and with WISC-IV (r = .57, WNV Full Scale and Perceptual Reasoning Index; r = .58, WNV Full Scale and WISC-IV FSIQ).

Verbal Cognitive Ability

Verbal cognitive ability was assessed using the Slosson Intelligence Test – Revised (SIT-R), an instrument designed for use in schools, among other settings, when a quick, valid, and reliable estimate of intelligence is required (Nicholson & Hibpshman, 1996). This test is also recommended for use to confirm findings of other testing. Normative sample included 1,854 individuals chosen to match the 1990 U.S. census according to education, gender, race, and occupation. Responses to the SIT-R result in a Total Standard Score (TSS) (mean = 100, SD = 16).

In terms of validity, construct validity was established via modeling of the SIT-R domains and test items according to verbal subtests of the Weschsler intelligence measures; domains include global ability (g), crystallized ability, memory, verbal ability, quantitative reasoning. Test items were developed to assess the following cognitive domains: vocabulary, general information, similarities and differences, comprehension, quantitative, and auditory memory. Test developers assert that these areas of cognition have historically been assessed by intelligence measures and have proven reliability and validity. To ensure content validity, items reflective of these aptitudes were distributed throughout the measure such that at least one item for each aptitude are completed by an examinee within the ten-item basal and ceiling (note: there are two exceptions to this). Individual scores are not calculated according to aptitude; rather, only a final total score is obtained. The authors clearly state that the SIT-R is not intended for the purpose of evaluating all domains of intelligence. It is a screening measure of crystallized *verbal* ability. Regarding item development, more than half of the items from the original SIT were included and some items from the

SIT were updated. In addition, 600 new items were developed and field-tested if the item met specified criteria. Based on a sample of 234 examinees, results of a correlational study reveal significant correlation between the SIT-R TSS and the WISC-R verbal intelligence quotient (VIQ) ($r = .89$) indicating concurrent validity. With regard to reliability, split-half estimate of reliability using the Spearman-Brown correction is strong ($r = .97$), indicating internal consistency. Evidence of test-retest reliability is unavailable.

Language Ability

The Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4; Semel et al., 2003) is an individually administered, standardized test of language ability appropriate for children ages 5 to 21. The current study examined the Core Language Score (CLS), and Receptive (RLI) and Expressive Language Indices (ELI). The purpose of examination of these scores was two-fold: (1) to assess for group differences between OLD and OLD/ADHD, and (2) to determine if language scores are correlated with dependent variables so that primary analyses can account for such associations via the use of covariate(s). Subtests comprising CLS, RLI and ELI vary depending on age. For children ages five to eight, four subtests form the CLS. These subtests are (a) Concepts and Following Directions (C&FD), a measure of a child’s ability to interpret spoken instructions that is increasingly complex and lengthy, and recall and recognition of objects shown during subtest administration (i.e., identify objects by pointing based on oral directions); (b) Word Structure (WS), a measure of understanding of morphological rules by orally completing sentences based on visual stimuli; (c) Recalling Sentences (RS), a measure of one's ability to recall and reproduce sentences that are increasingly long and of complex syntax; and (d) Formulated Sentences (FS), a measure of a child's ability to form sentences that are correct semantically and grammatically, increasingly complex, and lengthy by producing a sentence based on orally presented word or phrase. For children ages 9 to 21, the CLS is also composed of C&FD, RS, and FS, but WS is replaced with Word Classes-Total (WCT), a measure of one's ability to identify words related semantically and verbally explain the relationship between the two words; WCT is based on a WC-Receptive score and a WC-Expressive score.

For ages five to eight, the RLI is comprised of C&FD, WC-R, and Sentence Structure (SS). SS is a measure of knowledge of grammatical rules for sentences; it involves identifying the correct picture that represents an orally presented sentence. The RLI for ages 9 to 12 is comprised of C&FD, WC-R and for ages 13 to 21, WC-R, Understanding Spoken Paragraphs (USP) and Semantic Relationships (SR). The USP subtest is a measure of a child's understanding of facts of a story and ability to make inferences based on presented facts. SR subtest requires the child to identify correct visually presented stimuli after listening to and interpreting oral sentences (e.g., serial order). The ELI for ages five to eight is comprised of WS, RS, and FS; for ages 9 to 21, scores for the RS, FS, and WC-E subtests form the ELI.

The normative sample for the CELF-4 included 2,650 individuals and was stratified according to age, sex, ethnicity, geographic region, and parent education level to ensure adequate representation across age groups. In an evaluation of test-retest reliability, 320 examinees were administered the CELF-4 on two separate occasions; retest interval ranged from seven to 35 days. Test-retest coefficients for the CLS, RLI, and ELI were .92, .89, and .92, respectively. Chronbach's coefficient alpha and split-half reliability were used to evaluate the internal consistency of the CELF-4. Across age groups, results indicated strong internal consistency; average coefficient alpha was .95 (CLS), .89 (RLI), and .93 (ELI). Split-half reliability estimates according to the Spearman Brown formula also indicated good internal consistency with values of .95 (CLS), .90 (RLI), and .93 (ELI). For subtests requiring clinical judgment to score responses (i.e., FS, WS, and WC), interrater reliability was calculated and indicated adequate agreement (i.e., .90, .98, and .95, respectively).

Test items for the CELF-4 were developed and selected for inclusion based on extensive research of language development and skills, providing evidence of content validity. Intercorrelational studies indicate moderate to high correlations among subtests with respective composites, high correlation between CLS and other indices, and moderate to high correlations between ELI and RLI with other language indices. Compared to subtests independent of a specific composite, higher correlations are noted for subtests and the composite they contribute to. Validity was also examined via comparisons of the CELF-4 with external measures of similar constructs. Evaluation of the CELF-4 to its predecessor the CELF-3 supports convergent validity, with correlations of .84 (CLS and corresponding CELF-3 composite), and .79 (RLI and ELI with corresponding CELF-3 index scores).

Shelton School teachers completed the Teacher Rating Scales (TRS) of the Behavioral Assessment System for Children, 2nd Edition (BASC-2) in the Spring 2008 or in the Fall 2008, depending on a child’s LI enrollment status. BASC data were obtained from participants’ cumulative file for preliminary analyses in the current study.

The Behavioral Assessment System for Children, 2nd Edition

The BASC-2 TRS is an assessment of both adaptive and problem behaviors observable within the academic environment. The forms for children ages 6 through 11 and ages 12 through 21 were used for LI participants involved in the current study. The TRS form evaluates several broad domains of behavior. For the present study, data for the following domains were obtained: Externalizing Problems (i.e., Hyperactivity, Aggression, and Conduct Problems scale scores), Internalizing Problems (i.e., Anxiety, Depression, and Somatization scale scores), and Adaptive Skills (i.e., Adaptability, Social Skills, Leadership, Study Skills, and Functional Communication scale scores). In addition, scores on the Behavioral Symptoms Index (BRI), a composite of overall level of problem behavior, were analyzed. The BASC-2 TRS includes descriptors of problem and adaptive behavior; teachers respond on a four point nominal scale, *Never*, *Sometimes, Often,* and *Almost Always.* Completion of the BASC-2 TRS requires 10 to 15 minutes.

Raw scores for each scale are summed and converted to individual T-scores (mean 50, SD 10) and the corresponding percentile, based on the "General Norms." The normative sample for the "General Norms" was based on a representative sample of children from across the United States and resembled the population with respect to sex, parental education, race, ethnicity, and geographic location. The general norms are divided according to age group, which for the TRS are the following: 2 – 3, 4 - 5, 6 – 7, 8 – 11, 12 – 14, and 15 – 18. T-scores greater than 60 for the clinical scales/composites are considered "high" (e.g., problematic level of aggression). T-scores less than 41 for the Adaptive Behavior Composite are considered indicative of problematic adaptive skills. Internal consistency, test-retest, and inter-rater reliability are adequate. Evidence for the validity of the BASC-2 TRS is based on factor analytic studies of BASC scales and composites, correlations between TRS composite and scale scores and other behavioral measures, and the relationship between TRS profiles and clinical diagnoses.

The Current Study

ADHD Diagnosis

Kaufman's Schedule for Affective Disorders and Schizophrenia in School Age Children, Present and Lifetime (K-SADS-P/L) (Kaufman et al., 1997) is the updated version of the K-SADS-P (Chambers et al., 1985), and is consistent with diagnostic criteria outlined in DSM-IV-TR (Ambrosini, 2000). The K-SADS-P/L is an 82-item semi-structured diagnostic interview, divided into 20 different diagnostic entities at the present time and in the participant's history. After the completion of the screening criteria for each diagnostic area, "skip-out" criteria are provided; if even one threshold criterion is met, the diagnostic supplement for that area is completed. The diagnostic supplements include: (1) Affective Disorders, (2) Psychotic Disorders, (3) Anxiety Disorders, (4) Behavioral Disorders, and (5) Substance Abuse, Eating, and Tic Disorders. K-SADS-P/L items are generally scored on a nominal scale from zero to three. A score of zero indicates no information is available, score of one indicates the absence of a symptom, a score of two means that subthreshold symptomatology is present, and a score of three indicates threshold criteria is met.

For a diagnosis of ADHD, a child must have received ratings of “three” for six of the nine inattentive symptoms (i.e., diagnosed as ADHD-IA), six of the nine hyperactive symptoms (i.e., diagnosed as ADHD-HI), or six inattentive and six hyperactive/impulsive symptoms (i.e., diagnosed as ADHD-C). Children could also be designated as ADHD NOS if ratings did not meet full symptom criteria (e.g., < 6 inattentive symptoms rated as a “three”), but prominent symptoms of inattention and/or hyperactivity/impulsivity were present and caused impairment. In exploratory analyses, children diagnosed as ADHD NOS were compared to children who met criteria for a specific ADHD subtype on dependent measures of attention, movement, and EF. Exploratory analyses also examined dependent variables according to ADHD subtype. For children identified as ADHD NOS, a decision-making rule for designating these children as ADHD-IA, ADHD-HI or ADHD-C was defined (i.e., majority of total symptoms inattentive = inattentive type; majority of total symptoms hyperactive/impulsive = hyperactive/impulsive type; equal distribution of symptoms = combined type).

An investigation of the reliability and validity of the K-SADS-P/L indicated that this interview creates accurate and consistent diagnoses. To assess inter-rater reliability, audio taped interviews for fifteen randomly selected child participants were selected and re-rated by a blind interviewer. Results revealed that inter-rater reliability ranges from 93% to 100%; the specific value for inter-rater reliability of ADHD diagnoses was not reported (Kaufman et al., 1997). Test retest reliability for current diagnosis of ADHD was fair (*k* = .63) (Kaufman et al., 1997). In an examination of concurrent validity, children who met current criteria for ADHD also obtained higher scores on the Conners' Parent Rating Scale (Conners, 2008); Kaufman and colleagues note that while this data provides support for the validity of K-SADS-P/L ADHD diagnosis, rating scales are relatively insensitive to specific disorders in children.

The Quotient/ADHD System™

The *Quotient/ADHD System™* (Quotient™) was the CPT used in the current study. It was originally named the OPTAx™, designed by OPTAx™ Systems Inc. Martin Teicher and the Developmental Biopsychiatry Research Program at McLean Hospital further developed the OPTAx™, and it was subsequently renamed the McLean Motion and Attention Test (M-MAT™; i.e., M-MAT/ADHD System™). The change from the OPTAx™ to the MMAT™ included a new physical design, revised movement assessment (i.e., OPTAx™ movement assessment was limited to the head but for children over age twelve, the M-MAT™ gathers movement data for the head and legs), updated normative data, revised report format, and revised scoring variables, including the provision of age percentiles. The BioBehavioral Diagnostics Company (BioBdx) has a licensing agreement with the McLean Hospital to make this system commercially available.

In the Summer 2008, the M-MAT™ underwent further revision and was renamed the Quotient™. Differences between the Quotient™ and M-MAT™ are limited to a more user-friendly and visually appealing instrument in terms of its physical design and a revised report format. The current Quotient™ and previous M-MAT™ involve the exact same task and are scored according to the same variables and normative data. Assessments of all participants in the current study were performed on the same machine (M-MAT™); however, given that this instrument is now called the Quotient™, throughout the study it is referred to as the Quotient™.

The Quotient™ is a non-invasive, laboratory measure designed to provide an objective assessment of the core symptoms of ADHD: (1) attention, (2) impulsivity, and (3) movement. The administration of the attention task involves a Macintosh computer, and movement is assessed via an infrared optical tracking system (i.e., Motion Tracking System; MTS). This instrument can be administered to individuals over age five. For children age 6 through 12, the attention task lasts 15 minutes; for adolescents age 13 and 14, the same task last 20 minutes. “Adults,” age fifteen and above, complete a slightly different task that also last 20 minutes.

To complete the attention task, the participant is seated in front of the computer and is instructed to respond to one of two geometric stars, and inhibit a response when the non-target star appears. The participant is instructed to watch the computer screen for the entire duration of the task, and to press the space bar as *quickly as possible* each time an eight-point star appears and to not press the space bar (or any other keys) when the five-point star appears. While the examiner is providing the instructions for the task, both the eight and five-point stars are present on the screen. To ensure the child understands the task, the examiner asks the child what he/she is going to do when the eight-point star appears on the screen and when the five-point star appears. During the actual examination, the eight-point and five-point stars appear on the screen, one at a time, randomly, and at random locations on the screen. Each star appears for 100 milliseconds at intervals of 2 seconds. Throughout the duration of the task, data regarding the participant's responses to both target and non-targets are collected, and upon completion of the test, the data are analyzed according to several different dimensions.

The Quotient™'s MTS assesses movement during the task. Child participants under age 13 wear a reflective marker placed on a headband on their forehead. In addition to the head reflector, participants age 13 and over also wear a reflector on the right leg and one on the left leg. For the current study, only movement data collected by the head reflector was analyzed. This was due to the relatively small number of thirteen-year-old participants and need to include their movement data in the overall statistical analyses given the realistic limitations on group size. The reflectors are monitored by the MTS, situated five feet in front of the child, and movement data are recorded fifty times per second. Any vertical or horizontal position change greater than 0.4 mm is detected by the MTS. Upon completion of the test, the attention and movement data are submitted instantly to the central server of BioBdx, where the data are analyzed and compared to age and gender adjusted normative data comprised of approximately 3000 controls. Within minutes after test completion, the study coordinator accessed individual test results, including statistical and graphical information for attention and movement, via a secure web portal. See Table 3 for a detailed description of all Quotient™ variables.

Children's Executive Functions Scale

The Children's Executive Functions Scale (CEFS; Silver et al., 1993) is a 99-item parent report measure of their child's level of EF over the past four weeks compared to their same age peers. Parent responses to individual items include: (a) "never or almost never" (i.e., zero), (b) "sometimes" (i.e., one), and (c) "very much" (i.e., two). Based on these ratings, subscale scores for Inhibition, Problem Solving, Social Appropriateness, Initiative, and Motor-Planning were calculated; the CEFS Total Score is the sum of scores for the individual areas. It should also be noted that the parent was asked to indicate whether or not their child has a movement disorder (e.g., cerebral palsy) to rule out this as a reason for certain responses. In a study examining the utility of the CEFS for discriminating between ADHD and non-ADHD children, results indicated that on the basis of the CEFS, children were accurately differentiated in 90.4% of cases (Silver, Benton, Goulden, Molho, & Clark, 1999). Results of a study examining CEFS scores in a sample of children with a traumatic brain injury to unimpaired children offer further support for the CEFS utility in detecting deficits in executive function (Goulden et al., 1997). See Table 3 for a description of the CEFS scores.

Working Memory Measures

Verbal and visual-spatial WM measures were selected from the Wecshler Intelligence Scale for Children, Fourth Edition, Integrated (WISC-IV-I; Wechsler et al., 2004). The WISC-IV-I was developed by combining the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003) and the Wechsler Intelligence Scale for Children – Third Edition as a Process Instrument (WISC-III PI; Kaplan, Fein, Kramer, Delis, & Morris, 1999). The verbal WM tasks on this measure are the same as those on the WISC-IV; the visual-spatial WM tasks are included on the WISC-III-PI and the Wechsler Nonverbal Scale of Ability (previously described). For the WISC-IV-I, no changes were made to any of the subtests used in the current study in terms of the item content, administration or scoring (Wechsler et al., 2004).

Verbal working memory.

Digit Span (DS) is one of the subtests that comprises the Working Memory Composite on the (WISC-IV-I; Wechsler et al., 2004) It is composed of two separate tasks, Digits Forward (DSF), which requires the child to repeat a sequence of numbers in the same order as spoken by the examiner, and Digits Backward (DSB), which requires the child to repeat the numbers in the reverse order of that spoken by the examiner. There are eight items in DSF and eight items in DSB; each item has two trials and items increase successively in length. DSB is a more specific assessment of working memory (Kaplan et al., 2004). Research indicates that DSF and DSB involve different cognitive skills and involve varying degrees of demand on cognitive resources (Reynolds, 1997; Rosenthal, Riccio, Gsanger, & Jarratt, 2006). Hence, for analyses in the current study, performance on the individual tasks were examined rather than the overall performance (i.e., total DS score). Raw scores for DSF and DSB were converted into age-adjusted scaled scores (mean = 10, SD = 3).

For the ages involved in the current study, estimates of internal consistency range from .83 to .78. Reliability coefficients for specific groups of children with ADHD, an ELD, and a RELD range from .81 to .84 for DSF and DSB. Pearson's product-moment coefficients indicate good (i.e., in the .80s) test-retest reliability for DSF and DSB. With regard to validity, factor analytic studies indicate that DS loads highest on the Working Memory Composite. An examination of convergent validity demonstrates high correlation between the WM Composite on the WISC-IV-I and the Attention/Concentration Index on the Children's Memory Scale (CMS) (.74); this finding is consistent with results of convergent validity analysis between the WISC-III and CMS (.73). Research consistently indicates verbal working memory deficits in varying degrees in children with ADHD and OLD (Gathercole & Alloway, 2006; Jonsdottir et al., 2005; Martinussen & Tannock, 2006). Examinations of the effect sizes for group mean differences in the Working Memory Composite (which included DS) on the WISC-IV provides additional support for validity. Among ADHD children, a small effect size for WMI was noted; large effect sizes were observed for children with an ELD and RELD (Kaplan et al., 2004).

It is well established that children with OLD exhibit significant deficits on non-word repetition tasks, which some conclude is an indication of the limited capacity of the phonological loop. Among children with ADHD, however, the deficit in WM is not limited to the functioning of the phonological loop. Furthermore, language problems are thought to have a lesser impact on number repetition tasks, such as DS (Baddeley, 2003; Baddeley et al., 1998; Marton & Schwartz, 2003). Hence, to evaluate the impact of a comorbid ADHD diagnosis on verbal WM in children identified as having a OLD, DS was administered rather than a non-word repetition task because it is assumed that both study groups, OLD and OLD/ADHD would be impaired on a non-word repetition task.

Visual-spatial working memory.

Spatial span (SSp) is a process subtest of WM on the WISC-IV-I (Kaplan et al., 2004). Like DS, it is divided into two components, SSp Forward (SSpF) and SSp Backward (SSpB); each item has two trials of the same length, successive items increase in length, and all items are administered using the Spatial Span Board. For SSpF, the child repeats the same sequence of tapped blocks as the sequence demonstrated by the examiner. For SSpB, the sequence of tapped blocks is completed in the reverse order of that demonstrated by the examiner (Kaplan et al., 2004). Unlike DS, there is not a total score for SSp; rather, performance on tasks is evaluated individually (i.e., there is scaled score for SSpF and a scaled score for SSpB). Similar to DSF, SSpF measures rote learning, memory, encoding, and the processing of spatial information. On the other hand, SSpB is a more specific assessment of attention and WM (Lezak, 1995; Smyth & Scholey, 1992). Given the motor component of the SSp tasks, some assert that they are also a measure of motor and self-regulation (Goldstein & Green, 1995). Raw scores for SSpF and SSpB were converted into age-adjusted scaled scores for data analyses (mean = 10, SD = 3).

For the ages involved in the current study, estimates of internal consistency for SSpF and SSpB range from .74 to .87. Reliability coefficients for specific groups of children with ADHD, ELD, and RELD range from .75 to .91

for SSpF and SSpB. Pearson's product-moment coefficients indicate adequate test-retest reliability for SSpF (.65) and SSpB (.68). Further evidence of the validity of SSpF and SSpB is based on results of studies comparing performance of the normative group to that of special groups including ADHD, ELD, and RELD; mean differences in test performance are significant for ADHD and RELD, but negligible for ELD. Results are consistent with visual-spatial WM deficits observed in ADHD. The lack of significance for the ELD group is consistent with prior research suggesting that language difficulties are likely to produce deficits on verbal WM tasks. The discrepancy in findings between the ELD and RELD groups, however, speaks to the need for continued research on WM in language disorders.

DESIGN AND PROCEDURE

As previously discussed, all students in the LI program were diagnosed with an OLD based on results of a comprehensive evaluation, and according to criteria determined by Shelton administrators and licensed professionals employed by the Shelton School. Prior to enrollment in the LI program, informed consent was obtained from parents, and informed assent was given by children entering the LI program. In general, LI enrollment occurred at the time of school admission. However, for some LI participants, enrollment in the program was delayed (e.g., the following school year) due to limited space and staff for LI classrooms.

For all study participants, scores for nonverbal cognitive ability were based on results of the WNV, administered as part of school admission testing. LI progress testing occurred annually, during the school day, and usually across several sessions with different examiners depending on the measure (i.e., certified speech-language pathologist, licensed psychologists, and educational diagnosticians). Relevant data from progress testing in Spring of 2008 (i.e., language and verbal cognitive testing) was analyzed in the current study. For children who entered the LI program in the Fall of 2008, needed data were based on testing completed during the Summer of 2008. This data was obtained from participants' cumulative school files. Language and cognitive test administration was according to standardized procedure and results were double scored by Shelton testing personnel.

As previously mentioned, consent for all LI testing was obtained at the time the child entered the LI program. An additional consent form was developed for the use of this data in the present study; informed consent for the current study was obtained at the time of the K-SADS-P/L interview (as described below). Consent forms and analyses of Shelton data were approved by UTSW and Shelton review boards; the LI program and use of LI data for the current study were funded by the Sparrow Foundation.

As a part of testing for LI program evaluation, all LI children age six and above were administered the Quotient™ in Spring of 2008 or in Fall of 2008, depending on time of entry to the LI program. For the purpose of this study and LI program evaluation, it was imperative that the effects of prescribed stimulant medication did not impact the results of Quotient™ testing. Thus, children who were taking prescribed stimulant medication were tested initially with their medication, and then a second testing time was scheduled so that the Quotient™ could be re-administered at a time when medication ingestion could be delayed until after test completion. Prior to the delay-medication testing, parents were contacted; it was explained that this testing was part of annual LI progress testing, and if approved by them and/or their child's prescribing physician, a delay-med testing time was scheduled. Also, for the present study, Shelton administrators approved the administration of WM measures at the time of Quotient™ testing; assessment of WM was completed at the time of delay-medication Quotient™ testing for those participants prescribed stimulant medication. It is noted that following the completion of delay-medication testing, the child participant was escorted to the school nurse's office for administration of prescribed medication. All relevant child test data (i.e., Quotient™ and WM measures) for participants enrolled in the LI program during the 2007 – 2008 and/or 2008 - 2009 school year was collected by the end of February of 2009. As previously mentioned, Shelton research personnel analyzed data in an effort to evaluate the LI program; however, this same data was analyzed for the purposes of the current study.

The K-SADS-P/L was completed with parent(s) of all children in the current study; prior to the initiation of the interview, background information was obtained to ensure the child met all inclusionary criteria and did not meet any of the exclusionary criteria. Regarding the K-SADS- P/L, all ADHD items were completed regardless of parent response to ADHD screening items. Due to time constraints and to minimize parent burden, if information gathered during the history taking indicated the possibility of other forms of psychopathology (e.g., anxiety, depression), screening questions and relevant modules for other disorder groups were completed. Following completion of the diagnostic interview, parent(s) were provided feedback regarding their child's testing on the Quotient™. At the end of the feedback session, parents were asked to complete the CEFS. Due to scheduling conflicts and time constraints, some parents took the CEFS to complete at home, and mailed it back upon its completion; directions for the completion of the CEFS were explained in advance. After the completion of the feedback session, a brief summary of background information gathered and K-SADS-P/L diagnostic results was written. This summary was printed and stored in the participant's respective research file.

It is noted that due to personnel constraints, the author completed nearly all the testing, conducted most interviews, and provided all testing feedback. In an effort to reduce bias, the author did not look at the results of the Quotient™ testing prior to conducting the diagnostic interview. However, it could not be avoided that the author had knowledge of the child's medication status and testing behavior. All data collection was completed by February of 2009 (see Figure 1).

DATA COLLECTION AND STORAGE

To maintain confidentiality, all participants were assigned codes based on letters in their first and last names; codes were used on all testing forms, computer files, and in data analyses. A list of subject names and matching codes was kept separately in a secure location. All test protocols, interview forms, and Quotient™ reports were stored in participants' respective file; all test protocols (i.e., WM measures and CEFS) were double scored by the author and a research assistant to ensure reliability of scoring. If there was a discrepancy in scoring, the test protocol was rescored by both the author and research assistant to resolve the discrepancy. As previously mentioned, data for language and cognitive tests were obtained from participants' cumulative file at Shelton, and reviewed for accuracy.

Complete data for each participant were entered and stored on a database created using the Statistical Package for the Social Sciences (SPSS) electronic software. For all test variables, abbreviated labels were defined and a list of definitions for the abbreviated labels was created. The individual code name and respective data regarding demographic information, OLD diagnostic information, ADHD status, medication status, individual variables for child and parent completed measures, nonverbal and verbal cognitive ability, language ability, and measurements of movement, impulsivity, and attention generated by the Quotient^{TM} were entered as separate variables into the SPSS database. All data was double-entered and verified for accuracy.

CHAPTER FIVE
Statistical Analyses

CHARACTERISTICS OF THE SAMPLE

Of the children enrolled in the LI program, 75 were eligible for participation in the current study based on the age criterion alone. Of those eligible, parents of 55 children consented to participate. However, four parents were unable to complete the interview portion of the study and thus, their child's testing data were excluded from analyses. It is noted that two children were prescribed Stratterra. Collected data for these participants were excluded from analyses due to the mechanisms of action of this medication and the impact of the medication on the behavior/cognition under investigation. Based on parent-report, one child was prescribed an antidepressant medication, Imipramine, at the time of the evaluation; this child's data was included in the analyses. Three eligible child participants were unable to complete the Quotient™ task and one child was excluded on the basis of an identified seizure disorder. Parents of three eligible children declined request for consent. Six parents did not respond to recruitment efforts and five eligible children withdrew either from the LI program or from the Shelton School during the course of the study. See Figure 1 for description of data collection.

The current study consisted of 51 participants, ranging in age from 6 to 13, (M = 9.5 years, SD = 2.4). Demographic characteristics for the sample of 51 participants are summarized in table 6 below. At the time of data collection, all children were enrolled in a specialized Language Intervention (LI) program at the Shelton School in Dallas, Texas. Children were assigned to this program based on the presence of a moderate to severe oral language disorder (OLD), per results of a comprehensive psychoeducational/ language evaluation conducted by licensed professionals employed by the Shelton School. Within the overall sample (N = 51), 30 (58.8%) children met criteria for a diagnosis of ADHD based on the K-SADS-P/L. Group assignment was based on ADHD diagnostic status (i.e., OLD versus OLD/ADHD). Table 6 below presents data regarding ADHD subtype and stimulant medication status. This sample did not include any children who met DSM-IV diagnostic criteria for a comorbid mood, anxiety, psychotic, or behavior disorder. However, based on information gathered during the K-SADS-P/L, 5 children (9.8%) displayed subthreshold mood/anxiety symptoms, and one child (2%) had a historical diagnosis of disruptive behavior disorder, but no longer met diagnostic criteria.

Table 6. Demographic Characteristics of the Study's Sample

	Total Sample (N = 51) N (%)	OLD (n = 21) n (%)	OLD/ADHD (n = 30 n (%)
Gender			
Male	28 (55)	11 (52.4)	17 (56.7)
Female	23 (45)	10 (47.6)	13 (43.4)
Ethnicity			
Caucasian	42 (82.4)	19 (90.5)	23 (76.7)
Hispanic	4 (7.8)	0 (0)	4 (13.3)
African Am.	1 (2)	0 (0)	1 (3.3)
Asian Am.	1 (2)	0 (0)	1 (3.3)
Other	3 (5.9)	2 (9.5)	1 (3.3)
ADHD Type			
Inattentive	7 (13.7)		7 (23.3)
Hyperactive-Impulsive	2 (3.9)		2 (6.7)
Combined	8 (15.7)		8 (26.7)
NOS	13 (25.5)		13 (43.3)
$^{\Psi}$Medication	30 (58.8)	7 (33)	23 (74)

$^{\Psi}$Participants prescribed stimulant medication; participants prescribed Stratterra excluded.

Chi-squares and independent-samples *t* tests (depending on the categorical or continuous nature of the variables) were conducted to determine demographic differences between the OLD and OLD/ADHD groups. Groups were similar with regard to gender, ethnicity, and age. As expected, chi-square analysis of medication status revealed that compared to those without a comorbid ADHD diagnosis, significantly more children in the OLD/ADHD group were prescribed stimulant medication. See Table 7 below for summary of demographic comparisons.

Table 7. Demographic Differences between OLD and OLD/ADHD Participants

	Statistic	df	Value	*p*
Gender	χ^2	2	.092	.762
Ethnicity	χ^2	4	5.291	.259
[a]Age	*t*	49	1.081	.285
[b]Medication	χ^2	2	9.577	.002**

[a]OLD participants (*M* = 9.9, *SD* = 2.5); OLD/ADHD participants (*M* = 9.2, *SD* = 2.4). [b]Analysis of OLD and OLD/ADHD participants prescribed stimulant medication; participants prescribed Stratterra excluded from study.
$^{**}p < .01$

As mentioned, all participants received a complete psychoeducational/ language evaluation at the time of admission to the LI program. Evaluation results for language and cognitive functioning were reviewed and results of independent-samples *t* tests indicated groups were similar with respect to language functioning, verbal cognitive ability, and nonverbal cognitive ability. Data from the BASC-2 TRS were examined to determine if groups differed with respect to internalizing symptoms (Internalizing Composite), externalizing symptoms (Externalizing Composite), overall behavioral symptoms (Behavioral Symptoms Composite) and adaptive behavior (Adaptability Composite). Results of independent-samples *t* tests did not reveal significant group differences on the BASC-2 TRS. See Table 8 below for summary of these analyses.

Table 8. Independent Samples *t*-tests of Cognitive Abilities, Language, and Behavioral Symptoms

Skill	OLD (n = 21) *M* (*SD*)	OLD/ADHD (n = 30) *M* (*SD*)	df	$^{\Psi}t$	*p*
[a]Core Language	79.9 (17.1)	76.6 (13.9)	49	.768	*ns*
[a]Receptive	84.5 (15.1)	82.8 (12.3)	49	.447	*ns*
[a]Expressive	81.4 (17.0)	77.4 (14.3)	49	.916	*ns*
[b]Verbal IQ	77.8 (16.1)	78.9 (11.2)	49	.075	*ns*
[c]Nonverbal IQ	89.3 (15.4)	87.7 (14.6)	49	.631	*ns*
[d]Internalizing Sx.	54.2 (14.3)	54.8 (9.7)	49	-.439	*ns*
[d]Externalizing Sx.	51.1 (7.8)	52.5 (7.6)	49	-.681	*ns*
[d]Behavioral Sx.	54.3 (9.0)	57.7 (9.2)	49	-1.295	*ns*
[d]Adaptability	45.4 (8.8)	42.3 (6.3)	49	1.438	*ns*

$^{\Psi}t$ = independent samples *t-tests* based on comparison of OLD and OLD/ADHD groups. *ns* = non significant p-value. Sx. = symptoms. [a]Clinical Evaluation of Language Fundamentals. [b]Slosson Intelligence Test-Revised. [c]Weschler Nonverbal Scale of Ability. [d]Behavioral Assessment System for Children (BASC)

EXAMINATION OF DATA FOR ANALYSES OF GROUP DIFFERENCES

Data were examined for the presence of outliers or extreme values. If such values were identified, data were first examined for accurate entry and then transformations were applied to create more normal distribution(s) and remove the presence of these values. If outliers remained, they were excluded from analyses involving relevant variables. This decision to remove these values was based on the sensitivity of the proposed analyses to the presence of outliers and the impact such values have on producing either a Type I or a Type II error, with no indication in the analysis regarding what type of error may be occurring (Tabachnick & Fidell, 2007). Further description of the outliers and the decision-making process to exclude such values from relevant analyses is elaborated where relevant.

Kolmogorov-Smirnov tests were performed on residual data of all dependent variables to evaluate the normality of the distribution of scores for each dependent variable; Lilliefors significance corrections were used to identify significance. For data that did not meet the assumption of normality, appropriate data transformations (e.g., logarithmic and square root) were applied depending on the characteristics of the non-normal distribution (Tabachnick & Fidell, 2007). In some cases, although transformed data corrected non-normal distributions, transformed data, but not untransformed data, violated the multiple analysis of variance (MANOVA) assumption of linearity. When this occurred, untransformed data was used in analyses. This decision was based on MANOVA's robustness to violations of normality, but substantial reduction in the power of this statistical test in the case of non-linearity/curvilinearity among variables (Green & Salkind, 2005; Tabachnick & Fidell). Linearity among dependent variables and between covariates and dependent variables was evaluated via visual examination of scatter plots. The assumptions of homoscedasticity and homogeneity of variance were evaluated using the Box's M test and Levene's test, respectively. When statistical assumptions could not be met, even after appropriate data transformations were attempted, and when violations of such assumptions were identified in the literature as creating an invalid statistical test, equivalent non-parametric tests were applied.

Analyses failed to demonstrate that gender affected attention and movement as measured by the Quotient™, EF as measured by the CEFS, or WM. Bivariate correlational analyses were conducted to determine the presence of a relationship between dependent variables and age, language, and/or cognition. If a significant correlation occurred, scatter plots of the potential covariate and dependent variables were visually examined to confirm a linear association. It is noted that if the Pearson product-moment coefficient (*r*) was greater than .8, then the variable was included as a covariate to limit covariates to those that can be reliably measured (Tabachnick & Fidell, 2007). Despite Pearson product-moment values less than .8 for correlational analyses between age and DVs of attention, movement, EF, and WM, analyses were conducted to evaluate the possibility of a significant interaction between age and DVs; no significant interactions were identified.

Furthermore, bivariate correlations among DVs were evaluated. MANOVA is best when DVs are highly negatively correlated; the use of this statistic is acceptable when DVs are moderately correlated (i.e., .60; Tabachnick & Fidell, 2007) in either direction. If correlational analyses did not support the use of MANOVA for a hypothesis, individual ANOVA's were employed. Familywise Type I error rate was controlled by applying a Bonferroni correction to each test. One-way between-subjects multivariate analyses MANOVAs and/or analysis of variance (ANOVA) were conducted to determine the effect of ADHD on attention and movement, as objectively assessed by the Quotient™. The between-subjects factor for primary analyses was diagnostic group, with two levels: OLD and OLD/ADHD. Main effects were tested using the multivariate criterion Wilks' lambda (Λ). In the case of a significant Λ in MANOVA, results of the individual between-subjects analyses (i.e., one-way analysis of variance, ANOVA) were examined; tests were evaluated at a Bonferroni corrected alpha level (i.e., .05 / number of dependent variables in the MANOVA) to protect against Type I error.

Impact of Comorbid ADHD on Attention and Movement

Hypothesis 1a

It was predicted that with respect to attention, Quotient™ performance of children diagnosed with comorbid OLD/ADHD would be characterized by lower accuracy scores, greater percentage of omission and commission errors, slower response latency, and greater variability in response time compared to the performance of children with OLD and no comorbid ADHD diagnosis.

A one-way between subjects multivariate analysis of variance (MANOVA) was employed to evaluate hypothesis 1a; this analysis was performed on four DVs: Response Accuracy, Omission Errors, Commission Errors, and Response Variability. The independent variable was ADHD comorbidity (i.e., OLD or OLD/ADHD). The DV Response Latency did not demonstrate acceptable correlations with the DVs included in the MANOVA; a one-way analysis of variance (ANOVA), with a Bonferroni corrected alpha level, was used to evaluate the effect of Response Latency on ADHD diagnostic status. See Table 9 for results of bivariate correlational analyses among DVs relevant for hypothesis 1a.

With the use of Wilks' criterion, $\Lambda = .915$, the combined DVs in the MANOVA were not significantly affected by comorbid ADHD in children with an identified OLD, $F(4, 46) = 1.071$, $p = .382$; however, with the exception of the variable Commission Errors, group differences were in the expected direction. Despite the lack of significance, according to (Cohen, 1988) guidelines for effect size (i.e., small effect, $\eta^2 = .01$; medium effect, $\eta^2 = .09$; large effect, $\eta^2 = .25$), results indicated moderate association between the combined DVs and ADHD diagnostic status, $\eta^2 = .085$. The one-way ANOVA for the DV Response Latency was not significant $F(1, 49) = 1.141$, $p = .291$, $\eta^2 = .023$. See Table 10 below for means, standard deviations, and results of analyses.

Table 10. Analyses of Variance to Examine Group Differences on Quotient™ Attention Variables

Quotient™ Variable	OLD *M* (*SD*)	OLD/ADHD *M* (*SD*)	*F*	*p*	η^2
$^{\Psi}$Accuracy (%)	81.1 (11.2)	77.8 (13.7)	$^{\Psi}$1.071	.382	.085
$^{\Psi a}$Omission (%)	11.9 (13.6)	19.4 (16.2)			
$^{\Psi}$Commission (%)	25.6 (15.3)	25.0 (17.5)			
$^{\Psi}$Variability	194.1 (79.0)	234.8 (81.2)			
Latency	567.4 (114.4)	604.7 (128.2)	1.141	.291	.023

$^{\Psi}$DVs included in MANOVA; overall MANOVA not significant so between-subject tests not examined. [a]Log-transformed data analyzed.

Despite the non-significant MANOVA, exploratory analyses for the DVs included in the MANOVA were completed. This decision was due to the lack of any prior research evaluating the use of the Quotient™ in an LD population. Degree and direction of group differences were examined qualitatively and considered in light of previous Quotient™ research on healthy controls and children with pure ADHD. Results of individual ANOVAs were not significant.

In sum, with regard to attention as assessed via Quotient™ performance, contrary to that hypothesized, the presence of comorbid ADHD did not affect a child’s ability to sustain attention on this 15-minute task. Children with and without comorbid ADHD in the context of an OLD respond similarly in terms of the overall percent of correct responses, percent of missed targets and percent of incorrect responses to non-targets. Moreover, when a target appeared, the speed of response time and consistency of response time across the duration of the Quotient^{TM} task are similar.

Hypothesis 1b

Given that attention is a process that fluctuates over time, it was predicted that on the Quotient^{TM}, compared to children without a comorbid ADHD diagnosis, children with ADHD would demonstrate a greater number of shifts in their attention (i.e., Attention Shifts), spend less time on task (i.e., On Task), spend a greater percentage of time responding impulsively (i.e., Impulsive), and spend more time in a distracted state (i.e., Distracted).

MANOVA was not employed due to the lack of strong association among DVs (see Table 11). Multiple one-way analyses of variance (ANOVAs) evaluated the relationship between attentional processes and ADHD. Analyses were Bonferroni corrected to protect against familywise Type I error (alpha level = .0125). For all ANOVAs, the independent variable, ADHD diagnostic status, included two levels: OLD and OLD/ADHD. Dependent variables included Attention Shifts, On Task, Impulsive, and Distracted, analyzed individually. Bonferroni corrected ANOVA results ($\alpha < .0125$) did not indicate significant differences between groups on DVs. Despite the lack of significance, group differences were in the expected direction with the exception of Impulsive. See Table 12 below for means, standard deviations, and results of analyses.

Table 12. Analyses of Variance to Examine Group Differences on Quotient™ Attention State Shift Variables

Quotient™ Variable	OLD *M* (*SD*)	OLD/ADHD *M* (*SD*)	*F*	*p*	η^2
Attention Shifts	14.3 (5.1)	14.9 (4.0)	.197	.659	.004
On Task	41.5 (30.7)	34.0 (25.9)	.904	.396	.018
[a]Distracted	13.6 (11.0)	24.6 (18.2)	6.782	.013*	
Impulsive	29.0 (16.9)	20.6 (16.9)	3.084	.085	.059

[a]Analyzed using Brown-Forysthe statistic due to assumption violation; value for η^2 not available.
*Not significant following application of Bonferroni correction (p < .0125).

In sum, contrary to that hypothesized, children with comorbid ADHD did not experience significantly greater fluctuations in their attention throughout the duration of the Quotient™ task. In addition, children with and without ADHD spent similar percentages of the task responding accurately (i.e., hitting many targets and few non-targets) and responding impulsively (i.e., hitting many targets but some non-targets). However, as predicted, children with comorbid ADHD did spend a greater percentage of time responding as if “distracted” (i.e., hitting some targets and some non-targets), but this group difference was not significant following application of the Bonferroni correction.

Hypothesis 1c

It was predicted that during the Quotient™ task, the behavior of children with comorbid ADHD/OLD would be characterized by more frequent (i.e., Immobility Duration, Movements, and Temporal Scaling) and less complex movement (i.e., Spatial Complexity), and overall, they will move a greater distance (i.e., Displacement) and area (i.e., Area) than children without ADHD (i.e., OLD).

Multiple ANOVAs were employed to evaluate the relationship between motion and ADHD. Analyses were Bonferroni corrected to protect against familywise Type I error ($\alpha < .008$). For all ANOVAs, the independent variable, ADHD diagnostic status, included two levels: OLD and OLD/ADHD. DVs included Immobility Duration, Movements, Temporal Scaling, Spatial Complexity, Displacement, and Area, analyzed individually. MANOVA was not employed due to the pattern of associations among DVs (see Table 13). More specifically, despite some highly negatively correlated DVs, some DVs were highly positively correlated. In cases of high positive correlation, the overall multivariate analysis is acceptable, but after the highest priority DV is accounted for there is limited variance associated with other DVs to be related to the independent variable. The limitation of separate ANOVAs for multiple DVs is the occurrence of Type I errors; however, this can be controlled for by applying a Bonferroni correction to the alpha level .05. Six outliers were identified for the

DV Spatial Complexity, and one extreme value was identified on the DV Area; these data were excluded from analyses involving these variables due to their effect on the accuracy of the resulting *p*-values.

Results of the one-way analyses for the DVs Area and Spatial Complexity were significant following application of the Bonferroni correction. Movement of children with comorbid ADHD (i.e., OLD/ADHD) covered a significantly greater area than the movement of children without ADHD (i.e., OLD), F (1, 48) = 10.035, p = .003. As expected, children with ADHD demonstrated significantly more linear and less complex movement (i.e., Spatial Complexity) than children without comorbid ADHD, F (1, 43) = 16.992, p = .000. The strength of the relationships between ADHD diagnostic status and overall space covered (i.e., Area) and complexity of movement (i.e., Spatial Complexity), as assessed by η^2, were moderate to strong, with ADHD accounting for 17% and 28%, respectively, of the variance of the DVs. Although results of one-way analyses for the DVs Immobility Duration, Movements, and Displacement were significant prior to application of a Bonferroni correction, following this correction results only approached significance at an alpha level of .008. Contrary to that expected, groups did not differ in frequency of movement (i.e., Temporal Scaling). See Table 14 below for means, standard deviations, and results of analyses.

Table 14. Analyses of Variance to Examine Group Differences on Quotient™ Movement Variables

Quotient™ Variable	OLD *M* (*SD*)	OLD/ADHD *M* (*SD*)	*F*	*p*	η^2
[a]Immobility Duration	2.14 (.33)	1.89 (.32)	7.481	.009*	.132
[b]Movements	51.9 (18.4)	66.6 (21.3)	7.449	.009*	.132
[a]Displacement	.517 (.38)	.807 (.40)	7.527	.008*	.133
[b]Area	10.05 (5.22)	14.98 (5.57)	10.035	.003**	.173
Temporal Scaling	.751 (.38)	.976 (.42)	4.022	.050	.076
[c]Spatial Complexity	1.16 (.12)	1.09 (.11)	16.992	.000**	.283

[a]Log-transformed data analyzed. [b]Square-root transformed data analyzed. [c]Analysis of variable spatial complexity based on *n* of 45 after exclusion of 6 outliers.
*Not significant following application of Bonferroni correction ($p < .0125$).
**Bonferroni corrected alpha level significant ($p < .0125$).

The initial bivariate correlational analyses indicate that despite the specific aspects of movement assessed by the various Quotient™ movement variables (see Table 3), there is substantial redundancy in what is being measured across variables. Results indicate that overall, children with comorbid ADHD evidence greater movement during the Quotient™ task of sustained attention. However, examination of the qualitative aspects of the sample's movement, as measured by the individual Quotient™ movement variables, revealed that group differences did not always reach significance after results were Bonferroni corrected. Yet, despite a stringent Bonferroni corrected alpha level of .008, children with comorbid ADHD demonstrated significantly less complex, more linear movement, and their movement covered a greater amount of space compared to the movement of those with an OLD but without comorbid ADHD.

Hypothesis 1d

It was predicted that for children with comorbid OLD/ADHD, Quotient™ performance will be characterized by poorer sustained attention (i.e., Inattention), greater movement (i.e., Motion), and worse overall performance (i.e., Global), compared to participants without comorbid ADHD (i.e., OLD group).

Multiple ANOVAs were employed to evaluate the relationship between global Quotient™ performance and ADHD. Analyses were Bonferroni corrected to protect against familywise Type I error ($\alpha < .017$). For all ANOVAs, the independent variable, ADHD diagnostic status, included two levels: OLD and OLD/ADHD. DVs included, overall Motion, overall Inattention, and overall performance (i.e., Global ADHD), analyzed individually. This decision was based on the recommendation of Tabachnick and Fidell (2007); that is, in the case of component scores, such as these, a multivariate test has less power than univariate analyses but helps to protect against type I errors from multiple comparisons. However, as previously discussed, familywise Type I error associated with multiple univariate tests can be controlled for with the application of a Bonferroni correction. See Table 15 for results of bivariate correlational analyses among DVs.

Bonferroni corrected results ($\alpha < .017$) for overall motion and overall performance were consistent with that hypothesized. Compared to participants with an OLD, those with comorbid OLD/ADHD evidenced significantly greater motion while completing the Quotient™'s continuous performance task (i.e., Motion), F (1,49) = 8.931, p = .004. The strength of the relationship between ADHD diagnostic status and overall motion was moderate, accounting for 15% of the variance of the DV ($\eta^2 = .154$). Overall, Quotient™ performance, as measured by the Global ADHD score, was significantly more impaired in children with a comorbid ADHD diagnosis, F (1,49) = 8.620, p = .005. Again, the strength of this relationship was moderate ($\eta^2 = .150$). Contrary to that hypothesized, groups did not differ in their ability to sustain attention for accurate responding throughout the duration of the task (i.e., Inattention), F (1,49) = 3.627, p = .063. See Table 16 below for means and standard deviations for the DVs.

Table 16. Analyses of Variance to Examine Group Differences on Quotient™ Scaled Scores

Quotient™ Scaled Score	OLD *M* (*SD*)	OLD/ADHD *M* (*SD*)	*F*	*p*	η^2
Inattention	6.52 (2.31)	7.74 (2.21)	3.627	.063	.069
Motion	5.13 (2.45)	7.18 (2.40)	8.931	.004**	.154
Global ADHD	5.82 (2.17)	7.46 (1.79)	8.620	.005**	.150

**Bonferroni corrected alpha level significant ($p < .017$).

Previous analyses have examined group differences on specific variables measuring aspects of attention and movement characteristics. Analyses of participants' overall attention and movement reveal that children with comorbid OLD/ADHD evidence greater movement. Although the evaluation of group differences in terms of overall attention (i.e., Inattention) only approached significance, when attentional performance and movement are combined (i.e., Global ADHD), children with comorbid ADHD demonstrate significantly greater impairment on the Quotient™.

Impact of Comorbid ADHD on Executive Functioning

Hypothesis 2

It was predicted that compared to children without ADHD (i.e., OLD) the behavior of children with comorbid OLD/ADHD would reflect greater impairment in executive functioning (i.e., CEFS Total), with less socially appropriate behavior (i.e., Social Appropriateness), greater problems with behavioral inhibition (i.e., Inhibition), more difficulties with daily problem solving (i.e., Problem-solving), more difficulty initiating goal-directed behavior (i.e., Initiative), and greater problems completing tasks that require planned sequences of movement (i.e., Motor-planning).

A one-way between-subjects MANOVA was performed on five DVs of EF: Social Appropriateness, Inhibition, Problem Solving, Initiative, and Motor Planning. The independent variable was ADHD diagnostic status (i.e., OLD or OLD/ADHD). One participant was identified as an extreme value on multiple CEFS variables; this subject was excluded from analyses. Given the multifaceted nature of EF and high positive collinearity (r > .8) between CEFS Total Score and CEFS subscale scores (see Table 17), the CEFS Total Score was excluded from the MANOVA. It is noted that Pearson-product moment correlation values among CEFS subscale scores are near an *r* of .6, but MANOVA is acceptable with this degree of association (Tabachnick & Fidell, 2007). A separate one-way analysis of variance (ANOVA) was employed on the CEFS Total Score to evaluate group differences in overall parent-reported executive functioning. Results of statistical analyses for hypothesis 2 were evaluated at a Bonferroni corrected alpha level of .008.

Wilks' lambda criterion, $\Lambda = .593$, indicated that the combined DVs were significantly affected by ADHD diagnostic status, F (5, 37) = 5.000, $p = .001$. Results revealed a strong association between ADHD and executive functions, with the combined DVs accounting for 41% of the variance associated with ADHD diagnostic status ($\eta^2 = .407$). Follow-up tests of between-subject differences revealed that group differences on the variables Social Appropriateness ($p = .009$) and Problem Solving ($p = .015$) were not significant after the application of the Bonferroni correction. Results also failed to indicate group differences on the DVs Initiative and Motor Planning. However, as expected, compared to children with an OLD, children with comorbid OLD/ADHD had greater trouble inhibiting inappropriate behavior according to parent-report, F (1, 41) = 20.560, p = .000. The strength of the relationship between ADHD diagnostic status and Inhibition was quite strong, with diagnostic status accounting for 33% of the variance in the DV (η^2 = .334). Results of a separate one-way analysis of variance (ANOVA) indicated that overall, compared to children with an OLD, children with comorbid OLD/ADHD demonstrated poorer executive functioning (i.e., CEFS Total Score), F (1, 41) = 11.340, p = .002, η^2 = .217. See Table 18 below for means, standard deviations, and results of analyses.

Table 18. Analyses of Variance to Examine Group Differences in Executive Functioning

CEFS Variable	OLD *M* (*SD*)	OLD/ADHD *M* (*SD*)	*F*	*p*	η^2
Inhibition	12.56 (6.40)	22.12 (7.11)	20.56	.000**	.334
Problem-Solving	14.61 (10.35)	22.80 (10.54)	6.413	.015*	.135
Social-Appropriateness	6.50 (2.79)	9.16 (3.33)	7.631	.009*	.157
Initiative	6.72 (3.93)	9.36 (5.64)	2.906	.096	.066
Motor-Planning	5.94 (4.60)	6.80 (5.25)	.308	.582	.007
Total Score	46.33 (19.76)	70.24 (24.98)	11.340	.003**	.217

*Result not significant following application of Bonferroni correction (α = .008). ***p* < .008.

In sum, results indicate that the presence of comorbid ADHD is associated with greater executive dysfunction overall. More specifically, examination of individual aspects of executive function via the CEFS subscales reveals that children with comorbid ADHD have more difficulty inhibiting their behavior. Other areas of executive dysfunction, including problems with daily problem solving and demonstration of socially appropriate behavior, are substantially worse among children with comorbid ADHD, but group differences did not reach significance following application of a Bonferroni correction to analyses. Results indicated that comorbid ADHD does not impact a child's ability to initiate goal-directed behavior or to complete tasks that require planned sequences of behavior/movement.

Impact of Comorbid ADHD on Working Memory

Hypothesis 3

It was expected that compared to children with an OLD, children with comorbid OLD/ADHD would demonstrate significantly poorer visual-spatial working memory.

An independent-samples t test was conducted to evaluate group differences in visual-spatial working memory. The test was not significant, $t(49) =$

1.114, p = .271, but group differences were in the expected direction with OLD/ADHD children (M = 7.77, SD = 2.88) performing worse than children without ADHD (i.e., OLD) (M = 8.71, SD = 3.13). It is noted that exploratory analyses of group differences in verbal working memory were not significant. See Table 19 below for means, standard deviations and statistical results.

Table 19. Analyses of Variance to Examine Group Differences in Memory

Measure	Skill	OLD *M* (*SD*)	OLD/ADHD *M* (*SD*)	*t*	*p*
Spatial Span Backward	VS WM	8.71 (3.13)	7.77 (2.88)	1.114	.271
[a]Digit Span Backward	Verbal WM	7.19 (2.38)	8.03 (2.08)	-1.334	.189
[a,b]Spatial Span Forward	VS storage	.911 (.137)	.852 (.169)	1.318	.194
[a,b]Digit Span Forward	Verbal storage	.847 (.183)	.800 (.206)	.837	.407

Note. VS = visual-spatial. WM = working memory. Storage refers to short-term memory. [a]Exploratory analysis. [b]Log-transformed data analyzed.

In sum, results indicate that in the context of an OLD, the presence of comorbid ADHD does not impact a child's ability to store verbal or visual-spatial information (i.e., Digit Span Forward and Spatial Span Forward, respectively) and does not impact his/her ability to then manipulate this information in some way for the production of a desired response (i.e., Digit Span Backward and Spatial

Span Backward). Thus, overall, comorbid ADHD does not affect a child's short-term or working memory as measured by relevant subtests on the WISC-IV-I.

EVALUATION OF CLASSIFICATION ACCURACY: THE QUOTIENT/ADHD SYSTEM^{TM} AND CEFS

At the time of the study's design, discriminant function analysis (DA) was identified as the statistic to evaluate the usefulness of dependent measures (i.e., the Quotient and the CEFS) for accurately identifying the presence of comorbid ADHD in children with an oral language disorder. Compared to logistic regression (LR), DA provides more accurate classification, hypothesis testing, and greater statistical power (i.e., less chance of Type II error, accepting a false null hypothesis) (Grimm & Yarnold, 1995; StatSoft, 2008; Tabachnick & Fidell, 2007). However, in the event that predictor variables do not meet DA assumptions, LR is recommended for evaluating the classification accuracy of the model. It is noted that DA statistical assumptions are the same as multivariate analysis of variance, as previously described. LR is relatively free of restrictions; assumptions include linearity between predictors and the logit transformation of the DV and absence of multicollinearity among predictor variables (Tabachnick & Fidell). Both DA and LR are extremely sensitive to the presence of outliers with such values impacting the robustness of classification accuracy; hence, outliers/extreme values were eliminated from analyses. Data were evaluated to determine if assumptions were met for DV; if data met all necessary assumptions, DA was employed for hypothesis testing. However, if data did not meet DA assumptions, but were appropriate for LR, LR was used to evaluate the hypothesis.

Classification Accuracy: The Quotient/ADHD System™

Hypothesis 4a

It was expected that similar to the findings of Teicher et al. (1996) in his sample of ADHD children and non-ADHD controls, Quotient variables Accuracy, Spatial Complexity, and Response Variability would distinguish OLD/ADHD and OLD children with an appropriate level of accuracy.

A direct logistic regression analysis was performed to assess prediction of ADHD diagnostic status (i.e., OLD or OLD/ADHD). Predictors included Response Accuracy, Response Variability, and Spatial Complexity. Predictor variables were chosen based on the aim to replicate Teicher and colleagues' (1996) findings that children with ADHD can be distinguished from normal control children with adequate sensitivity (88.9%) and specificity (100%) via a discriminant function of these Quotient variables. Data for outliers on the variable

Spatial Complexity were excluded from analyses. A test of the full model with all three predictors against a constant-only model was statistically significant, $\chi 2$ (3, N = 45) = 14.485, *p* = .002, indicating that the predictors, as a set, reliably distinguished between children with an OLD and those with comorbid OLD/ADHD. The amount of variance in ADHD diagnostic status accounted for by the full model is strong, with Nagelkerke R^2 = .372.

Overall classification was adequate with a success rate of 77.8%. More specifically, children with comorbid OLD/ADHD could be distinguished from those with only OLD with 92.6% sensitivity and 55.6% specificity. That is, of the 27 participants identified as OLD/ADHD per clinician evaluation, the logistic model identified 25 as OLD/ADHD and misidentified 2 as OLD. Of the 18 participants identified as not having comorbid ADHD (i.e., OLD), 10 were identified as such and 8 were misidentified identified as having comorbid ADHD (i.e., OLD/ADHD).

Table 20 shows regression coefficients and Wald statistics for each predictor. According to the Wald criterion, only the complexity of the child's movement (i.e., Spatial Complexity) significantly predicted ADHD diagnostic status, β = -23.298, Wald(1) = 7.181, *p* = .007. The direction of the regression coefficient indicates that more linear and less complex movement (i.e., lower values on the variable Spatial Complexity) predicts the presence of ADHD in this sample of children. A logistic regression model run with Spatial Complexity omitted was not reliably different from a constant only model, $\chi 2$ (2, N = 45) = 3.221, $p = .200$, however, this model was reliably different than the full model (i.e., Response Variability, Response Accuracy, and Spatial Complexity), $\chi 2$ (1, N = 45) = 11.264, $p = .0008$. This confirms the finding that more linear, less complex movement (i.e., Spatial Complexity) is the only statistically significant predictor of ADHD diagnostic status.

Based on this finding, a direct logistic regression analysis was performed to confirm the prediction of ADHD diagnostic status (i.e., OLD or OLD/ADHD) based on the predictor variable Spatial Complexity alone. A test of the model with the predictor Spatial Complexity against a constant-only model was statistically significant, $\chi 2$ (1, N = 45) = 14.277, $p = .000$, indicating that the predictor reliably distinguished between children with an OLD and those with comorbid OLD/ADHD. The amount of variance in ADHD diagnostic status accounted for by the full model is strong, with Nagelkerke $R^2 = .368$. Overall classification was adequate with a success rate of 77.8%. More specifically, children with comorbid OLD/ADHD could be distinguished from those with only OLD with 92.6% sensitivity and 55.6% specificity. According to the Wald criterion, Spatial Complexity reliably predicted ADHD diagnosis, $\beta = -22.912$, Wald(1) = 8.796, $p = .003$. Results are consistent with preceding analyses. See Table 20 for summary of these logistic regressions.

In sum, findings indicated that for children with an OLD, the variable

Spatial Complexity predicted the presence of comorbid ADHD with 77.8% overall accuracy. Response accuracy and variability in response time on the Quotient^{TM} did not contribute to the accurate prediction of comorbid ADHD in the context of an OLD. It is noted, however, that examination of the values for sensitivity and specificity reveal that the Spatial Complexity of a child's movement alone (i.e., more linear, less complex) is not specific to ADHD. In other words, although children with comorbid ADHD demonstrate significantly less complex movement than those without ADHD, movement complexity alone is not necessarily indicative of ADHD.

Hypothesis 4b

It was expected that a statistically based function of Quotient^{TM} variables of attention and motion will accurately distinguish OLD and OLD/ADHD children.

Potential predictors of outcome were identified by analyses of variance between ADHD diagnostic status and Quotient^{TM} variables of attention and motion, as described in the results of hypotheses 1a, 1b, 1c, and 1d. Prior to analyzing the predictive power of Quotient^{TM} variables on ADHD diagnostic status, variables were assessed for multicollinearity via correlational analyses among the following potential predictors: Area, Spatial Complexity, Motion, and Global ADHD. Analyses yielded significant correlations among the predictor variables, *p*<.001 (see Table 21). Due to the extreme degree of multicollinearity, it was determined that individual variables would not contribute to predicting unique variance in ADHD diagnostic status. Theoretically, it appears that Global ADHD assesses symptoms of inattention and motion in a broader sense than the specific movement variables Area and Spatial Complexity and the overall variable Motion. Therefore, Global ADHD was the only predictor variable included in the direct logistic regression for ADHD diagnostic status.

A direct logistic regression analysis was performed to confirm the prediction of ADHD diagnostic status (i.e., OLD or OLD/ADHD) based on the predictor variable Global ADHD alone. A test of the model with the predictor Global ADHD against a constant-only model was statistically significant, $\chi 2$ (1, N = 51) = 7.916, $p = .005$, indicating that the predictor reliably distinguished between children with an OLD and those with comorbid OLD/ADHD. The amount of variance in ADHD diagnostic status accounted for by the full model was moderate, with Nagelkerke $R^2 = .194$. Overall classification was adequate with a success rate of 72.5%. More specifically, children with comorbid OLD/ADHD could be distinguished from those with only OLD with 83.3% sensitivity and 57.1% specificity. Global ADHD significantly predicted ADHD diagnosis, $\beta = .412$, Wald(1) = 6.764, $p = .009$.

Due the limited research on the use of the Quotient™ in children with comorbid ADHD and comorbid language/learning disabilities, a forward stepwise logistic regression was completed to determine the strongest predictors for ADHD among the predictor variables Area, Motion, and Global ADHD. Given the number of outliers on the variable Spatial Complexity, already small sample size, and prior analyses with this DV, Spatial Complexity was not included in the regression. The predictor variables Area, Motion, and Global ADHD were entered into the stepwise regression equation; only the variable Area was included in the regression equation as *uniquely* contributing to the discrimination between cases. A test of the model with the predictor variable Area was statistically significant, $\chi 2$ (1, N =50) = 9.223, $p = .002$, indicating that this predictor alone reliably distinguished between OLD and OLD/ADHD children. The variance in ADHD diagnostic status accounted for is moderate, with Nagelkerke $R^2 = .227$. Classification was moderate with an overall accuracy success rate of 72%; sensitivity of 79.3% and specificity of 61.9%. Area significantly predicted ADHD diagnosis, $\beta = .164$, Wald(1) = 7.614, $p = .006$. See Table 20 for summary of logistic regressions.

In sum, results indicated that the overall Quotient™ variable Global ADHD was best able to predict the presence of comorbid ADHD with an overall classification accuracy rate of 72.5%. However, analyses of the predictive utility of the Quotient™ movement variable Area for correctly identifying the presence of comorbid ADHD revealed similar overall accuracy (72%). Compared to Global ADHD, results indicate that Area is less sensitive but more specific to the presence of comorbid ADHD; however, differences among models in sensitivity and specificity are not substantial.

Classification Accuracy: CEFS

Hypothesis 5a

It was expected that CEFS variables identified as differing significantly between OLD and OLD/ADHD participants (per evaluation of hypothesis 2) will distinguish groups according to ADHD diagnostic status.

A discriminant analysis (DA) was conducted to determine whether scores from the CEFS could predict the presence of ADHD in children with an identified OLD. One extreme value was identified and was excluded from the analysis. Potential predictors of outcome were identified by analyses of variance between ADHD diagnostic status and parent-reported executive functions, as assessed by the CEFS, and as described in the results of hypothesis 2. Prior to analyzing the predictive power of CEFS scores on ADHD diagnostic status, variables were assessed for multicollinearity via correlational analyses among the following potential predictors: Inhibition and CEFS Total Score.

Analyses yielded a significant correlation between variables, $p<.001$ (see Table 17). Due to the high degree of multicollinearity between variables, it was determined that the individual variables would not contribute to predicting unique variance in ADHD diagnostic status. Theoretically, it appears that CEFS Total Score assesses executive functioning in a broader sense than the specific CEFS subscale score Inhibition. However, the CEFS Total Score is comprised of more specific executive functions (i.e., CEFS subscale scores; see Table 3); with the exception of Behavior Inhibition, prior analyses did not reveal significant group differences in other areas of executive function as assessed by the CEFS subscale scores (see Table 18). Therefore, Inhibition was the only covariate included in the direct discriminant analysis for ADHD diagnostic status.

A direct discriminant analysis was performed using the CEFS subscale score Inhibition as the predictor of ADHD diagnostic status (i.e., OLD or OLD/ADHD). The overall Wilks's lambda for the function was significant, Λ = .666, χ^2 (1, N = 43) = 16.461, p < .000, indicating that the function differentiated between OLD and OLD/ADHD children. The function accounted for 33% of the total relationship between Inhibition and ADHD diagnostic status, as assessed by canonical R^2 (R^2 = .334). The predictor Inhibition was able to correctly classify 79.1% of the individuals in the sample relative to ADHD diagnostic status; with 80% sensitivity (20 of 25 OLD/ADHD participants correctly classified) and 77.8% specificity (14 of 18 OLD participants correctly classified). To take into account chance agreement, a kappa coefficient was computed; results indicated a moderate value of .573, p = .000 (Green & Salkind, 2005). Finally, to assess how well this classification variable would predict in a new sample, the leave-one-out technique was utilized; according to this procedure, data for Inhibition would correctly classify 79.1% of cases; values for sensitivity and specificity are unchanged with this technique of classification. See Table 20 for summary of results.

Hypothesis 5b

It was hypothesized that consideration of Quotient^{TM} performance *and* EF, as measured by the CEFS, would increase the accuracy of diagnostic classification (i.e., OLD versus OLD/ADHD) over that of either test alone.

A direct logistic regression analysis was performed on ADHD diagnostic status as outcome and predictors of EF and movement: Inhibition and Area (see Table 3 for description), respectively. Predictors were chosen on basis of prior classification analyses (see Table 20). Outliers and extreme values were excluded from analyses resulting in an *n* of 42 (OLD = 18, OLD/ADHD = 24). Predictor variables did not violate multicollinearity assumption, $r(42) = .384$, $p = .012$. A test of the full model with the two predictors against a constant-only model was statistically significant, $\chi 2$ (2, N = 42) = 19.673, $p = .000$, indicating that the predictors, as a set, reliably distinguished between children with an OLD and those with comorbid OLD/ADHD. The amount of variance in ADHD diagnostic status accounted for by the full model is strong, with Nagelkerke R^2 = .502. Overall classification was adequate with a success rate of 78.6%. More specifically, children with comorbid OLD/ADHD could be distinguished from those with only OLD with 79.2% sensitivity (i.e., 19/24 OLD/ADHD correctly classified) and 77.8% specificity (14/18 OLD correctly classified). According to the Wald criterion, Inhibition reliably predicted ADHD diagnosis, β = .183, Wald(1) = 7.673, p = .006; Area approached significance, β = .145, Wald(1) = 3.214, p = .073.

Log-likelihoods of the logistic regressions for Area as the sole predictor and for both Area and Inhibition as predictors were analyzed by computing the difference in their log-likelihoods (times -2) and using a chi-square analysis (Tabachnick & Fidell, 2007). Degrees of freedom (df) are equal to the difference between the df for the bigger (df = 2) and the smaller (df = 1) models. Results indicated that the model with both predictors, Area and Inhibition, is better than the model with only the predictor Area, $\chi 2$ (1, N = 42) = 26.783, p = .000. Despite this, for the purposes of classification accuracy, the addition of the Quotient™ movement variable Area to the model did not improve the overall classification accuracy, sensitivity or specificity.

In addition, for exploratory purposes, analyses were conducted to evaluate the model with predictors Global ADHD and Inhibition. A test of the full model with the two predictors against a constant-only model was statistically significant,

$\chi2$ (2, N = 42) = 20.733, p = .000, indicating that the predictors, as a set, reliably distinguished between children with an OLD and those with comorbid OLD/ADHD. The amount of variance in ADHD diagnostic status accounted for by the full model is strong, with Nagelkerke R^2 = .507. Overall classification was adequate with a success rate of 79.5%. More specifically, children with comorbid OLD/ADHD could be distinguished from those with only OLD with 84% sensitivity (21/25 correctly identified as OLD/ADHD) and 74% specificity (14/19 correctly identified as OLD). According to the Wald criterion, Inhibition reliably predicted ADHD diagnosis, β = .197, Wald(1) = 8.464, p = .004; Global ADHD was not a reliable predictor, β = .323, Wald(1) = 2.418, p = .120.

In sum, although differences among models are significant in terms of the ability of the model to differentiate between groups, classification analyses are quite similar. Overall, it appears that Inhibition, with or without the addition of the Quotient™ specific movement variable Area or the overall Quotient performance score Global ADHD, demonstrates nearly equivalent sensitivity and specificity related to the identification of ADHD in the context of an OLD. See Table 20 for summary of CEFS classification analyses.

EXPLORATORY ANALYSES

Medication and Quotient/ADHD System^{TM} Performance

Hypothesis 1

It was hypothesized that for children diagnosed with ADHD, symptoms of inattention, impulsivity, and hyperactivity, as objectively measured by the Quotient^{TM}, will improve with the ingestion of stimulant medication.

All variables except Omission Errors (%) and Displacement met the normality assumption; non-parametric Wilcoxon Sign tests were used to evaluate this data. All other data were examined using paired t-tests. Due to multiple t-tests and to protect against Type I error, results were Bonferroni corrected prior to evaluating significance. As expected, with regard to Quotient^{TM} variables measuring attention and attentional states (see Table 3), performance while taking prescribed stimulant medication was associated with more accurate performance (i.e., Accuracy), less percent of omission errors (i.e., Omission Errors), quicker response time to the target stimuli (i.e., Response Latency), more consistent response time to target stimuli throughout the duration of the task (i.e., Response Variability), and less duration of the task spent in a distracted state (i.e., Distracted). Contrary to that hypothesized, taking stimulant medication was not significantly associated with less impulsivity (i.e., percent Commission Errors and Impulsivity), fewer shifts in attention (i.e., Attention Shifts), and greater task duration spent responding as instructed (i.e., On Task). As expected, medication performance on the Quotient™ was associated with significantly less movement and better overall performance (i.e., lower Quotient™ scaled scores). See Table 22 for means, standard deviations and results of statistical analyses.

It is noted that if OLD participants prescribed stimulant medication (n = 7), were included in the above analyses, significance of results were unchanged. However, if medication and no medication data for these participants were analyzed separately, even with a sample size of 7, when taking stimulant medication OLD children's response time was more consistent (i.e., Variability), and overall attention was better (i.e., Inattention). However, results did not indicate an improvement in movement with the ingestion of prescribed stimulant medication. It is noted that due to the substantially limited sample size (n = 7), power is substantially reduced; results must be interpreted with caution and are only exploratory in nature. See Table 23 for all means, standard deviations, and results of statistical tests.

In sum, for children with comorbid OLD/ADHD, attention and movement, as measured by Quotient™ performance, improves significantly with the ingestion of prescribed stimulant medication. However, it is noted that changes in a child's impulsivity, as measured by the Quotient™ variables Commission

Errors (%) and Impulsivity, did not improve with ingestion of stimulant medication. Among those without comorbid ADHD but prescribed stimulant medication, medication significantly improved consistency of response time, overall attention (i.e., Inattention), and overall Quotient^{TM} performance. Again, due to the small sample size (n = 7), these later results are only exploratory in nature. Concerns related to overall power will be addressed in the discussion.

ADHD Subtypes versus ADHD Not Otherwise Specified

Hypothesis 2a

It was predicted that children with a “pure” ADHD subtype (i.e., inattentive, hyperactive-impulsive, or combined) would evidence greater impairment in attention, more impulsivity, and more movement, as assessed by performance on the Quotient^{TM}, than children diagnosed as ADHD NOS.

Multiple ANOVAs were employed to evaluate the relationship between ADHD symptom severity per diagnostic label and objectively measured symptoms of inattention, impulsivity, and movement. Analyses were Bonferroni corrected to protect against familywise Type I error. The independent variable was ADHD severity (i.e., ADHD “pure” subtype versus ADHD NOS). Participants diagnosed as ADHD-IA, ADHD-H/I, and ADHD-C were collapsed into one group, ADHD “pure” subtype; participants diagnosed as ADHD NOS comprised the second group. DVs included all Quotient^{TM} variables (see Table 3).

Results of one-way analyses for all Quotient^{TM} DVs were not significant. It is noted, however, that prior to application of Bonferroni correction, group differences on the variables Attention Shifts and Temporal Scaling were significant. More specifically, compared to children with less severe ADHD symptoms (i.e., ADHD NOS), children with a “pure” ADHD subtype demonstrated greater shifts in their attention throughout the 15-minute CPT task on the Quotient^{TM}, F (1, 28) = 5.038, p = .033. Also, children with a “pure” ADHD subtype moved more frequently than those labeled ADHD NOS, F (1, 28) = 5.507, p = .026. In sum, exploratory analyses suggest that the NOS label is not indicative of less severe problems with attention and/or movement, as objectively evaluated on the Quotient^{TM}. However, given the small group sizes, power is substantially reduced and the likelihood of Type II error is high; thus, results must be interpreted with caution.

Hypothesis 2b

It was predicted that children with a “pure” ADHD subtype (i.e., inattentive, hyperactive-impulsive, or combined) will evidence greater impairment in executive function than children with ADHD NOS.

A one-way between subjects MANOVA was performed on five DVs: Social Appropriateness, Inhibition, Problem Solving, Initiative, and Motor Planning. The independent variable was ADHD severity (i.e., ADHD "pure" subtype versus ADHD NOS). One participant was identified as an extreme value on multiple CEFS variables and thus, was excluded from analyses. Group difference in overall EF (i.e., CEFS Total Score) was evaluated separately with the use of an ANOVA. Results were Bonferroni corrected to protect against familywise Type I error. Wilks' lambda criterion, $\Lambda = .868$, indicated that the combined DVs were not significantly affected by ADHD severity, F (5, 20) = .609, $p = .694$. Results of a separate one-way ANOVA for the CEFS Total Score revealed that ADHD severity did not affect overall EF, F (1, 23) = 1.713, p = .203. In sum, exploratory analyses indicate that the NOS label is not indicative of less impairment in EF. However, as with the other exploratory analyses, power is substantially reduced and the likelihood of Type II error is high due to small group sizes; thus, results must be interpreted with caution.

Comparison of ADHD Subtypes

Hypothesis 3a

It was predicted that during the Quotient™ task, the movement of children with ADHD Hyperactive-Impulsive and Combined types would be greater and characterized as more frequent, less complex movement, and covering a greater distance and area than children with ADHD-IA type.

Multiple ANOVAs were employed to evaluate the relationship between ADHD subtype and overactivity. Analyses were Bonferroni corrected to protect against familywise Type I error due to multiple comparisons. Prior to analyses, participants diagnosed as ADHD NOS were assigned to a "pure" ADHD subtype. Decision for group assignment of ADHD NOS participants was based on the relative number of Inattentive and Hyperactive-Impulsive symptoms present per K-SADS-P/L ratings. Of the 13 ADHD NOS participants, 7 were designated as Inattentive type, 1 as Hyperactive-Impulsive type, and 5 as Combined type. Due to the small number of total ADHD participants identified as Hyperactive-Impulsive (n = 3), these subjects were included with the ADHD Combined types (n = 13) for analyses. For all ANOVAs, the independent variable ADHD subtype included two levels: ADHD Inattentive (n = 14) and ADHD Combined (n = 16). DVs included Quotient™ movement variables: Motion, Immobility Duration, Movements, Temporal Scaling, Spatial Complexity, Displacement, and Area (see Table 3 for variable description).

Results of one-way analyses for the above-named DVs were not significant. It is noted, however, that prior to application of Bonferroni correction, group differences on the variable Temporal Scaling was significant, F (1, 28) =

6.096, *p* = 020. More specifically, as expected, children with either ADHD Hyperactive-Impulsive or Combined type moved more frequently during the Quotient^{TM} task of sustained attention. Exploratory analyses also examined differences in attention and attentional processes according to ADHD subtype (i.e., ADHD-IA versus ADHD-H/I or ADHD-C). Analyses of multiple Bonferroni corrected ANOVAs revealed that on the Quotient^{TM}, ADHD subtype did not affect attention. In sum, results indicate that the Quotient^{TM}'s assessment of attention and movement is not sensitive to symptom differences across ADHD type as characterized by the DSM-IV. Again, results are exploratory and must be interpreted with caution given the high likelihood of Type II error.

Hypothesis 3b

It was predicted that the ability to inhibit one's behavior, as measured by the CEFS subscale Inhibition, would be more impaired in children with ADHD Hyperactive-Impulsive or Combined types compared to children with ADHD Inattentive type.

A one-way between subjects ANOVA was employed to evaluate the relationship between ADHD subtype and the ability to inhibit behavior per parent-report. Results were not significant, F (1, 23) = .100, p = .755. Findings indicated that greater impulsivity and hyperactivity associated with the

Hyperactive-Impulsive and Combined types of ADHD as defined by the DSM-IV did not significantly affect behavioral inhibition as reported by parents on the CEFS.

Additional exploratory analyses evaluated EF impairment according to ADHD subtype. A one-way between subjects MANOVA was performed on four other specific areas of executive functioning from the CEFS: Social Appropriateness, Problem Solving, Initiative, and Motor Planning. The independent variable was ADHD subtype (i.e., ADHD Inattentive type versus ADHD Hyperactive-Impulsive or Combined types). Also, group difference in overall EF (i.e., CEFS Total Score) was evaluated separately with the use of an ANOVA. Results were Bonferroni corrected to protect against familywise Type I error.

Wilks' lambda criterion, $\Lambda = .571$, indicated that the combined DVs were significantly affected by ADHD subtype, F (4, 21) = 2.991, $p = .044$, $\eta^2 = .374$. Results revealed a strong association between ADHD subtype and executive functions, with the combined DVs accounting for 37% of the variance associated with ADHD subtype ($\eta^2 = .374$). Results failed to indicate group differences on the DVs Social Appropriateness ($p = .461$) and Motor Planning ($p = .144$). However, children with ADHD Inattentive type had significantly greater difficulty initiating goal-directed behavior (i.e., Initiative), F (1, 23) = 10.216, $p = .004$, $\eta^2 = .308$. Group difference in difficulty with daily problem-solving (i.e., Problem-Solving) was not significant after application of Bonferroni correction, F (1, 23) = 7.714, p = .011, η^2 = .251. Similarly, group difference in overall EF, as measured by the CEFS Total Score, was not significant upon Bonferroni correction (p = .008), F (1, 23) = 5.488, p = .028, η^2 = .193.

In sum, results of EF comparisons between ADHD subtypes reveal that the Inattentive type of ADHD is associated with greater difficulties initiating behavior for the purpose of achieving a pre-defined goal. Overall, analyses suggest greater EF impairment associated with symptoms of Inattentive-type ADHD symptoms. Given the limited power, results must be interpreted with caution; however, findings point to the need for future research with increased group sizes. See Table 24 below for means, standard deviations, and results of analyses.

Table 24. Analyses of Variance to Examine the Impact of ADHD Subtype on Executive Functioning

CEFS Variable	ADHD IA *M* (*SD*)	ADHD HI/C *M* (*SD*)	*F*	*p*	η^2
Inhibition	22.64 (7.86)	21.71 (6.73)	.100	.755	.004
Problem-Solving	28.64 (9.00)	18.21 (9.54)	7.71	.011*	.251
Social-Appropriateness	9.73 (3.41)	8.71 (3.31)	.561	.461	.024
Initiative	12.82 (4.69)	6.64 (4.88)	10.22	.004**	.308
Motor-Planning	8.56 (5.09)	5.43 (5.14)	2.286	.144	.090
Total Score	82.36 (22.56)	60.71 (23.21)	5.488	.028*	.193

Note. ADHD IA = ADHD Inattentive type. ADHD HI/C = ADHD Hyperactive-Impulsive type and Combined type collapsed into one group.
*Result not significant following application of Bonferroni correction (α = .008). **p < .008.

Number and Severity of ADHD Symptoms

Hypothesis 4

It was hypothesized that children with a greater number of threshold (i.e., rated a "3") and subthreshold (i.e., rated a "2") ADHD symptoms will have poor attention and excessive movement, over above that for children with only threshold level symptoms, as assessed by the Quotient Global ADHD score.

Two linear regression analyses were conducted to predict overall inattention and movement. The first analysis included the number of ADHD symptoms rated by clinician as a "3" on the K-SADS-P/L, indicating the symptom is of sufficient severity to meet the diagnostic criterion, as the predictor. The second analysis included the total number of threshold *and* subthreshold ADHD symptoms as the predictor; subthreshold symptoms were rated as a "2" on the K-SADS-P/L indicating that the symptom is present, but not severe enough to meet a diagnostic criterion. The regression equation with only number of threshold ADHD symptoms was significant, *R2* = .205, adjusted R^2 = .189, $F(1, 49) = 12.652$, p = .001. The regression equation with threshold and subthreshold ADHD symptoms was also significant, R^2 = .209, adjusted R^2 = .176, $F(2, 48) = 6.326$, $p = .004$. However, including number of subthreshold ADHD symptoms did not predict inattention/movement over and above the number of threshold ADHD symptoms, R^2 change = .003, $F(1,48) = .205$, $p = .653$. Based on these results, consideration of subthreshold ADHD symptoms appears to offer little additional predictive power of overall inattention/movement, as assessed by the Quotient™ Global ADHD score, beyond that contributed by the number of threshold ADHD symptoms identified as meeting the diagnostic criterion(s).

CHAPTER SIX
Discussion

OVERVIEW OF THE STUDY

The current study was designed to evaluate the impact of comorbid ADHD on attention, movement, and EF in children with an identified oral language disorder (OLD). Previous research has demonstrated a substantial overlap in the qualitative expression of symptoms associated with OLDs and ADHD. Clinicians are frequently faced with the difficulty of trying to determine if a child has ADHD, if symptoms of an OLD are manifesting as problems with attention or behavior, or if both conditions are present. Without accurate diagnosis, children are likely to go without appropriate treatment, contributing to continued academic, social, emotional, and familial difficulties.

Shared symptomatology of OLDs and ADHD threaten the internal validity of standardized measures of language, cognition, and behavior, contributing to inaccurate diagnosis and potentially creating artificially inflated comorbidity rates. Unfortunately, the availability of assessment instruments to facilitate the differential diagnostic process is substantially limited. Researchers must work to identify assessment tools that support a more reliable and valid evaluation of ADHD when language problems are present. Prior research has demonstrated that the Quotient™, an objective assessment of attention and movement, and the CEFS, a parent report of EF, successfully discriminate between ADHD children and their non-ADHD peers (Silver et al., 1999; Teicher et al., 1996). However, research on the usefulness of these instruments for the evaluation of ADHD in the context of an OLD, or more generally, in the context of an LD, is lacking.

The primary aim of this study was to explore attention and movement differences in children with an OLD and comorbid OLD/ADHD, and how performance in these domains, as objectively measured by the Quotient™, can be useful in assisting with accurate diagnosis of comorbid ADHD. A secondary aim was to evaluate the impact of comorbid ADHD on EF and to evaluate the utility of the CEFS, a parent-report of executive functions, for the accurate identification of ADHD in the context of an OLD. A third aim was to clarify the nature of working memory deficits associated with OLD and comorbid OLD/ADHD.

Participants included 51 students enrolled in a specialized language intervention program (LI) at the Shelton School in Dallas, Texas. Enrollment in the LI program was based on identification of an OLD; 30 of these children were diagnosed with comorbid ADHD. Attention and movement were assessed using the Quotient™, a 15-minute CPT that objectively quantifies a child's movement while he/she completes this task of sustained attention. Evaluation of EF was based on parent completion of the CEFS. Subtests of verbal and visual-spatial working memory from the WISC-IV Integrated were administered to child participants. For participants prescribed stimulant medication, medication ingestion was delayed until the completion of the Quotient™ and tests of working memory; children prescribed Stratterra were excluded from the study. Analyses of variance were conducted for Quotient™ variables of attention and movement, individual EF domains, overall EF, and working memory. Logistic regression and discriminant function analyses were employed to evaluate the predictive reliability of the Quotient™ and the CEFS for the identification of ADHD in the context of an OLD.

THE QUOTIENT/ADHD SYSTEM™

Impact of Comorbid ADHD on Attention

Inattention is a core symptom of ADHD and a common manifestation of weakness in oral language (APA, 2000; Paul, 1995). Researchers posit that language mediates attentional processes and hypothesize that inattention related to an OLD is attributable to impaired language processing (Baird, Stevenson, & Williams, 2000). CPTs offer an objective measure of attention and are frequently included in ADHD evaluations (Nass, 2006; Nichols & Waschbusch, 2004; Plizka et al., 2007). The Quotient™, a relatively new commercially available CPT, is the instrument under investigation in the current study. Prior research has consistently demonstrated impaired CPT performance in ADHD children compared to normal controls (Doyle et al., 2000; Nigg, 2001). Although a substantial number of studies have utilized the Quotient™ for the purposes of evaluating the pharmacological treatment of ADHD, to date only two published studies have used this measure to compare healthy controls and ADHD children (Teicher et al., 1996; Teicher et al., 2004).

It is noted that for comorbid OLD/ADHD, prior research on the specificity of the CPT for the attentional problems of ADHD limited and mixed. As reviewed, this body of literature is marked by substantial limitations including procedures for ADHD and OLD/LD diagnosis, medication confounds, and inherent weaknesses in the CPT measure itself. This makes it difficult to conclude about the usefulness of the CPT when ADHD and other language/learning problems are present. The current study aimed to improve upon previous research in terms of test selection (i.e., Quotient™ versus more traditional CPTs), group assignment procedures, and elimination of stimulant medication use during testing.

It was expected that given the minimal involvement of language for task completion, children with comorbid OLD/ADHD would demonstrate significant impairment in attention, as quantified by the Quotient™. Analysis of overall attention impairment (i.e., MANOVA) did not support this hypothesis. Given the lack of previous research with the Quotient™ among language impaired children, exploratory analyses examined the degree and direction of group differences on specific Quotient™ variables identified as evaluating attention.

For the present study, percent of omission and commission errors were similar for both groups. Despite the lack of significance, the group difference in percent of Omission Errors was in the expected direction; OLD/ADHD children failed to respond to the target stimulus for a greater percentage of the total responses. Group difference on percent of Commission Errors was not in the expected direction, but groups differed only by 0.6 percent. It is noted that results of prior Quotient™ research for differences in percent of omission and commission errors for ADHD children compared to non-ADHD normal controls are inconsistent (Teicher et al., 1996; Teicher et al., 2004). This research and findings of the current study for percent omission and commission errors is summarized in Table 25 below.

Table 25. Quotient™ Research: Percent Omission and Commission Errors

Study	Groups	Sample size	Omission	Commission
Teicher et al., 1996	HC	*n* = 11	3.0 ± 5.9	17.3 ± 13.2
	ADHD	*n* = 18	7.7 ± 8.8	29.9 ± 23.6
	[a]*p*-value		.057	.114
Teicher et al., 2004	HC	*n* = 8	1.2 ± 1.3	11.6 ± 7.9
	ADHD	*n* = 60	13.1 ± 14.7	27.9 ± 19.5
	[a]*p*-value		.030	.030
Current study	OLD	*n* = 21	11.9 ± 13.6	25.6 ± 15.3
	OLD/ADHD	*n* = 30	19.4 ± 16.2	25.0 ± 17.5
	[a]*p*-value		[c].092	[c].896

[a]*p-value* based on F-test. [b]Group comprised of children who met ICD-10 criteria for hyperkinetic disorder or attention deficit disorder without hyperactivity. [c]Data analyzed was log-transformed.

Inconsistency in prior Quotient™ research may be attributable to actual differences in CPT length. Percent of errors in the 1996 study was based on average percent over three 5-minute CPTs completed within 30 minutes. CPT task in the 2004 study is the same as the current study, one 15-minute test, and values represent percent of errors across the entire 15-minute task. In light of the 2004 Quotient™ data described in Table 25, lack of group differences in the current study suggest that despite the minimal involvement of oral language for task completion, attentional impairment in an OLD does affect CPT performance. Thus, for a child with an identified OLD, values for percent omission and commission errors are not reliable indicators of ADHD comorbidity. Findings of the present study are in fact consistent with the majority of prior CPT research, which reveals significant group differences for ADHD children and healthy controls, but similar performance in comparisons of ADHD and LD. Thus, despite the current study's methodological improvements in design and measurement, one cannot conclude that the impairment in attention, as indicated by percent of omission and/or commission errors, is specifically reflective of ADHD. Findings are important given that CPT omission and commission errors rates are commonly interpreted as indicators of attention problems associated with ADHD.

Unlike other commercially available CPTs, the Quotient™ provides information regarding overall performance Accuracy (i.e., percent of correct responses). Prior Quotient™ research has revealed a significant association between putamen abnormalities in ADHD and less accurate CPT performance; but has indicated similar performance accuracy between ADHD children and healthy controls (Max et al., 2002; Teicher et al., 1996). The lack of significance in the 1996 study was thought to be a result of low power as a consequence of the small group sizes. In addition, Accuracy values in the 1996 study reflected average performance accuracy over three five-minute testing sessions. Given that Quotient™ task in the current study was 15-minutes, it was thought that performance accuracy would diminish with increasing time on task, thus resulting in significantly less accurate performance in children with comorbid OLD/ADHD. However, despite increased task length and larger group sizes, results of the current study do not support examination of overall performance accuracy (i.e., Accuracy) on the Quotient™ for the evaluation of attention problems associated with ADHD when an OLD is present. See Table 26 below for a summary of relevant Quotient™ research on performance accuracy.

Table 26. Quotient™ Research: Overall Performance [a]Accuracy

Study	Groups	Sample size	Accuracy (%)	[b]*p*
Teicher et al.	HC	*n* = 11	90.0 ± 8.6	.069
1996	ADHD	*n* = 18	81.3 ± 14.7	
Current study	OLD	*n* = 21	81.1 ± 11.2	.360
	OLD/ADHD	*n* = 30	77.8 ± 13.7	

[a]Accuracy is defined as percentage of correct responses. [b]*p*-values based on results of *F* tests.

Informal comparison of mean Accuracy values for OLD children in the current study, and ADHD children in the prior study (i.e., Teicher et al., 1996; see Table 26 above) suggests that the presence of an OLD impacts sustained attention. This would imply that the attentional problems observed in children with an OLD are not merely a "by-product" of impaired language processing. It must be emphasized that this is only a hypothesis. To empirically evaluate the attention problems evidenced on a CPT that are unique to an OLD, comparison of healthy controls to OLD children and pure ADHD to comorbid OLD/ADHD children, sampled from the same population, would be needed. Findings point to the importance of such Quotient™ research in the future.

If the proposed research revealed impaired attention in OLD children compared to healthy controls, and poorer attention in children with comorbid OLD/ADHD versus children with an OLD, one may hypothesize that the attentional impairment in an OLD is not merely an outward consequence of poor language processing, but it attributable to problems in the brain's attentional networks. In this case, more traditional treatments for attention, such as pharmacotherapy, may be warranted for addressing the attentional problems in an OLD.

In fact, researchers have asserted that the frontal lobe dysfunction associated with ADHD is also common to LDs (Lazar & Frank, 1998; Shaywitz et al., 1995). Recent functional brain imaging research has uncovered the “causal” role of disrupted attentional mechanisms in dyslexia (Shaywitz & Shaywitz, 2008). Findings prompted research on the use of pharmacotherapy as an adjunct treatment for improving the reading fluency of dyslexic students. Preliminary studies have suggested that medications used to treat ADHD are effective in improving reading in dyslexic students with and without ADHD (e.g., Bental & Tirosh, 2008; Grizenko, Bhat, Schwartz, Ter-Stepanian, & Joober, 2006; Keulers et al., 2007). Results of imaging and pharmacotherapy research in dyslexic children point to the need for similar research among children with impaired oral language. Future research should also consider investigating the potential efficacy of fish oil for OLDs as there is preliminary empirical evidence for the use of omega-3 fatty acids in the treatment of ADHD, dyslexia, developmental coordination disorder, and autism (Richardson, 2006).

Similar to traditional CPTs, the Quotient™ evaluates variability and latency in response time, which are interpreted as indicators of processing speed (Stins et al., 2005). Research has identified processing speed deficits as common to OLDs and ADHD, and prior CPT research consistently indicated such deficits in ADHD children compared to healthy controls (Dickerson & Calhoun, 2007; Shanahan et al., 2007; Stins et al., 2005; Teicher et al., 1996). Due to the impact of comorbid ADHD on the already weak processing speed associated with an OLD, it was expected that children with comorbid OLD/ADHD would demonstrate significantly greater Response Variability and longer Response Latency. Results failed to indicate significant group differences on these variables, but differences were in the expected direction. Thus, it appears that comorbid ADHD does not significantly impact processing speed deficits related to an OLD. Hence, results suggest that if evaluating a child with an identified OLD for comorbid ADHD, processing speed as measured by the Quotient™ does not contribute information to enhance the accuracy of the ADHD evaluation.

Unlike other commercially available CPTs, the Quotient™ evaluates a child's attention states throughout the duration of the 15-minute task, offering substantial qualitative information regarding a child's attentional processes. Prior Quotient™ research revealed that compared to healthy controls, ADHD children shift their attention more frequently, spend less time "On Task" and more time responding impulsively (see Table 27 below) (Teicher et al., 2004). Given the focus of the current study, it should be noted that Teicher and colleagues (2004) included 4 children with a reported LD in the ADHD group. Results of the current study related to attention shifts and "On Task" performance are not consistent with prior research. Contrary to that expected, OLD and OLD/ADHD children evidenced a similar number of shifts in their attentional state, and amount of time "On Task" (i.e., hitting *many* targets and *few* non-targets) was not significantly different between groups; however, group differences in "On Task" performance was in the expected direction.

As expected, children with comorbid OLD/ADHD spent a *substantially* greater percentage of time Distracted (i.e., hitting some targets and some non-targets) (p = .013), but this difference was not significant following Bonferroni correction. It seems probable that lack of significance may be a consequence of Type II error associated with the small group sizes. Results of a power analysis indicate that to detect differences with 80% and at a Bonferroni corrected alpha level of .0125, a sample size of 182 subjects is needed. It is noted that this is the first attention variable on the Quotient™ that seemed to capture the attentional differences in OLD and OLD/ADHD children. This is an important finding given that the Quotient™'s manner of characterizing disruptions in sustained attention is unique and may be more specific to the attentional impairment in ADHD, thereby facilitating the differentiation of OLD and OLD/ADHD. Without a healthy control group and pure ADHD group for comparisons, however, the specificity of the variable Distraction for the attention deficit associated with ADHD is unclear. Based on the current study and the earlier 2004 study, it appears that attention state variables provide valuable information regarding attentional processes of ADHD children. However, given the extremely disparate sample sizes of the 2004 evaluation of healthy controls and ADHD children, findings should be interpreted with caution. Consideration of the current study and the 2004 study points to the need for future research, with a substantially increased *N*, to explore the relation between "distractability" on the Quotient™ and ADHD.

Table 27. Comparisons among Healthy Controls, OLD, ADHD and Comorbid OLD/ADHD on Quotient™ Variables of Attention State

	[a]HC	[a]ADHD		[b]OLD	[b]OLD/ADHD	
	n = 8	n = 60		n = 21	n = 30	
	$M \pm$ SD	$M \pm$ SD	[a]p	$M \pm$ SD	$M \pm$ SD	[b]p
1	5.4 + 5.7	12.8 + 4.3	.000	14.3 +5.1	14.9 + 4.0	.659
2	82.4 + 20.4	42.6 + 30.3	.000	41.5 + 30.7	34.0 + 25.9	.396
3	1.9 + 2.8	11.0 + 13.1	.060	13.6 + 11.0	24.6 + 18.2	.013
4	14.8 + 18.5	32.7 + 18.8	.020	29.0 + 16.9	20.6 + 16.9	.085

Note. 1 = Attention Shifts. 2 = On Task. 3 = Distracted. 4 = Impulsive
[a]Data and *p*-values based on *F* tests from comparison of HC and ADHD in Teicher et al., 2004.
[b]Data and *p*-values based on *F* tests from comparison of OLD and OLD/ADHD in current study.

Before concluding the discussion of state variables (e.g., Distracted), attention must be given to findings for the variable "Impulsive." Generally speaking, results of the present study for Quotient™ variables purported to evaluate impulsive responding are puzzling. Contrary to that hypothesized, group difference on the attention state variable "Impulsive" was not significant. More importantly, however, children *without* comorbid ADHD spent a greater percentage of the task responding impulsively (i.e., hitting *many* targets *but* also hitting *some* non-targets); this difference approached significance (p = .08). Furthermore, exploratory analyses indicated that for OLD/ADHD participants, average time spent in an "Impulsive" state and percent of Commission Errors did not improve with the ingestion of stimulant medication; these were the only two Quotient™ variables not significantly affected by stimulant medication.

In an effort to understand the meaning of this discrepancy, the author investigated the association between Impulsivity and Distractibility. Teicher et al. (2004) asserted that the Quotient™ variables "Distracted" and "Impulsivity" reflect "distinct states…and percent of time in any one inattentive performance state seems to provide no information about the time spent in another inattentive state" (p. 229). However, in the current study, "Distracted" and "Impulsive" are significantly related, $r(49) = -.414$, $p = .003$; as percentage of time responding in a "Distracted" state *increases,* time spent responding impulsively *decreases*. "Impulsive" is described by the makers of the Quotient™ as "hitting *many* targets and *some* nontargets," while Distracted is described as "hitting *some* targets and *some* nontargets." Thus, perhaps OLD participants are not responding more "impulsively" as indicated by the variable name, but rather are hitting *sufficient* targets and thus the response style is described as "Impulsive" rather than "Distracted." On the other hand, the OLD/ADHD participants may spend just as much time hitting *some* non-targets but because they are missing more targets, the response style is labeled "Distracted."

It seems that further research needs to clarify the nature of these Quotient™ variables, and more specifically, quantify what is meant by "*some*" versus "*many*." In fact, Teicher and colleagues (2004) have noted that these categorizations of attentional state are “without empirical justification.” Moreover, attention may shift more quickly than in 30-second increments, as quantified by the variable Attention Shifts. Thus it is possible that fluctuations in the attention of the children in the current sample were more rapid; hence, values for percent of time spent On Task, Distracted, or Impulsive may not be valid. It is noted that according to Teicher et al. (2004), attentional state shift data has been collected in a community sample of 1185 children; to date, however, a report on this data has not been published.

It is likely quite evident to the readers that there are a substantial number of attention-related variables on the Quotient™, and as mentioned, correlational analyses indicate substantial overlap among variables. From a clinical perspective, it is helpful to understand which of these attentional variables is/are the best indication of the attentional problems associated with ADHD. Moreover, from a practical standpoint, in the context of an evaluation, clinicians must be mindful to not overwhelm parents with data, interfering with their overall understanding of their child’s difficulties. A clear understanding of the nature of their child’s difficulties will likely empower them and guide them in their pursuit of appropriate treatment/intervention.

It seems likely that the Quotient™’s Inattention scaled score may provide clinicians and parents with the best overall understanding of the severity of a child’s attentional problems. For the present study, OLD and OLD/ADHD participants' overall attention as assessed by the Inattention scaled score on the Quotient^{TM} was not significantly different. However, the group difference approached significance ($p = .063$) and was in the expected direction with OLD/ADHD participants scoring higher on the variable Inattention, indication of greater attentional impairment. Again, it seems probable that this lack of significance is attributable to the relatively small sample size compared to that needed to detect group differences of medium effect size, at a Bonferroni corrected alpha level and with 80% power (i.e., $N = 200$).

It is noted that Quotient^{TM} scaled scores became available to clinicians in January 2009; at this point in time, research on the scaled scores is unpublished. However, consultants for BioBdx (the maker of the Quotient^{TM}) and Quotient^{TM} researchers report that children with ADHD score greater than or equal to a 7 on Quotient^{TM} indices of Inattention, Motion, and Global ADHD performance (C. Hughes, personal communication, April 9, 2009; L. Cerfolio, personal communication, January 8, 2009). Scores in this study's sample are consistent with this; OLD/ADHD children earned a mean Inattention score of 7.74 compared to a 6.52 by OLD participants. It is noted that although the mean Inattention scaled score for OLD participants was below that indicative of ADHD, without a normal control group, it is unclear if a score of this magnitude denotes an attentional impairment. The lack of normative comparison data is a weakness of this instrument and will be addressed in the discussion of methodological limitations.

The Impact of Comorbid ADHD on Movement

The DSM-IV identifies hyperactivity as a defining feature of Hyperactive-Impulsive and Combined subtypes of ADHD (APA, 2000). However, research has demonstrated that overactivity is strongly associated with inattention, regardless of ADHD subtype (APA, 2000; Halperin et al., 1992). Moreover, with respect to OLDs, there is an association between an OLD and parent/teacher report of hyperactivity, but in general, the degree of overactivity is not clinically significant (Botting & Conti-Ramsden, 2000; Stanton-Chapman et al., 2007).

Studies have consistently supported the utility of an objective assessment of movement for the evaluation of ADHD (Dan et al., 2000; Teicher, 1995). Yet, to date, no studies have objectively evaluated movement associated with an OLD. Based on differing degrees of overactivity associated with ADHD versus an OLD, it seems probable that an objective assessment of movement, such as that provided by the Quotient™ may facilitate accurate identification of ADHD when a comorbid OLD is present. Such information is particularly important in light of the current study's finding that in general, OLD and OLD/ADHD do not differ significantly with respect to inattention as assessed by the Quotient™ CPT.

For the current study, it was predicted that during the 15-minute Quotient™ CPT, children with comorbid OLD/ADHD would evidence significantly greater movement than children with an OLD, and movement would be qualitatively more similar to that of ADHD children as described in prior Quotient™ research (e.g., more linear movement). As hypothesized, group differences on Quotient™ variables Area and Spatial Complexity were significant; OLD/ADHD participants' movement covered a greater amount of space (i.e., Area), and was characterized as more linear and less complex (i.e., Spatial Complexity). Group differences for Quotient™ movement variables Immobility Duration, Movements, and Displacement were in the expected direction, but were not significant after application of a Bonferroni correction. Group differences in the frequency of movement (i.e., Temporal Scaling) approached significance ($p = .05$), with OLD/ADHD children moving more often.

Findings cannot be compared to previous research since to date no studies have objectively evaluated the overactivity associated with an OLD. However, findings can be considered in light of previous Quotient™ research evaluating the activity of ADHD children ($n = 18$) and healthy controls ($n = 11$) (Teicher et al., 1996). Results of Teicher et al. (1996) revealed that all Quotient™ movement values were in the pathological direction for ADHD children.

Although between-group movement differences for Area and Spatial Complexity reached the stringent alpha level of .007 for only two variables, it seems futile to hypothesize about the “lack of significant group differences” in the current study when differences on other movement variables achieved alpha levels of .009 and .008. Moreover, the significant correlations among movement variables suggest that Quotient™ movement variables are measuring much of the same thing. Thus, a less stringent alpha may be warranted. Furthermore, results of a power analysis indicate that a sample size of 204 is needed to detect group differences of a medium effect size, at a Bonferroni corrected alpha level, and with 80% power; thus significance level in the current study may be related to its relatively small sample size.

It is also noted that similar to the Quotient™’s provision of an overall indication of attention (i.e., Inattention scaled score), there is a scaled score for overall movement (i.e., Motion). Evaluation of overall movement revealed significantly greater movement for OLD/ADHD children compared to those without comorbid ADHD. Furthermore, it is important to note that the Motion mean score was 7.18 for OLD/ADHD participants and 5.13 OLD participants. Findings are consistent that of recent field research, which found that children with ADHD tend to earn a score for Motion that is 7 or greater (C. Hughes, personal communication, April 9, 2009; L. Cerfolio, personal communication, January 8, 2009). In sum, overall results of movement analyses support examination of activity, as objectified by the Quotient™, for the evaluation of ADHD when there is a comorbid OLD diagnosis. It appears that movement is an important factor to consider, even if reported ADHD symptoms are not indicative of the Hyperactive/Impulsive or Combined subtypes.

The lack of a control group is a limitation of the current study as questions regarding the level of activity associated with an OLD compared to “normal” movement of healthy controls remain unanswered. It is surprising that of all the studies evaluating the Quotient™, or its earlier versions (i.e., MMAT and OPTAx) (see Table 2 for review), Teicher et al.’s 1996 study is the only one comparing ADHD and healthy controls on movement variables. Given the sophistication of the Quotient™ for the objective assessment of movement, it is important that future researchers replicate Teicher and colleagues’ findings, and continue to evaluate this instrument’s capacity to differentiate ADHD children from normal controls according to their activity.

It should be mentioned that results of movement analyses offer some insight on the utility of Quotient™ movement variables. Despite their ability to quantify specific characteristics of a child’s movement, in reality they are highly related and seem to provide little clinically relevant information when considered separately. This is not meant to minimize the importance of continued research on these variables and how specific aspects of movement may relate to certain disorders (e.g., movement in ADHD versus overactivity related to anxiety). It is clear that despite the usefulness of the Quotient™'s evaluation of activity, continued research on Quotient™ movement variables is necessary. Furthermore, relative to ADHD specifically, future research should examine the incremental validity of the individual movement variables for the objective evaluation of overactivity common to ADHD. From a clinical perspective, results of the current indicate that the Motion scaled score is likely the most useful for understanding the severity of a child's overactivity and for communicating results to parents and educators.

The Quotient™ also offers a Global ADHD score that is a combination of the Inattention and Motion indices. As predicted, groups differed significantly on the Global ADHD score. Children with comorbid OLD/ADHD scored significantly higher than OLD children. Mean scores were 7.46 for participants with comorbid OLD/ADHD and 5.82 for children with only an OLD. Results for OLD/ADHD participants are consistent with recent field research, and indicate greater difficulty sustaining attention and/or limiting activity during the Quotient™. Group differences on the Global ADHD score should not be interpreted as OLD/ADHD children having significantly worse attention and/or overactivity; this score does not offer any indication of the relative severity of these problems. Future research should examine the convergent validity of these indices in an effort to gain an understanding of how problems with sustained attention and overactivity on the Quotient™ relates to ADHD symptoms in real-life academic and/or social situations for instance.

Utility of the Quotient/ADHD System™ for Diagnosis

In addition to evaluating the impact of comorbid ADHD on attention and movement as measured by the Quotient™, the current study evaluated the utility of this instrument for the accurate identification of ADHD in the context of an OLD. Prior research has supported the use of the Quotient™ for the identification of ADHD among healthy controls (Teicher et al., 1996), but its usefulness in learning disabled children is unknown. The current study evaluated the utility of the Quotient™ for this purpose via logistic regression analyses.

Consideration of the Quotient™'s ability to reliably predict ADHD in the presence of an OLD warrants attention to the relative importance of sensitivity versus specificity of ADHD diagnosis. That is among children with an OLD, does Quotient™ performance tend to *"over-identify"* the presence of ADHD, or does the Quotient™ fail to support a diagnosis of comorbid ADHD even though other reliable data indicates that a child does meet diagnostic criteria for ADHD? Despite such questions, it must be emphasized that the aim of the current study is not to identify the Quotient™ as a "diagnostic instrument." In fact, the developers of the Quotient™ assert that "…results should be used as part of a comprehensive diagnostic evaluation, not as a substitute for the diagnostic process itself. Treatment decisions…should not be based on Quotient™ test results."

However, given the sometimes difficult evaluation of ADHD, especially in the context of an OLD or other LD, diagnostic status may be questionable even following a fairly thorough evaluation. As a result, clinicians may over rely on the Quotient™ for diagnostic purposes; hence the need to examine sensitivity and specificity of Quotient™ scores and the need to consider the risks and benefits of "over-diagnosing ADHD" versus "under-diagnosing ADHD." For instance, in the presence of an OLD, if ADHD goes unidentified, a child is likely to go without appropriate treatment, not only contributing to academic, social, and emotional difficulties but probably limiting the effectiveness of academic and language therapy/interventions. Yet, if a child with an OLD is diagnosed with ADHD on the basis of Quotient™ performance and this diagnosis is inaccurate, then a child may receive pharmacological treatment for ADHD unneccesarily.

Overall, results of logistic regressions in the current study support the use of the Quotient™ in the diagnostic process of ADHD when an OLD is present. More specifically, the movement variable Area and the Global ADHD score separately, but reliably, predicted ADHD comorbidity (refer to Table 20 for summary of analyses). Despite the significance of both logistic models, the primary interest of the current study is classification accuracy. Comparison of models reveals little variability in ADHD diagnostic accuracy; values for sensitivity and specificity vary slightly, but differences must be interpreted with caution given the relatively small group sizes (e.g., accurate classification of one more participant results in what appears to be a substantial change in sensitivity and specificity).

In a previous evaluation of the clinical utility of the Quotient™ for differentiating ADHD children from non-ADHD healthy controls, Teicher and colleagues (1996) found that Quotient™ variables Response Accuracy, Response Variability, and Spatial Complexity accurately identified 16 of 18 ADHD children and 11 of 11 non-ADHD controls. The current study attempted to replicate this finding in the case of comorbid OLD/ADHD versus OLD. Results supported the use of the variable Spatial Complexity for reliably predicting comorbid ADHD in the context of an OLD. However, despite a significant model, overall accuracy of 77.8% and sensitivity of 92.6%, this model inaccurately assigned an ADHD diagnosis to 8 of the 18 children who did not meet ADHD diagnostic criteria based on K-SADS-P/L ratings. Thus, it appears that among children with an OLD, the variable Spatial Complexity is able to account for movement associated with ADHD but is not specific to movement uniquely associated with ADHD, resulting in the “over-identification” of ADHD.

The variables Response Accuracy and Response Variability contributed significantly to Teicher and colleagues’ (1996) model but failed to contribute to the model for the current study. This is likely attributable to the possible impact of attention problems associated with an OLD on the Quotient™. It is noted that Teicher et al. (1996) specifically stated that children with a "severe LD" were excluded from their study. Given the potential advantages of the Quotient™ for ADHD evaluations, future research must aim to replicate the findings of Teicher et al. (1996), especially given the small sample size in that study. Furthermore, continued efforts should be made to continue the evaluation of the Quotient™ for the differentiation of attention problems associated with ADHD and those common in non-ADHD LDs, such as an OLD.

EXECUTIVE FUNCTIONING

Impact of Comorbid ADHD on EF

Although research has revealed EF deficits in both ADHD and OLDs, studies of such deficits in comorbid OLD/ADHD are lacking. As hypothesized, compared to children with an OLD, OLD/ADHD children attained significantly higher scores on the Inhibition subscale and the CEFS Total Score. Results indicate that among children with an OLD, comorbid ADHD predicts poorer overall EF and limited ability to inhibit his/her behavior when necessary. It is noted that items on the Inhibition subscale closely resemble DSM-IV criteria (e.g., "is easily distracted," "interrupts others," "cannot sit still," etc.), and most parents completed the CEFS immediately following the K-SADS-P/L and receiving feedback on their child's performance on the Quotient™. Thus, it is possible that parents of children with comorbid ADHD endorsed items in the positive direction as an artifact of the preceding discussion of their child's behavior in relation to ADHD symptoms. However, findings regarding Inhibition are consistent with the prominent inhibition theory of ADHD (Barkley, 1997; Brown, 2005); therefore, it would be erroneous to attribute impaired inhibition of behavior to simply to "order effects" (e.g., K-SADS-P/L completed first).

Regarding other areas of EF as measured by the CEFS, comorbid ADHD did not significantly affect a child's ability to initiate behavior aimed at achieving some goal (i.e., Initiative) or his/her ability to complete tasks that involve planned behavior (i.e., Motor Planning). However, prior to application of a Bonferroni correction, group differences in Problem Solving (e.g., "cannot see more than one way to solve a problem") and Social Appropriateness (e.g., "laughs at the wrong time") were significant, with comorbid ADHD having a negative impact on these areas of EF. It is also noted that both of these subscales are significantly positively correlated with the Inhibition subscale (see Table 17). It is noted, however, that compared to other subscales, effect size value for Inhibition indicates that this aspect of EF uniquely accounts for a strong amount of variance associated with ADHD status, suggesting that problems inhibiting behavior may be more specific for the EF difficulties in ADHD.

Another explanation for the lack of significant group differences on CEFS subscales, with the exception of Inhibition, is the occurrence of Type II error. In fact, results of a power analysis indicates that a sample size of 200 is necessary to achieve 80% statistical power for *F* tests using the desired medium effect size for this statistic (i.e., 0.25) and a Bonferroni corrected alpha level of .008 as the criterion for significance. Also, it is noted that CEFS responses are based on a four-week period of behavior, regardless of a child's medication status; thus, it is likely that for a child taking stimulant medication, parent ratings on the CEFS were less severe given the impact of such medication on EF in ADHD children. Thus, perhaps in reality group differences on individual subscales were larger, but parent ratings of their child's behavior were tempered as a consequence of stimulant medication usage.

Despite the lack of significant differences on some CEFS subscales, overall EF impairment associated with the impact of ADHD, even in the context of an OLD, is consistent with empirical evidence of robust differences in EF between ADHD and non-ADHD controls (Doyle et al., 2000; Willcutt et al., 2005). This evidence includes, but is not limited to, EF impairment per elevated CEFS scores in ADHD children compared to normal controls (Molho & Silver, 1997). Overall, findings of the current study support the use of the CEFS for the assessment of EF impairments associated with ADHD among children with an identified OLD.

In fact, use of a parent-report instrument for the evaluation of EF in this population of children in particular is especially useful given the possible impact of impaired language on a child's performance on standardized, individually administered tests of EF. Such tests involve oral language to varying degrees, and hence, identified deficits on testing may be at least partially attributable to impaired language processing rather than a reflection of the specific EF measured by the test. For an ADHD evaluation in a child with a previously identified OLD, it may be advisable to use the CEFS in combination with other standardized measures of EF; inconsistent results across measures may offer useful clinical information regarding the effects of a child's oral language weakness on tests performance.

As previously mentioned, a limitation of the current study is the lack of a control group or a pure ADHD group. As a result, questions regarding the impact of an OLD on executive functions, as assessed by the CEFS, remain unanswered. Given the high comorbidity of ADHD and OLD, and EF deficits associated with OLDs, future research on the CEFS in language, and learning disordered populations in general, is important. Such research would further our understanding of this complicated, multi-faceted cognitive construct, and offer valuable information related to enhancing the evaluation process for both OLDs and ADHD.

Utility of the CEFS for Diagnosis

In addition to examining the impact of comorbid ADHD on EF in children with an OLD, the current study also evaluated the utility of the CEFS in isolation and in combination with the Quotient™ for the diagnosis of ADHD in the presence of impaired oral language. Prior research has supported the use of the CEFS for distinguishing between ADHD and non-ADHD children (Molho & Silver, 1997). Results of discriminant function analyses supported the use of the CEFS Inhibition subscale for the reliable prediction of comorbid ADHD in the context of an OLD. Similar to Quotient™ analyses, of particular interest is the ability of this subscale to accurately classify those with and without comorbid ADHD (i.e., OLD/ADHD versus OLD). The Inhibition subscale had an overall classification accuracy of 79.1% with nearly equal sensitivity and specificity, 80% and 77.8%, respectively. Addition of Quotient™ scores to the logistic model for Inhibition contributed to the overall variance in ADHD diagnostic status accounted for by the predictor variables, but classification accuracy and rates of sensitivity and specificity remained relatively unchanged.

Empirical support of the Inhibition subscale on the CEFS for the diagnosis of ADHD, even in the context of an OLD, is consistent with recent research on the utility of the Behavior Rating Inventory of Executive Function (BRIEF; (Gioia, Isquith, Guy, & Kenworthy, 2000), a parent and teacher rating scale of

EF, for ADHD diagnosis (McCandless & O'Laughlin, 2007). Similar to results of the current study, McCandless and O'Laughlin found that parent report of a child's ability to inhibit his/her behavior, as measured on the Inhibit scale of the Behavioral Regulation Index on the BRIEF, predicted ADHD diagnostic status with 77.1% overall classification accuracy. See Table 28 below for summary of classification rates for the CEFS Inhibition subscale and the BRIEF Inhibit scale.

Table 28. Utility of Parent-Report Measures of Behavior Inhibition for ADHD Diagnosis

			Predicted Group Membership	
Study	Actual Group	Cases	ADHD Present	No ADHD
[a]BRIEF	Non-ADHD	25	6	19
			24.0%	**76.0%**
	ADHD	45	35	10
			77.8%	22.2%
[b]CEFS	OLD	18	4	14
			22.2%	**77.8%**
	OLD/ADHD	25	20	5
			80.0%	20.0%

[a]McCandless et al., 2007; predictor was parent rating on the Inhibit scale of the BRIEF and overall classification accuracy was 77.1% . [b]Current study; predictor was parent rating on the Inhibition subscale of the CEFS and overall classification accuracy was 79.1%.

The Impact of ADHD on Working Memory

The literature on working memory deficits in these populations (i.e., OLD and ADHD) is inconsistent and marked by a number of confounds limiting the validity and generalizability of findings. The present study aimed to improve upon previous research in this area through the use of standardized diagnostic procedures, eliminating the confound created by the impact of stimulant medication on WM performance, assessing WM with the use of standardized measures, and examining verbal and visual-spatial WM separately. It was hypothesized that children with comorbid OLD/ADHD would evidence significantly poorer visual-spatial working memory; although group differences were in the expected direction, differences were not significant. Exploratory analysis of verbal WM was not significant, indicating that comorbid ADHD did not exert a significant effect on verbal WM deficits common to OLDs. Despite the lack of significant differences in the area of WM, both groups evidenced below average visual-spatial and verbal WM. Thus, results are consistent with prior research's indication of WM deficits in these populations, but it appears that ADHD comorbidity does not have a significant impact on verbal or visual-spatial WM.

Given the limitations of prior WM research, it is difficult to evaluate the reliability of current findings. Moreover, given the small sample size, there is an increased likelihood of Type II error (i.e., significant group differences exists but are not identified). In fact, to obtain 80% statistical power with *t* tests using the desired medium effect size for this statistic (i.e., 0.25) and the .05 alpha level as the criterion for significance, a sample size of 102 participants would be needed . Thus, despite the methodological improvements in the current evaluation of WM, results of this study should be replicated in a larger sample before making assumptions about the impact of comorbid ADHD on WM, or making conclusions regarding the type of WM deficits unique and/or common to OLDs and ADHD.

EXPLORATORY ANALYSES

Additional analyses were conducted to explore the impact of stimulant medication on ADHD symptoms, as evaluated by Quotient™ performance, when there is a comorbid OLD. Prior CPT research has consistently indicated that Quotient™ performance improves with the ingestion of stimulant medication. Futhermore, there is substantial empirical support for use of the Quotient™ to aid in MPH dosing for children with ADHD (e.g., Teicher et al., 2003; Teicher et al., 2008). Some researchers have questioned the effectiveness of MPH for the treatment of ADHD when there is a comorbid LD (e.g., Tirosh, Berger, Cohen-Ophir, Davidovitch, & Cohen, 1998; Tirosh, Cohen, Berger, Davidovitch, & Cohen-Ophir, 2001). Comparisons of Quotient™ performance for OLD/ADHD participants with and without their medication, however, support the effectiveness of stimulant medication for improving attention and reducing overactivity in the case of comorbid OLD/ADHD. Results are consistent with the large evidence base for the effectiveness of pharmacological treatment for ADHD (e.g., MTA, 1999; Plizka et al., 2007).

The present study also examined changes in Quotient™ performance associated with the ingestion of prescribed stimulant medication in children with an OLD but without comorbid ADHD. Results are exploratory due to the extremely small sample size (n = 7) and thus, limited power and high likelihood of Type II error. Despite the small sample size, however, results indicated that for children with an OLD, response consistency (i.e., Response Variability), overall attention (i.e., Inattention), and overall signs of ADHD (i.e., Global ADHD), as evaluated on the Quotient™, improved significantly following the ingestion of stimulant medication. Despite the lack of significant group differences on other Quotient™ variables, all group differences were in the expected direction.

As previously mentioned, limited research has suggested the possible role for pharmacotherapy in the case of LDs, dyslexia in particular. If results of this exploratory evaluation can be replicated in a larger sample of children with an OLD (or other LD but without ADHD), who are prescribed stimulant medication, there may be additional evidence for the evaluation of pharmacotherapy in the treatment of OLDs; however, it is emphasized that this should not be recommended at the exclusion of more traditional academic and language therapies. In addition, in recent years, there has been a growing interest in the use of non-pharmacological interventions for the treatment of ADHD. Future research may address the efficacy of the use of such interventions to address the attentional impairment associated with an OLD, and utilize the Quotient™ as an objective assessment of this impairment and changes in attention due to such interventions.

Additional exploratory analyses evaluated the relationship between "severity" of ADHD symptoms and Quotient™ performance via examination of children classified as ADHD NOS versus those who met diagnostic criteria for a specific subtype of ADHD. In the current study, children receiving the label NOS demonstrated prominent symptoms of inattention and hyperactivity/impulsivity, but did not meet criteria for a specific subtype. It is frequently assumed that the "NOS" label is indication of a less severe variant of ADHD. However, comparisons of children with comorbid OLD/ADHD NOS and those with comorbid OLD and ADHD of a specific subtype on the Quotient™ did not find significant differences in inattention or activity level. Findings reveal that despite the NOS designation, upon objective evaluation, these children evidence a similar degree of problems with attention and/or overactivity. Exploratory comparisons of ADHD NOS and "pure" subtypes may suggest that ADHD "severity" does not impact the degree of impairment relative to attention/movement. However, another possible explanation for findings is that the NOS designation does not imply a less "severe" variant of the disorder.

In addition to considering severity differences according to diagnostic classification (e.g., ADHD "pure" subtype versus NOS), symptom severity was evaluated via consideration of symptom ratings on the K-SADS-P/L. It was hypothesized that given the nature of the academic environment at Shelton and the substantial resources/education Shelton parents' receive to support them in the implementation of structure and/or strategies to reduce the impact of symptoms on their child's functioning, parent report of ADHD symptoms for the children in the present study may be less severe (i.e., "subthreshold" and rated a "2" on the K-SADS-P/L). Hence, Quotient^{TM} performance would be negatively impacted regardless of the reported "severity" of a child's symptoms (i.e., "subthreshold" versus "threshold"). However, results indicated that consideration of "subthreshold" ADHD symptoms did not improve the prediction of Quotient^{TM} performance beyond that predicted by "threshold" ADHD symptoms. Thus, results support the validity of the DSM-IV defined criteria for ADHD, even within a specialized learning environment such as Shelton that may minimize the impact of symptoms on academic functioning, and in the context of an OLD that is also associated "ADHD-like" symptoms (e.g., impact of receptive language difficulties behaviorally manifested as inattention).

Prior CPT research is limited with regard to the evaluation of performance differences according to ADHD subtype. Thus, further exploratory analyses compared OLD children with comorbid ADHD-IA type to those with comorbid ADHD-H/I OR ADHD-C. Differences in attention and activity as measured by Quotient^{TM} performance were not significant. Results for activity level are consistent with prior research that did not find significant differences in the activity level of ADHD inattentive type and combined type children as assessed via actigraph recordings (Dane et al., 2000). Regarding inattention, results are consistent with prior research which found more similarities than differences in CPT performance of inattentive versus hyperactive-impulsive children (Baeyens et al., 2006).

Given the exploratory nature of this analysis and extremely small group sizes, findings must be interpreted with caution. Results should not be interpreted as a lack of empirical support for the DSM's subtype classification. However, as other researchers have asserted (e.g., Lee et al., 2008; Nigg, 2001), results do suggests that despite the existence of specific diagnostic entities, there is substantial overlap in the clinical characteristics of ADHD subtypes, warranting comparison of individuals of different subtypes. Future research should continue to examine attention and movement differences among ADHD subtypes and the utility of an instrument such as the Quotient™ for assisting clinicians in differenting among ADHD subtypes.

Exploratory analyses also evaluated EF relative to ADHD severity (i.e., ADHD NOS versus ADHD "pure" subtype) and ADHD subtypes (i.e., ADHD-IA versus ADHD-H/I and ADHD-C). Group differences in EF attributable to ADHD severity as designated by the NOS diagnostic category were not significant, possibly suggesting that "severity" does not impact the degree of EF impairment or that the NOS designation is not equivalent to reduced severity.

Exploratory comparisons of ADHD subtypes and EF revealed a strong association between the nature of ADHD symptoms and EF. Overall, results indicated that children with Inattentive type were more impaired in EF and evidenced a specific weakness in initiating goal-directed behavior. Results are consistent with the research of McCandless and colleagues (2007) who found a significant association between inattention and teacher report of difficulty initiating tasks as measured by the BRIEF. Future research is needed to evaluate the specific pattern of EF impairments associated with ADHD and its subtypes. Again, given limited power, the meaning of exploratory analyses related to EF is questionable. However, findings point to the need for continued research to examine EF impairments in ADHD children and differences in EF functions according to subtype.

CONCLUSIONS AND CLINICAL IMPLICATIONS

Overall, results indicate that for children with an OLD, the Quotient™ is effective in the detection of overactivity associated with ADHD comorbidity.

Given the Quotient™'s capacity to objectively assess movement, results strongly support the utility of this instrument in the context of a comprehensive evaluation, for the evaluation of ADHD among children with impaired oral language. However, findings point to the limitations of the Quotient™ CPT in the evaluation of ADHD for language impaired or learning disordered children. While providing valuable information regarding a child's attention and related processes, examination of this cognitive construct with the use of the Quotient™ does not appear to improve the accuracy of ADHD evaluations in children with an identified OLD.

Clinicians must consider the meaning of these findings in light of available CPT research. It appears that the use of a CPT for the evaluation of ADHD in the context of possible language/learning problems could contribute to the over-diagnosis of this disorder in children. If evaluators interpret impaired attention, per poor CPT performance, as indicative of an attentional disorder, underlying language/learning problems are at risk for going unidentified.

However, this is not to say that information regarding a child's attention, as garnered from a CPT, is without value. Quantitative and qualitative information regarding a child's attentional processes, such as that provided by the Quotient™ CPT, contributes to the understanding of the nature of a child's attentional difficulties. Moreover, this information provides clinicians with data that can be helpful in the design of behavioral and environmental strategies for the classroom and home environment to minimize the impact of attentional weaknesses on a child's functioning. In sum, by using the Quotient™ in a comprehensive ADHD evaluation, not only will the clinician have information on a child's attention, but movement data that truly contributes to the identification of ADHD is provided; no other commercially available CPT offers this information.

In addition, the current study offers strong evidence of the impact of comorbid ADHD on EF in children with an OLD. Results indicate that the presence of ADHD significantly impairs overall EF, and more specifically, a child's ability to appropriately inhibit his or her behavior. Furthermore, findings add to the growing body of research on the utility of the CEFS for the identification of EF impairments associated with ADHD and speak to the need for future research to evaluate and establish the psychometric properties of this instrument. Among children with oral language deficits, it appears that a child's capacity to appropriately inhibit his/her behavior, as evaluated via parent-report, is indicative of whether or not comorbid ADHD may be contributing to problems with hyperactivity. Results support the use of this measure for the clinical evaluation of ADHD among children with an OLD. To date, this is the first study to demonstrate the utility of the Quotient™ and the CEFS for the evaluation of ADHD among learning different children, particularly those with impaired oral language.

Results of exploratory analyses support the Quotient™'s potential role in the pharmacological treatment of ADHD among children with an OLD. Findings offer important information regarding the effectiveness of stimulant medication in children with an OLD for ADHD-related symptoms of attention and hyperactivity. Exploratory analyses raise questions regarding the meaning of the ADHD NOS category as findings demonstrated similar impairment in attention, movement, and EF among children with ADHD NOS and a "pure" ADHD subtype. In the ADHD research reviewed, children with an NOS designation are rarely mentioned; it is unclear whether this means these children were are excluded or were assigned to a specific subtype for study purposes. However, exploratory findings in the present study point to the importance of future research to evaluate symptom severity associated with a "pure" subtype versus NOS disorder, and to examine the usefulness of assessment tools, such as the Quotient™ and/or the CEFS, for the evaluation of symptom severity. Finally, as other researchers have asserted, analyses of attention and movement among ADHD "pure" subtypes highlight the substantial symptom overlap across diagnostic entities.

METHODOLOGICAL LIMITATIONS AND FUTURE RESEARCH

Despite significant findings and the important implications for the evaluation of ADHD, the present study is marked by a number of limitations that must be considered. Future research should aim to improve upon these limitations and to address unanswered questions highlighted by the results of this study. First, as noted throughout the discussion, the small sample size and resulting lack of power may not have detected important group differences, especially related to attention. Future research, with an increased sample size, should continue the investigation of attention, movement, and EF as it relates to ADHD and OLDs.

In addition, the inclusion of a normal control group could have garnered significant information and the lack of one leaves important questions unanswered. Without data on this group, it is impossible to determine the kinds of deficits OLD children display relative to non-OLD, healthy controls. Such information could provide insight into the degree of inattention and hyperactivity associated with an OLD specifically. Furthermore, by evaluating attention with a "language-free" task, such as the Quotient™, identified impairments in attention related to an OLD would argue against the hypothesis that inattention in this population is attributable solely to impaired language processing. Such information could then spark additional research on necessary therapy and intervention for OLDs.

One must also consider that the sample in the present study may not be representative of the population and thus findings not generalizable. Study participants were all enrolled in an intensive language-intervention program at a specialized school for students with learning differences. Due to the severity and complexity of the language/learning issues of participants, findings may not generalize completely to other language/learning disabled populations (e.g., a child with a language disorder, but functioning adequately with traditional services/accommodations in a public school system). Moreover, the sample was not normally distributed with respect to ethnicity, with 82.4% of the sample Caucasian. Also, although data were not gathered on the socioeconomic status of the families involved in the current study, the Shelton School is an elite school, and the student body is largely comprised of children from upper-middle to upper class families. Hence, there is inherent selection bias based on the population from which this sample was drawn.

Related to this, all LI children over the age of six were eligible to participate in the present study; however, although nearly all LI parents consented to participate, a number of them did not complete all portions of the study (e.g., K-SADS-P/L) and thus their child was excluded from analyses (see Figure 1). It is unknown how participants in the present study compare to those in the LI program, who chose not to participate or failed to complete all parts of the study. Given the study’s emphasis on ADHD, it seems likely that parents whose child had been previously diagnosed with this condition or who were invested in finding an explanation for their child's complex learning issues and/or behavior problems participated in the study. This could have impacted parent report to the K-SADS-P/L and parent responses on the CEFS.

Although the current study focused on oral language impairments, child participants presented with additional learning related issues including disorders of written language (included dyslexia and written expression) and dysgraphia. Hence, it is possible that impairments associated with other learning differences affected findings. It is difficult to bypass this confound given that the sample was selected from a school that specializes in the education of learning different children. It would be unusual to find a child at this school with a single, clearly defined LD. However, the author acknowledges that this represents a confound to the internal validity of this study; continued research on the Quotient™ among learning disabled children is needed. Similar to the methodology of the current study, and to improve upon the existing CPT and EF literature among ADHD and LD populations, it is imperative that future research base LD designation on a comprehensive assessment as recommended by the AACAP's most recent practice parameters for the assessment of children with language and learning disorders (Beitchman et al., 1998).

Use of the Quotient™ at two time points for a portion of the sample (i.e., medication and no medication) also presents a possible confound due to practice effects. No research has been published on the test re-test reliability of the Quotient™; however, this instrument is utilized and designed for monitoring symptom improvement associated with pharmacological therapy thereby requiring multiple testings. Thus, it seems unlikely that practice effects impacted results to a meaningful degree.

The use of medication also warrants attention; 59% of the sample took prescribed stimulant medication within 24 hours of Quotient™ and working memory testing. Children were taking stimulants known to have short-half lives and most children had the last dose of medication either the morning before the testing or at lunch time the day prior to the testing, leaving ample time for the effects of the medication to wear off. Thus, it seems probable that the medication either had minimal or no effect on test performance. In fact, prior research with the Quotient™ evaluated children within 3 to 5 hours after taking stimulant medication and considered this testing to be "off medication;" the present study makes a substantial improvement with regard to minimizing the effects of such medication, but it is difficult to say precisely how the medication may have affected the results of the study.

Children with an OLD and OLD/ADHD evidenced similar attentional impairment on the Quotient™. Questions regarding the underlying nature of the attention problems associated with impaired oral language disorders and other LDs remain unanswered. As discussed, functional brain imaging research has uncovered a “causal” role of attentional mechanisms in dyslexia, but similar research on the cognitive processes affected by impaired oral language, such as attention, is lacking. Research in this area is needed and will contribute to the development of new therapies and interventions to address these deficits and hopefully improve the functioning of these children.

Limitations related to the Quotient™ itself must also be addressed. Although this instrument offers substantial advantages over other commercially available CPTs and provides an objective measurement of movement, further research on the Quotient™ is needed. Formal evaluation of the instrument’s reliability and validity is lacking. Furthermore, scores must be standardized and normative data published. The creation of “scaled scores” for overall Inattention, Motion, and a combined index (i.e., Global ADHD) is a recent improvement. However, although the makers describe these indices as “scaled scores,” *published* information regarding the mean and SD within the community sample, or among ADHD subjects, is unavailable. This prevents comparison of an individual child or group to the normative sample or a clinical group. Without such comparisons, questions regarding the degree of impairment for a specific child or clinical group remain unanswered. It is imperative that researchers continue to investigate and establish the Quotient™’s psychometric properties. Furthermore, as discussed, results of the Quotient™ involve a substantial number of attention and movement variables, many of which are related and appear to measure much of the same thing. The quantitative information included in Quotient™ results can be confusing to clinicians. At the present time, available literature regarding score development, interpretation, and clinical relevance is insufficient and must be addressed by the makers of this instrument. Also, this instrument is marketed for the evaluation of ADHD; yet, only two small scale studies are published on the use of this instrument for the comparison of ADHD and non-ADHD controls. Although research speaks to the potential incremental validity this instrument offers in the evaluation of ADHD, large scale published studies on the Quotient™ in ADHD and non-ADHD control populations are needed; without such research, the actual use of this instrument in clinical settings will be limited.

TABLES

Table 1

Review of Commercially Available CPTs

	Connors	Gordon	IVA	TOVA	Quotient™
1.				X	X
2.					X
3.	X	X	X	X	X
4.	X		X	X	X
5.	X		X	X	X
6.					X
7.					X
8.			X	X	X
9.		X			

Note. 1 = "language" free; stimulus is not a letter or a number . 2 = measures movement. 3 = omission errors. 4 = commission errors. 5 = response variability. 6 = response latency. 7 = evaluates attention state (e.g., On Task). 8 = validity; provides data on subjects approach to the task. 9 = reinforcers; flashing light after a correct response or number of points visible to examinee

Table 2
Review of Quotient^{TM} Studies

Citation	n	Groups	Gender	Diagnostic criteria	Test version	Results (see Table 3 for variable description)
Teicher et al. (2008)	11	ADHD	M	Semistructured interview DSM-IV	MMAT	Same MPH dose associated with best overall improved MMAT performance and parent report of best clinical outcome
Teicher et al. (2005)	48	ADHD (Subjects compared to self pre MPH & at various MPH doses)	M	Semistructured interview + rating scales DSM-IV	MMAT	MPH associated with improvement in stimulus sensitivity (i.e., capacity to discriminate targets from nontargets)
Faedda et al. (2005) *Case study	2	BP (Compared to previous data for ADHD and NC)	M	DSM-IV	MMAT	BP > % commission and omission errors, number of attention shifts, movement, area, displacement BP < accuracy, immobility duration
Teicher et al. (2004)	60 8	ADHD-C NC	M M	Semistructured interview DSM-IV	MMAT	ADHD-C < % On Task and > Attention Shifts with MPH, ADHD-C > time On Task & < time Distracted, Impulsive, and Random Significant correlation b/w # Microevents & time Distracted
Greenaway (2004)	18 18	MDD MDD/ADHD	M/F M/F	Semistructured interview DSM-IV	MMAT	Statistically significant differences in expected direction for % Accuracy, % omission & commission errors, variance in response speed, immobility duration, movements, displacement, & temporal scaling
Heiser et al. (2004)	25	HD (Subjects compared to self pre & post MPH)	M	Clinician interview + rating scales ICD-10	OPTAx	Statistically significant differences in microevents, % commission errors, accuracy, & variability

Table 2 (continued).

Citation	n	Groups	Gender	Diagnostic criteria	Test version	Results (see Table 3 for variable description)
Teicher et al. (2003)	12 2	ADHD-C M ADHD-C F		Semistructured interview DSM-IV	MMAT	Higher MPH dose exert rate dependent effects on activity and attention
Teicher et al. (2000)	11 6	ADHD NC	M M	Semistructured interview (6 symptoms IA or H/I) DSM-IV	Computerized vigilance test + Motion tracking system (MTS)	ADHD > putamen abnormalities (fMRI) than normal controls > Putamen abnormalities strongly correlated with performance accuracy and ability to sit still
Teicher et al. (1996)	18 11 (8) (4) (6)	ADHD NC (ADHD-IA) (ADHD-HI) (ADHD-C)	M M	Semistructured interview + rating scales DSM-IV	TOVA + Infrared motion analysis	ADHD > microevents & area ADHD < spatial complexity, immobility duration ADHD > variability ADHD < accuracy, latency

Note. M = male; F = female; ADHD = Attention-Deficit/Hyperactivity Disorder; ADHD-IA = ADHD Inattentive type; ADHD-HI = ADHD Hyperactive Impulsive type; ADHD-C = ADHD Combined type; BP = Bipolar; MDD = Major Depressive Disorder; NC = normal controls; HD = hyperkinetic disorder

Table 3

Definitions of Dependent Variables and Their Corresponding Hypotheses

Quotient/ADHD System™, Attention Variables		
Variable	Definition	Hypothesis
Accuracy	Percentage of correct responses	1a, 4a, 4b
Omission Errors	Percentage of missed targets	1a, 4b
Commission Errors	Percentage of incorrect responses to non-target	1a, 4b
Latency	Mean time, in milliseconds, to respond to target (ms)	1a, 4b
Variability	Standard deviation of response time to target	1a, 4a, 4b
Coefficient of Variance (COV)	A more stringent measure of response consistency: (100 x variability) / latency	Additional attention
variable		

Table 3 (continued)

Quotient/ADHD System™, Attention State Variables

Variable	Definition	Hypothesis
Attention Shifts	Number of shifts in attention state	1b, 4b
On Task (A)	Percent of time hit many targets and few non-targets	1b, 4b
Distracted (D)	Percent of time hits some targets and some non-targets; accuracy is better than chance	1b, 4b
Impulsive (I)	Percent of time hits many targets and some non-targets	1b, 4b
Random Responding (R)	Hits most targets and non-targets accuracy of responding is as good as chance	Additional variable
Minimal Responding (M)	Misses most targets and non-targets; accuracy is about as good as chance	Additional variable
Contrary (C)	Response accuracy is significantly worse than chance	Additional variable

Table 3 (continued)

Quotient/ADHD System^{TM}, Motion Variables

Variable	Definition	Hypothesis
Immobility Duration	Average amount of time, in seconds, spent sitting still (moving less than 1 mm)	1c, 4b
Movements	Average number of position changes (movement greater than 1 mm), measured in total meters	1c, 4b
Displacement	Total distance traveled (in meters) by the marker	1c, 4b
Area	Size and shape, measured in cm^2, of the space covered by the marker	1c, 4b
Spatial Complexity	Complexity of the movement path. (values range from one to two) Lower values indicate more linear, back & forth movement; higher values indicate more complex movement	1c, 4a, 4b
Temporal Scaling	Frequency of movement (scale from 0 to 1; 0 = no movement and 1 = constant movement)	1c, 4b

Table 3 (continued)

Quotient/ADHD System™, Scaled Scores		
Variable	Definition	Hypothesis
Motion	Composite of how a child's movement compares to a community sample (Values range from 0 to 10, with higher scores more indicative of ADHD).	1d, 4b
Inattention	Composite of how a child's attention compares to a community sample (Values range from 0 to 10, with higher scores more indicative of ADHD).	1d, 4b
Global ADHD	Combination of Motion and Inattention; compares child to a community sample (Values range from 0 to 10, with higher scores more indicative of ADHD).	1d, 4b

Table 3 (continued)

WISC-IV-I Working Memory Variables

Variable	Definition	Hypothesis
Digit Span (DS)	Age-adjusted scaled score for digit span	Additional WM variable
Digits Forward	Age-adjusted scaled score for digit span forward	Additional WM variable
Digits Backward	Age-adjusted scaled score for digit span backward	Additional WM variable
Longest DS Forward	Maximum number of digits recalled accurately on DS forward	Additional WM variable
Longest DS Backward	Maximum number of digits recalled accurately on DS backward	Additional WM variable
Spatial Span Forward	Age-adjusted scaled score for spatial span forward	Additional WM variable
Spatial Span Backward	Age-adjusted scaled score for spatial span backward	3
Longest Spatial Span Forward	Maximum number of blocks recalled accurately in Spatial Span Forward	Additional WM variable
Longest Spatial Span Backward	Maximum number of blocks recalled accurately in Spatial Span Backward	Additional WM variable

Table 3 (continued)

Children's Executive Functions Scale (CEFS) Variables

Variable	Definition	Hypothesis
Total Score	Higher scores indicate more executive dysfunction	2, 5a, 5b
Inhibition	Higher scores indicate more trouble inhibiting behavior	2, 5a, 5b
Problem-Solving	Higher scores indicate more difficulty in daily problem-solving	2, 5a, 5b
Social Appropriateness	Higher scores indicate less socially appropriate behavior	2, 5a, 5b
Initiative	Higher scores indicate difficulty initiating goal-directed behavior	2, 5a, 5b
Motor-Planning	Higher scores indicate problems completing tasks that require planned sequences of movements	2, 5a, 5b

Table 4

Review of Verbal Working Memory Literature

Citation	Groups	Diagnostic Method	WM	Medication	Results
Adams & Gathercole, 2000	Poor non-word repetition Good non-word repetition (n = 15 / group)	Comparison to cohort mean on CNRep	Non-word repetition (NR) (standardized)	Not available	Poor non-word repetition associated with reduced less word production, shorter utterances, & limited syntax **Verbal WM ⇓ in children with language problems**
Dollaghan & Campbell, 1998	LI LN (n = 20 / group)	**Dx.** by certified speech pathologist & enrolled in a language intervention	NR (novel)	Not available	LI significantly worse performance than LN **Verbal WM ⇓ in children with language problems**
Marton & LI Schwartz, 2003	LI LN (n = 13 / group)	**Dx.** by certified speech pathologist & enrolled in a language intervention	NR (novel) Digit Span F&B (WISC-R)	Not available	LI significantly worse performance than LN on NR No significant differences on Digit Span tasks **Verbal WM ⇓ in children with language problems** **For task with limited language, no differences.**
Cohen et al., 2000	ADHD (n = 36) ADHD+LI (n = 69) OPD (n = 31) OPD+LI (n = 30)	**LI Dx.** 2 SD < mean on one language test OR 1 SD < mean on two language tests **ψ Dx.,** structured interview DSM-III-R	Sentence recall / completion (novel)	Not available	ADHD+LI & OPD+LI significantly worse performance on WM tasks than ADHD & OPD **Verbal WM ⇓ children with language problems**
Jonsdottir et al., 2005	ADHD-C/LI (n = 19) ADHD-C (n = 15) Controls (n = 15)	**LI Dx.** SLQ < 80 & nonverbal IQ > 85 **ψ Dx.** interview based on Achenbach & ADHD rating scales DSM-IV	Word order Number recall (K-ABC)	Not available	ADHD-C/LI significantly worse than ADHD-C and controls on both WM tasks **Verbal WM ⇓ children with language problems**

Table 4 (continued).

Citation	Groups	Diagnostic Method	WM	Medication	Results
Martinussen & Tannock, 1996	ADHD (n = 62) RD/LI (n = 15) ADHD+RD/LI (n = 32) Controls (n = 11)	**RD Dx.,** 1.5 SD < mean on 1 decoding test OR 1 SD < mean on two tests. **LI Dx.,** 1.5 SD < mean on expressive or receptive index OR 1 SD < mean on expressive & receptive index. **ψ Dx.,** semi-structured interview DSM-IV criteria	Digit Span F & B (WISC-III)	Not available	RD/LI and ADHD+RD/LI significantly worse than ADHD and controls on Digit Span Forward RD/LI, ADHD & ADHD+RD/LI significantly worse than controls on Digit Span Backward **Verbal WM ⇓ for children with language problem and/or ADHD** **Comorbid ADHD dx. does not have a significant effect on verbal WM**
Williams et al., 2000	LI LI+H H Controls (n = 10 / group)	**LI Dx**. 1 SD < mean on 1 language test **ψ Dx.,** "high" score on impulsive/hyperactive factor on the CPRS	Digit Span F & B (WISC-III)	Not available	No significant difference between F & B LI and LI+H significantly worse than H and controls on Digit Span Lowest score was for the LI+H, but not significant No significant difference between H and controls **Verbal WM ⇓ for children with language problem** **Hyperactivity does not have a significant effect on verbal WM.**
Pennington & Ozonoff, 1996	ADHD Controls	N/A	N/A	N/A	No significant differences in verbal WM for 10 of the 13 studies reviewed **Verbal WM not affected by presence of ADHD.**

CPRS = Connors' Parent Rating Scale; CNRep = Children's Test of Nonword Repeition; F&B = Forward and Backward; Good non-word repetition = > 1 SD above cohort mean; Poor non-word repetition = > 1 SD below cohort mean; H = hyperactivity; LI = diagnosed with a language disorder; LN = age matched controls with normally developing language; OPD = other psychiatric diagnosis; SD =standard deviation

Table 5

Review of Visual-Spatial Working Memory Literature

Citation	Groups	Diagnostic Method	WM	Medication	Results
Cohen et al., 2000	ADHD (n = 36) ADHD+LI (n = 69) OPD (n = 31) OPD+LI (n = 30)	**LI Dx.** 2 SD < mean on 1 language test OR 1 SD < mean on 2 language tests **ψ Dx.,** structured interview DSM-III-R	Recall dot location (novel)	Not available	ADHD+LI and OPD+LI performed significantly worse than ADHD and OPD on visual-spatial task **Visual spatial WM ⇓ children comorbid LI**
Jonsdottir et al., 2005	ADHD-C/LI (n = 19) ADHD-C (n = 15) Controls (n = 15)	**LI Dx.** SLQ < 80 & nonverbal IQ > 85 **ψ Dx.** interview based on Achenbach & ADHD rating scales (DSM-IV)	Hand movements Spatial memory (K-ABC)	Not available	No significant differences on individual tasks No significant differences on WM composite **Presence of ADHD does not affect visual-spatial WM**
Williams et al., 2000	LI LI+H H Controls (n = 10 / group)	**LI Dx**. 1 SD < mean on 1language test **ψ Dx.,** "high" score on impulsive/ hyperactive factor on the CPRS	CANTAB Spatial Span (novel)	Not available	No significant differences on CANTAB H and LI+H performed significantly worse on Spatial Span than LI and controls **Hyperactivity associated with ⇓ visual-spatial WM; In LI, visual-spatial WM unaffected**
Martinussen & Tannock, 1996	ADHD (n = 62) RD/LI (n = 15) ADHD+RD/LI (n = 32) Controls (n = 11)	**RD Dx.,** 1.5 SD < mean on 1 decoding test OR1 SD < mean on 2 tests. **LI Dx.,** 1.5 SD< mean On expressive or Receptive index OR 1 SD < mean on expressive & receptive index. **ψ Dx.,** semi-structured interview DSM-IV criteria	Finger Windows forward Novel backwards procedure	Not available	RD/LI, ADHD & ADHD+RD/LI significantly worse than controls on forwards and backwards versions. No significant differences among clinical groups. **Visual-spatial WM ⇓ for children with language problems and/or ADHD.** **Comorbid ADHD dx. does not have a significant effect on visual-spatial WM.**

Table 5 (continued).

Citation	Groups	Diagnostic Method	WM	Medication	Results
*Willicut et al., 2005	ADHD Controls	N/A	N/A	N/A	ADHD children consistently demonstrate impaired visual-spatial WM compared to controls. **ADHD is associated with ⇓ visual-spatial WM.**

CANTAB = computerized test of visual-spatial WM; CPRS = Connors' Parent Rating Scale; CNRep = Children's Test of Nonword Repeition; F&B = Forward and Backward; Good non-word repetition = > 1 SD above cohort mean; Poor non-word repetition = > 1 SD below cohort mean; H = hyperactivity; LI = diagnosed with a language disorder; LN = age matched controls with normally developing language; OPD = other psychiatric diagnosis; SD = standard deviation; SLQ = Spoken Language Quotient from the Test of Language Development-2-Intermediate; Spatial span = maximum length of spatial sequence remembered.
*Meta-analysis

Table 9

Intercorrelations Among Quotient™ Variables of Attention (N = 51)

Quotient™ Variable	1	2	3	4	5
1. Response Accuracy	1.00				
2. Response Variability	-.752 .000**	1.00			
3. Response Latency	-.118 .409	.632 .000**	1.00		
4. [a]Omission Errors (%)	-.724 .000**	.786 .000**	.484 .000**	1.00	
5. Commiss-ion Errors (%)	-.806 .000**	.452 .001**	-.171 .229	.270 .055	1.00

[a]Log-transformed data analyzed.

**p<.01 (Bonferroni corrected) .

Table 11

Intercorrelations Among Quotient^{TM} Variables of Attention State (N = 51)

Quotient^{TM} Variable		1	2	3	4
1. Attention Shifts	*r*	1.00			
	p-value				
2. On Task	*r*	-.497	1.00		
	p-value	.000**			
3. Impulsive	*r*	.506	-.201	1.00	
	p-value	.000**	.158		
4. [a]Distracted	*r*	-.218	-.476	-.347	1.00
	p-value	.125	.000**	.013*	

[a]Square-root transformed data analyzed.

*Result not significant following application of Bonferroni correction (α = .0125)

**p<.0125 (Bonferroni corrected)

Table 13

Intercorrelations Among Quotient™ Movement Variables

Quotient™ Variable	1	2	3	4	5	6
1. [a]Immobility	1.00					
2. [a]Displace-ment	-.988 .000**	1.00				
3. [b,c]Area	-.917 .000**	.945 .000**	1.00			
4. Movements	-.934 .000**	.944 .000**	.829 .000**	1.00		
5. Temporal Scaling	-.949 .000**	.929 .000**	.810 .000**	.924 .000**	1.00	
6. [d]Spatial Complexity	.901 .000**	-.892 .000**	-.917 .000**	-.727 .000**	-.793 .000**	1.00

[a]Log transformed data analyzed. [b]Square root transformed data analyzed. [c]n = 50; 1 extreme value excluded from analyses with the variable Area. [d]n = 45; six outliers excluded from analyses with the variable Spatial Complexity.

**p<.007 (Bonferroni corrected)

Table 15

Intercorrelations Among Quotient™ Overall Scaled Scores (N = 51)

Quotient™ Variable	Motion	Inattention	Global ADHD
Motion	1.000		
Inattention	.452 .001**	1.000	
Global ADHD	.869 .000**	.834 .000**	1.000

**p<.0125 (Bonferroni corrected)

Table 17

Intercorrelations Among CEFS Executive Functioning Subscales and Total Score (N = 43)

CEFS Variable	1	2	3	4	5	6
1. Social Appropriate-ness	1.00					
2. Behavioral Inhibition	.463 .002**	1.00				
3. Problem-Solving	.389 .010*	.695 .000**	1.00			
4. Initiative	.120 .443	.314 .040*	.622 .000**	1.00		
5. Motor-Planning	.036 .818	.360 .018*	.541 .000**	.588 .000**	1.00	
6. Total Score	.479 .001**	.816 .000**	.937 .000**	.700 .000**	.666 .000**	1.00

Note. Analyses based on the number of child participants whose parent(s) completed the CEFS; one child participant was an outlier on multiple CEFS subscales and on the CEFS Total and was excluded from analyses involving CEFS variables.

**p-value* significant prior to application of Bonferroni correction ($\alpha = .007$).

**$p < .007$ (Bonferroni corrected)

Table 20

Summary of Classification Analyses: Prediction of ADHD Diagnostic Status (i.e., OLD or OLD/ADHD)

Variable(s)	χ^2	*p*	R^2	β	Wald	*p*	Classification accuracy	Sensitivity	Specificity
Response accuracy	14.485	.002**	.372	.019	.180	*ns*	77.8%	92.6%	55.6%
Response variability				.042		*ns*			
Spatial complexity				-23.3	7.181	.007**			
Response accuracy	3.221	*ns*							
Response variability									
Spatial Complexity	14.277	.000**	.368	-22.9	8.796	.003**	77.8%	92.6%	55.6%
[a]Global ADHD	7.916	.005**	.194	.412	6.764	.009**	72.5%	83.3%	57.1%
[ψ,a]Area	9.223	.002**	.227	.164	7.614	.006**	72%	79.3%	61.9%
Motion									
Global ADHD									

Table 20 (continued)

Variable(s)	χ^2	*p*	R^2	β	Wald	*p*	Classification accuracy	Sensitivity	Specificity
Behavioral Inhibition	16.461	.000**	.334				79.1%	80%	77.8%
[a]Behavioral Inhibition	19.673	.000**	.502	.183	7.673	.006**	78.6%	79.2%	77.8%
Area				.145	3.214	.073			
[a]Behavioral Inhibition	20.733	.000**	.507	.197	8.464	.004**	79.5%	77.8%	80.8%
Global ADHD					2.418	.120			

Note. Sensitivity = number of OLD/ADHD participants correctly classified / total number of OLD/ADHD participants. Specificity = number of OLD participants correctly classified / total number of OLD participants.

[ψ]Analysis was forward stepwise logisitic regression; only the variable Area was included in the regression equation.

[a]Total number of OLD/ADHD participants differed due to exclusion of an extreme value on the variable Area.

$^{**}p < .01$

Table 21

Intercorrelations Among Potential Predictor Variables of ADHD Diagnostic Status

Predictor		1	2	3	4
1. [a]Area	*r*	1.00	-.855	.924	.822
	p-value		.000**	.000**	.000**
	n		45	50	50
2. Spatial Complexity	*r*	-.828	1.00	-.940	-.808
	p-value	.000**		.000**	.000**
	n	45		45	45
3. Motion	*r*	.971	-.875	1.00	.858
	p-value	.000**	.000*		.000**
	n	50	45		51
4. Global ADHD	*r*	.866	-.776	.869	1.00
	p-value	.000**	.000**	.000**	
	n	50	45	51	

Note. Sample sizes vary due to exclusion of outliers/extreme values. For analyses with the variable Area, *n* = 50 due to exclusion of 1 extreme value. For analyses with the variable Spatial Complexity, *n* = 45 due to exclusion of 6 outliers. For analyses of all other variables, entire sample, *n* = 51, included in analysis. [a]Square-root transformed data analyzed.

**p<.006 (Bonferroni corrected).

Table 22

P-values for Paired Sample t-tests: Medication versus No Medication Quotient^{TM} Testing for Children with Comorbid OLD/ADHD (n = 21)

	Quotient^{TM} Performance		
Quotient^{TM} Variable	No Medication *M* (*SD*)	Medication *M* (*SD*)	*p*-value
[a]Attention			
Accuracy	80.29 (13.1)	85.54 (12.08)	.001**
Omission Errors	17.80 (14.86)	6.55 (7.55)	.000**
Commission Errors	21.59 (15.65)	22.40 (20.69)	.782
Variability	229.05 (77.83)	165.76 (74.65)	.000**
Latency	614.33 (117.47)	556.00 (113.48)	.001**
[b]Attention State			
Attention Shifts	14.38 (4.02)	11.24 (4.89)	.032*
On Task	38.95 (27.25)	53.00 (29.46)	.007**
Distracted	25.32 (17.82)	11.78 (18.27)	.001**
Impulsive	19.59 (17.20)	24.20 (18.32)	.358

Table 22 (continued).

Quotient™ Variable	Quotient™ Performance No Medication *M* (*SD*)	 Medication *M* (*SD*)	*p*-value
[c]Movement			
Immobility Duration	115.71 (119.64)	212.90 (148.51)	.000**
Movements	4869.33 (2923.76)	2316.62 (1449.88)	.000**
Displacement	8.82 (6.51)	3.34 (2.55)	.000**
Area	249.95 (156.38)	81.29 (76.37)	.000**
Temporal Scaling	.975 (.44)	.659 (.34)	.000**
Spatial Complexity	1.10 (.128)	1.19 (.140)	.000**
[d]Scaled Scores			
Inattention	7.63 (2.24)	5.22 (2.61)	.000**
Motion	7.01 (2.61)	4.20 (2.08)	.000**
Global ADHD	7.32 (1.86)	4.71 (1.96)	.000**

Note. Participants prescribed stimulant medication; children taking Stratterra excluded from analyses.

[a]Results significant at Bonferroni corrected alpha level of less than .01. [b]Results significant at Bonferroni corrected alpha level of less than .0125. [c]Results significant at Bonferroni corrected alpha level of less than .008. [d]Results significant at Bonferroni corrected alpha level of .0167.

*Result not significant after application of Bonferroni correction.

**Bonferroni corrected p-value significant.

Table 23

P-Values for Paired Sample t-tests: Medication versus No Medication Quotient™ Testing for Children with an OLD (n = 7)

Quotient™ Variable	Quotient™ Performance: No Medication *M* (*SD*)	Medication *M* (*SD*)	*p*-value
[a]Attention			
Accuracy	85.46 (9.90)	90.17 (5.11)	.231
Omission Errors	6.34 (6.86)	1.76 (3.50)	.124
Commission Errors	22.64 (15.27)	18.04 (7.68)	.381
Variability	170.14 (63.20)	114.14 (29.76)	.018**
Latency	540.57 (131.09)	507.86 (106.24)	.094
[b]State Shift			
Attention Shifts	13.71 (5.71)	12.71 (3.73)	.613
On Task	51.43 (32.84)	63.14 (20.10)	.313
Distracted	10.47 (7.80)	3.80 (8.69)	.050
Impulsive	29.04 (19.90)	30.94 (13.98)	.682

Table 23 (continued).

Quotient™ Variable	Quotient™ Performance No Medication *M* (*SD*)	 Medication *M* (*SD*)	*p*-value
[c]Movement			
Immobility Duration	220.57 (148.25)	255.71 (62.67)	.433
Movements	2326.43 (1459.18)	1613.14 (846.37)	.171
Displacement	3.32 (2.64)	2.00 (1.16)	.167
Area	89.43 (90.52)	38.14 (25.38)	.179
Temporal Scaling	.655 (.355)	.530 (.277)	.156
Spatial Complexity	1.21 (.125)	1.24 (.136)	.467
[d]Scaled Scores			
Inattention	5.76 (2.19)	3.45 (1.51)	.016**
Motion	4.50 (2.25)	3.26 (1.19)	.190
Global ADHD	5.13 (2.12)	3.35 (.994)	.021*

Note. Participants prescribed stimulant medication; children taking Stratterra excluded from analyses.

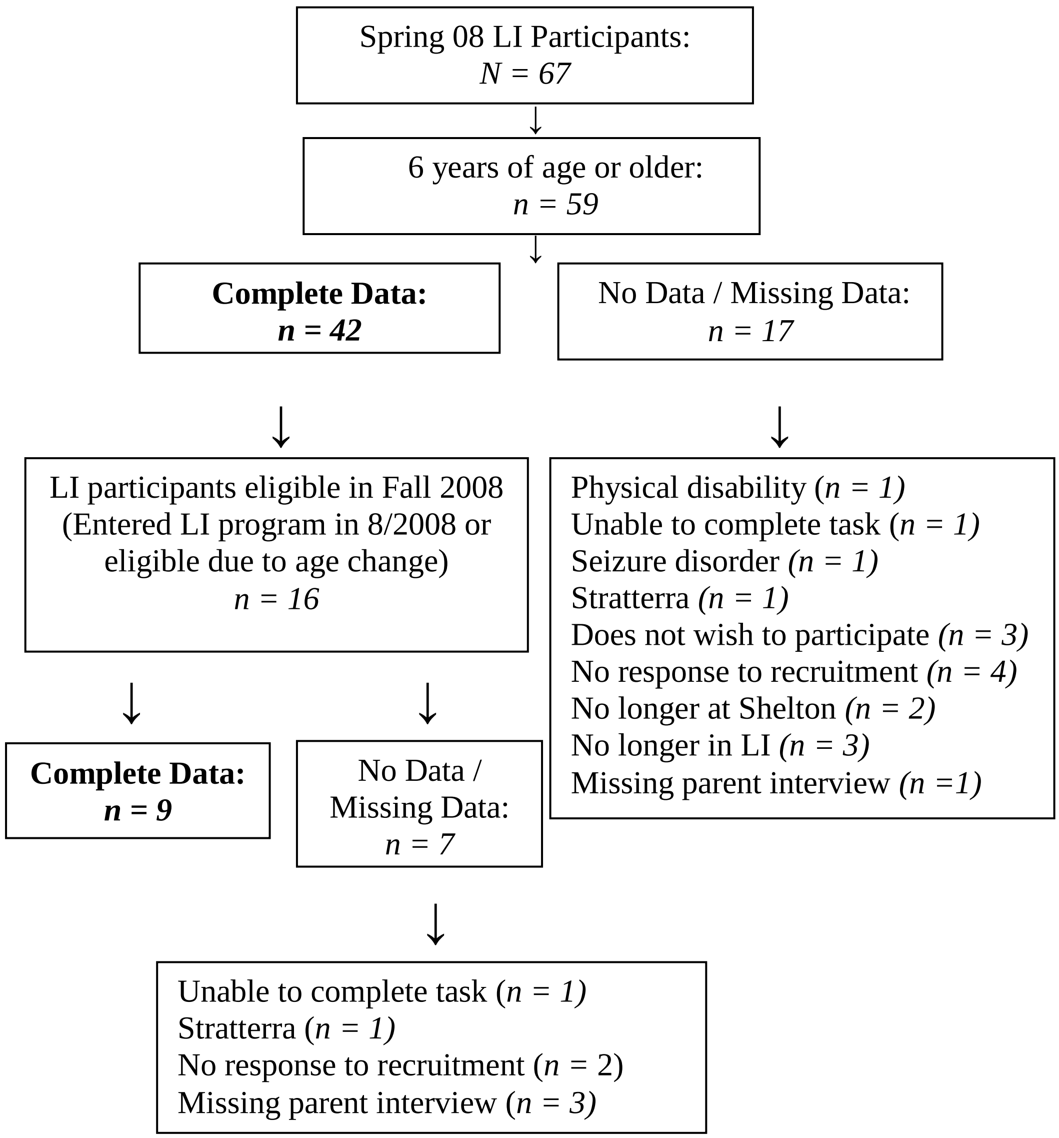
[a]Results significant at Bonferroni corrected alpha level of less than .01. [b]Results significant at Bonferroni corrected alpha level of less than .0125. [c]Results significant at Bonferroni corrected alpha level of less than .008. [d]Results significant at Bonferroni corrected alpha level of .0167.

*Result not significant after application of Bonferroni correction.

**Bonferroni corrected p-value significant.

Figure 1

Data Collection Process, March 2008 through February 2009 (N = 51)



**Note*. Missing the CEFS parent-report data for 7 children.

REFERENCES

Abikoff, H., Courtney, M., Pelham, W. E., & Koplewicz, H. S. (1993). Teachers' ratings of disruptive behaviors: The influence of halo effects. *Journal of Abnormal Child Psychology, 21*(5), 519 - 533.

Accardo, P. J., Blondis, T. A., Whitman, B. Y., & Stein, M. A. (2000). *Attention Deficits and Hyperctivity in Children and Adults*. New York: NY: Marcel Dekker, Inc.

Achenbach, T. M. (1991). *Child Behavior Checklist for Ages 4 - 18 (CBCL/Ages 4-18)*. Itasca, IL: Riverside.

Achenbach, T. M. (2001). *Child Behavior Checklist & Profile for Ages 6 - 18 (CBCL/Ages 6-18)*. Itasca, IL: Riverside.

Adams, A. M., & Gathercole, S. E. (1995). Phonological working memory and speech production in pre-school children. *Journal of Speech and Hearing Research, 38,* 403 - 414.

Adams, A. M., & Gathercole, S. E. (2000). Limitations in working memory: Implications for language development. *International Journal of Language and Communication Disorders, 35*(1), 95 - 116.

Ambrosini, P. J. (2000). Historical development and present status of the schedule for affective disorders and schizophrenia for school-age children (K-SADS). *Journal of the American Academy of Child and Adolescent Psychiatry, 39*(1), 49 - 58.

American Psychological Association. (1967). *Diagnostic and statistical manual of mental disorders* (2nd ed.). Washington, DC: Author.

American Psychological Association. (1980). *Diagnostic and statistical manual of mental disorders* (3rd ed.). Washington, DC: Author.

American Psychological Association. (1987). *Diagnostic and statistical manual of mental disorders* (3rd ed., revised). Washington, DC: Author.

American Psychological Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

American Psychological Association. (2000). *Diagnostic and statistical manual of mental disorders* (text revision). Washington, DC: Author.

Aram, D. M., Ekelman, B., & Nation, J. (1984). Preschoolers with language disorders: 10 years later. *Journal of Speech and Hearing Research, 27*, 232 - 245.

Aram, D. M., Morris, R., & Hall, N. E. (1993). Clinical and research congruence in identifying children with specific language impairment. *Journal of Speech and Hearing Research, 36,* 580 - 591.

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology, 49A*(1), 5 - 28.

Baddeley, A. (1999, November). *The episodic buffer: A new component of working memory?* Paper presented at the meeting of the Psychonomic Society, Los Angeles, CA.

Baddeley, A. (2003). Working memory and language: An overview. *Journal of Communication Disorders, 36*, 189 - 208.

Baddeley, A., Gathercole, S. E., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review, 105*(1), 158 - 173.

Baeyens, D., Roeyers, H., & Walle, J. V. (2006). Subtypes of Attention-Deficit/Hyperctivity Disorder (ADHD): Distinct or related disorders across measurement levels? *Child Psychiatry Human Development, 36*, 403-417.

Baird, J., Stevenson, J. C., & Williams, D. C. (2000). The evolution of ADHD: A disorder of communication. *The Quarterly Review of Biology, 75*(1), 17 - 35.

Baker, L., & Cantwell, D. P. (1987). A prospective psychiatric follow-up of children with speech/language disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 26*(4), 546-553.

Baker, L., & Cantwell, D. P. (1990). The association between emotional/behavioral disorders and learning disorders in children with speech/language disorders. *Advances in Learning and Behavioral Disabilties, 6*, 27 - 46.

Barkley, R. A. (1990). *Attention Deficit and Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. New York: Guilford Press.

Barkley, R. A. (1997a). *ADHD and the Nature of Self-Control*. New York: Guilford Press.

Barkley, R. A. (1997b). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65 - 94.

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2004). Young adult follow-up of hyperactive children: Antisocial activities and drug use. *Journal of Child Psychology and Psychiatry, 45*(2), 195 - 211.

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2006). Young adult outcome of hyperactive children: Adaptive functioning in major life activities. *American Journal of Child and Adolescent Psychiatry, 45*(2), 192 - 202.

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

Barnett, R., Maruff, P., & Vance, A. (2005). An investigation of visuospatial memory impairment in children with attention deficit hyperactivity disorder (ADHD), combined type. *Psychological Medicine, 35*(10), 1433 - 1443.

Beale, I. L., Matthew, P. J., Oliver, S., & Corballis, M. C. (1987). Performance of disabled and normal readers on the continuous performance test. *Journal of Abnormal Child Psychology, 15*, 229 - 238.

Bedard, A. C., Jain, U., Johnson, S. H., & Tannock, R. (2007). Effects of methylphenidate on working memory components: influence of measurement. *Journal of Child Psychology and Psychiatry, 48*(9), 872-880.

Bedard, A. C., Martinussen, R., Ickowicz, A., & Tannock, R. (2004). Methylphenidate improves visual-spatial memory in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 43*(3), 260-268.

Beitchman, J. H., Cantwell, D. P., Forness, S. R., Kavale, K. A., Kauffman, J. M., et al. (1998). Practice parameters for the assessment and treatment of children with language and learning disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 37*(10 supplement), 46S - 62S.

Beitchman, J. H., Hood, J., & Inglis, A. (1990). Psychiatric risk in children with speech and language disorders. *Journal of Abnormal Child Psychology, 18*, 283 - 296.

Beitchman, J. H., Hood, J., Rochon, J., & Peterson, M. (1989). Empirical classification of speech/language impairment in children II: Behavioral characteristics. *Journal of the American Academy of Child and Adolescent Psychiatry, 28*, 118 - 123.

Beitchman, J. H., Young, A., Jonson, C., & Wilson, B. (1997). *Early speech/language impairment as predictor of antisocial disorder and ADHD: A prospective community study.* Paper presented at the meeting of the American Academy of Child and Adolescent Psychiatry, Toronto, Canada.

Benasich, A. A., Curtiss, S., & Tallal, P. (1993). Language, learning, and behavioral disturbances in childhood: a longitudinal perspective. *Journal of the American Academy of Child and Adolescent Psychiatry, 32*(3), 585-594.

Benezra, E., & Douglas, V. I. (1988). Short-term serial recall in ADD-H, normal, and reading disabled boys on non-verbal memory tasks. *Journal of Abnormal Child Psychology, 16*, 511 - 525.

Bental, B., & Tirosh, E. (2008). The effects of methylphenidate on word decoding accuracy in boys with attention-deficit/hyperactivity disorder. *Journal of Clinical Psychopharmacology, 28*(1), 89 - 92.

Bhrolchain, M. N., Brown, G. W., & Harris, T. O. (1979). Psychotic and neurotic depression: Clinical characteristics. *British Journal of Psychiatry, 134*, 94 - 107.

Biederman, J., Mick, E., & Faraone, S. (2000). Age-dependent decline of symptoms of attention-deficit hyperactivity disorder: Impact of remission definition and symptom type. *American Journal of Psychiatry, 157*(5), 816 – 818.

Bishop, D. V. (1994). Is specific language impairment a valid diagnostic category? Genetic and psycholinguistic evidence. *Philosophical Transactions of the Royal Society of London: Biological Sciences, 346*(1315), 105 - 111.

Botting, N. (1998). Semantic-pragmatic disorder (SPD) as a distinct diagnostic entity: Making sense of the boundaries. *International Journal of Communication Disorders, 33*(1), 87 - 90; discussion 95 - 108.

Botting, N., & Conti-Ramsden, G. (2000). Social and behavioural difficulties in children with language impairment. *Clinical Language Teaching and Therapy*, 105 - 120.

Brown, R. T., Freeman, W. S., Perrin, J. M., Stein, M. T., Amler, R. W., Feldman, H. M., et al. (2001). Prevalence and assessment of Attention-Deficit/Hyperactivity Disorder in primary care settings. *Pediatrics, 107*(3), 107 - 118.

Brown, T. E. (2001). *Brown Attention Deficit Disorder Scales (BADDS)*. San Antonio, TX: PsychCorp.

Brown, T. E. (2005). *Attention Deficit Disorder: The Unfocused Mind in Children and Adults*. London: Yale University Press Health and Wellness.

Brownlie, E. B., Beitchman, J. H., Escobar, M., Young, A., Atkinson, L., Johnson, C., et al. (2004). Early language impairment and young adult delinquent and aggressive behavior. *Journal of Abnormal Child Psychology, 32*(4), 453 - 467.

Byrne, J. M., Bawden, H. N., DeWolfe, N. A., & Beattie, T. L. (1998). Clinical assessment of psychopharmacological treatment of preschoolers with ADHD. *Journal of Clinical and Experimental Neuropsychology, 20*(5), 613 - 627.

Calhoun, S. L., & Dickerson, S. M. (2005). Processing speed in children with clinical disorders. *Psychology in the Schools, 42*(4), 333 - 343.

Camarata, S. M., & Gibson, T. (1999). Pragmatic language deficits in attention-deficit hyperactivity disorder (ADHD). *Mental Retardation and Developmental Disabilities Research Reviews, 5*, 207 - 214.

Cantwell, D. P., & Baker, L. (1991). *Psychiatric and Developmental Disorders in Children with Communication Disorders*. Washington: DC: American Psychiatric Press.

Chaban, P. (1996). Understanding language dysfunction from a developmental perspective: An overview of pragmatic theories. In J. H. Beitchman, N. J. Cohen, M. M. Konstantareas, & R. Tannock (Eds.), *Language, learning, and behavior disorders: Developmental, biological, and clinical perspectives* (pp. 23 – 37). Cambridge, UK: Cambridge University Press.

Chambers, W., Puig-Antich, J., Hirsch, M., Paez, P., Ambrosini, P. J., Tabrizi, M. A., Davies, M. (1985). The assessment of affective disorders in children and adolescents by semi-structured interview: Test-retest reliability of the Schedule for Affective Disorders and Schizophrenia for School-Age Children, Present Episode version. *Archives of General Psychiatry, 42*, 696 - 702.

Chee, P., Logan, G., Schachar, R., Lindsay, P., & Wachsmuth, R. (1989). Effects of event rate and display time on sustained attention in hyperactive, normal, and control children. *Journal of Abnormal Child Psychology, 17*(4), 371 - 391.

Cohen, N. J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Cohen, N. J. (2001). *Language impairment and psychopathology in infants, children, and adolescents*. Thousand Oaks, CA: Sage.

Cohen, N. J., Davine, M., Horodezky, N., Lipsett, L., & Isaacson, L. (1993). Unsuspected language impairment in psychiatrically disturbed children: Language and behavioral characteristics. *Journal of the American Academy of Child and Adolescent Psychiatry, 32*(3), 595-603.

Cohen, N. J., Davine, M., & Meloche-Kelly, M. (1989). Prevalence of unsuspected language disorders in a child psychiatric population. *Journal of the American Academy of Child and Adolescent Psychiatry, 28*, 107 - 111.

Cohen, N. J., Menna, R., Vallance, D. D., Barwick, M. A., Im, N., & Horodezky, N. B. (1998). Language, social cognitive processing, and behavioral characteristics of psychiatrically disturbed children with previously identified and unsuspected language impairments. *Journal of Child Psychology and Psychiatry, 39*(6), 853 - 864.

Cohen, N. J., Vallance, D. D., Barwick, M., Im, N., Menna, R., Horodezky, N. B., et al. (2000). The interface between ADHD and language impairment: An examination of language, achievement, and cognitive processing. *Journal of Child Psychology and Psychiatry, 41*(3), 353-362.

Collings, R. D. (2003). Differences between ADHD inattentive and combined types on the CPT. *Journal of Psychopathology and Behavioral Assessment, 25*(3), 177 - 189.

BioBehavioral Diagnostic Company (BioBdx) (2007). *The McLean Motion and Attention Test: MMAT/ADHD System*. Cambridge, MA: Author.

Conners, C. (1973). *Conners' Rating Scales Manual*. North Tonawanda, NY: Multi-Health Systems, Inc.

Conners, K. (1995). *The Conners' Continuous Performance Test Manual*. Toronto: Multi-Health Systems, Inc.

Conners, K. (2008). *Conners' Rating Scales-Revised*. Upper Saddle River, NJ: Pearson Education, Inc.

Conti-Ramsden, G., & Botting, N. (2004). Social difficulties and victimization in children with SLI at 11 years of age. *Journal of Speech, Language, and Hearing Research, 47*, 145 - 161.

Cornblatt, B. A., Lenzenweger, M. F., & Erlenmeyer-Kimling, L. (1989). The continuous performance test, identical pairs version (CPT-IP): II. Contrasting attentional profiles in schizophrenia and depressed patients *Psychiatry Research, 29*, 65 - 85.

Costello, A., Edelbrock, C., Kalas, R., Kessler, M., & Klaric, S. (1982). *The NIMH Diagnostic Interview Schedule for Children*. Pittsburg: Author.

Damico, J., Tetnowski, J., & Nettleton, S. (2004). Emerging issues and trends in attention deficit hyperactivity disorder: An update for the speech-language pathologist. *Seminars in Speech and Language*, *25*(3), 207 - 213.

Dane, A. V., Schachar, R. J., & Tannock, R. (2000). Does actigraphy differentiate ADHD subtypes in a clinical research setting. *Journal of the American Academy of Child and Adolescent Psychiatry, 39,* 752 - 760.

Demaray, M. K., Schaefer, K., & Delong, L. K. (2003). Attention-deficit/hyperactivity disorder (ADHD): A national survey of training and current assessment practices in the schools. *Psychology in the Schools, 40*(6), 583 - 597.

Denkla, M. B. (1998). Understanding the role of executive function in language, academics, and daily life. *American International College*. Springfield, MA.

Denkla, M. B. (Ed.). (1996). *A theory and model of executive function: A neuropsychological perspective*. Baltimore, MD: Paul Brookes.

Dickerson, S. M., & Calhoun, S. L. (2007). Learning, attention, writing, and processing speed in typical children and children with ADHD, autism, anxiety, depression, and oppositional-defiant disorder. *Child Neuropsychology, 13*(6), 469 - 493.

Dollaghan, C., & Campbell, T. (1998). Nonword repetition and child language impairment. *Journal of Speech, Language, and Hearing Research, 41*, 1136 - 1146.

Donahue, M., & Cole, D. (1994). Links between language and emotional/behavioral disorders. *Education and Treatment of Children, 17*(3), 244 - 256.

Douglas, V. I., & Benezra, E. (1990). Supraspan verbal memory in attention deficit disorder with hyperactivity, normal, and reading disabled boys. *Journal of Abnormal Child Psychology, 18*(6), 617 - 638.

Doyle, A. E., Biederman, J., Seidman, L. J., Weber, W., & Faraone, S. V. (2000). Diagnostic efficiency of neuropsychological test scores for discriminating boys with and without attention-deficit/hyperactivity disorder. *Journal of Consulting and Clinical Psychology, 68*, 477 - 488.

Dunn, L. M., & Dunn, D. M. (1981). *Peabody Picture Vocabulary Test - Revised*. Circle Pines, MN: American Guidance Service.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test, Fourth Edition*. Circle Pines, MN: American Guidance Service.

Earle-Boyer, E. A., Serper, M. R., Davidson, M., & Harvey, P. D. (1991). Continuous performance tests in schizophrenic patients: Stimulus and medication effects on performance. *Psychiatry Research, 37*, 47 - 56.

Edwards, M. C., Gardner, E. S., Chelonis, J. J., Schulz, E. G., Flake, R. A., & Diaz, P. F. (2007). Estimates of the validity and utility of the Conners' Continuous Performance Test on the assessment of inattentive and/or hyperactive-impulsive behaviors in children. *Journal of Abnormal Child Psychology, 35*, 393 - 404.

Fischler, I. (Ed.). (1998). *Attention and language*. Cambridge, MA: MIT Press.

Fleiss, J. L. (1972). Classification of the depressive disorders by numerical typology. *Journal of Psychiatric Research*, *9*, 141 - 153.

Forbes, G. B. (1998). Clinical utility of the Test of Variables of Attention (TOVA) in the diagnosis of Attention-Deficit/Hyperactivity Disorder. *Journal of Clinical Psychology*, *54*(4), 461 - 476.

Fujiki, M., Brinton, B., Morgan, M., & Hart, C. H. (1999). Withdrawn and sociable behavior of children with language impairment. *Language, Speech, and Hearing Services in Schools, 30*, 183 - 195.

Garfinkel, B. G., & Klee, S. H. (1983). A computerized assessment battery for attention deficits. *Psychiatry Hospitals, 14*, 163 - 166.

Gathercole, S. E., & Alloway, T. P. (2006). Practitioner review: Short-term and working memory impairments in neurodevelopmental disorders: Diagnosis and remedial support. *Journal of Child Psychology and Psychiatry, 47*(1), 4-15.

Gathercole, S. E., & Baddeley, A. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29*, 336 - 360.

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychopathology, 40*(2), 177-190.

Gibbs, D. P., & Cooper, E. B. (1989). Prevalence of communication disorders in students with learning disabilities. *Journal of Learning Disabilities, 22*(1), 60-63.

Gioia, G., Isquith, P., Guy, S., & Kenworthy, L. (2000). *The Behavior Rating Inventory of Executive Function*. Lutz, FL: Psychological Assessment Resources.

Goldstein, F. C., & Green, R. C. (Eds.). (1995). *Assessment of problem solving and executive functions*. New York: Plenum.

Gordon, M. (1991). *Instruction manual for the Gordon Diagnostic System, Model III-R*. DeWitt, NY: Gordon Systems.

Gordon, N. (1991). The relationship between language and behavior. *Developmental Medicine and Child Neurology, 33*(1), 86-89.

Goulden, L. G., Silver, C. H., Harward, H. S., & Levin, H. S. (1997). Utility of the Children's Executive Functions Scale in childhood brain injury. *Archives of Clinical Neuropsychology, 12*, 326.

Green, S. B., & Salkind, N. J. (2005). *Using SPSS for Windows and Macintosh: Analyzing and Understanding Data*. Upper Saddle River, NJ: Pearson Education, Inc.

Greenaway, D.S. (2004). Effects of depressed state on attention, movement, and executive functioning in children with depression and comorbid depression and attention-deficit/hyperactivity disorder. (Doctoral dissertation, University of Texas Southwestern Medical Center of Dallas, 2004).

Grimm, L. G., & Yarnold, P. R. (1995). *Reading and Understanding Multivariate Statistics*. Washington, DC: American Psychological Association.

Grizenko, N., Bhat, M., Schwartz, G., Ter-Stepanian, M., & Joober, R. (2006). Efficacy of methylphenidate in children with attention-deficit hyperactivity disorder and learning disabilities: A randomized crossover trial. *Journal of Psychiatry and Neuroscience 31*(1), 46 - 51.

Grodzinsky, G. M., & Barkley, R. A. (1999). Predictive power of frontal lobe tests in the diagnosis of attention deficit hyperactivity disorder. *The Clinical Neuropsychologist, 13*(1), 12 - 21.

Gualtieri, C. T., Koriath, U., Van Bourgondien, M., & Saleeby, N. (1983). Language disorders in children referred for psychiatric services. *Journal of the American Academy of Child and Adolescent Psychiatry, 22*(2), 165-171.

Halperin, J. M., Greenblatt, E., Sharma, V., & Schwartz, S. T. (1991). Assessment of the continuous performance test: Reliability and validity in a normal sample. *Journal of Consulting and Clinical Psychology*, *3*(4), 603 - 608.

Halperin, J. M., Matier, K., Bedi, G., Sharma, V., & Newcorn, J. H. (1992). Specificity of attention, impulsivity, and hyperactivity to the diagnosis of attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *31*, 190 - 196.

Halperin, J. M., Newcorn, J. H., Matier, K., Sharma, V., McKay, K. E., & Schwartz, S. (1993). Discriminant validity of attention-deficit hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *32*, 1038 - 1043.

Halperin, J. M., Wolf, L. E., Greenblatt, E., & Young, J. G. (1991). Subtype analysis of commission errors on the continuous performance test in children. *Developmental Neuropsychology*, *7*, 207 - 217.

Halperin, J. M., Wolf, L. E., Pascualvaca, D. M., Newcorn, J. H., Healey, J. M., O'Brien, J. D., et al. (1988). Differential assessment of attention and impulsivity in children. *Journal of the American Academy of Child and Adolescent Psychiatry*, *27*, 326 - 329.

Hammill, D. D., & Newcomer, P. L. (1997a). *Test of Language Development - Intermediate, 3rd Edition*. Circle Pines, MN: American Guidance Service.

Hammill, D. D., & Newcomer, P. L. (1997b). *Test of Language Development - Primary, 3rd Edition*. Circle Pines, MN: American Guidance Service.

Hart, K. I., Fujiki, M., Brinton, B., & Hart, C. H. (2004). The relationship between social behavior and severity of language impairment. *Journal of Speech, Language, and Hearing Research, 47*, 647 - 662.

Hayes, S. C., Gifford, E. V., & Ruckstuhl, L. E. (Eds.). (1996). *Relational frame theory and executive control*. Baltimore, MD: Paul Brookes.

Heiser, P., Frey, J., Smidt, J., Sommerlad, C., Wehmeier, P. M., Hebebrand, J., et al. (2004). Objective measurement of hyperactivity, impulsivity, and inattention in children with hyperkinetic disorders before and after treatment with methylphenidate. *European Child and Adolescent Psychiatry, 13*, 100 - 104.

Ickowicz, A., Schachar, R., Sugarman, R., Chen, S. X., Millette, C., & Cook, L. (2006). The Parent Interview for Child Symptoms: A situation-specific clinical research interview for attention-deficit hyperactivity and related disorders. *Canadian Journal of Psychiatry, 50*, 325 - 328.

Javorsky, J. (1996). An examination of youth with attention-deficit/hyperactivity disorder and language learning disabilities: A clinical study. *Journal of Learning Disabilities, 29*(3), 247-258.

Jonsdottir, S., Bouma, A., Sergeant, J. A., & Scherder, E. J. (2005). The impact of specific language impairment on working memory in children with ADHD combined subtype. *Archives of Clinical Neuropsychology, 20*(4), 443-456.

Kaplan, E., Fein, D., Kramer, J., Delis, D., & Morris, R. (1999). *Wechsler Intelligence Scale for Children - Third Edition as a Process Instrument*. San Antonio, TX: Psychological Corporation.

Kaplan, E., Fein, D., Kramer, J., Morris, R., Delis, D., & Maerlender, A. (2004). *Wechsler Intelligence Scale for Children Fourth Edition - Integrated (WISC-IV Integrated): Technical and Interpretive Manual*. San Antonio, TX: Psychological Corporation.

Kaufman, A., & Kaufman, N. (1990). *Kaufman Brief Intelligence Test*. Circle Pines, MN: American Guidance Services.

Kaufman, J., Birmaher, B., Brent, D., Rao, U., Flyn, C., Moreci, P., et al. (1997). The schedule for affective disorders and schizophrenia for school aged children present and lifetime version (K-SADS-P/L): Initial reliability and validity data. *Journal of the American Academy of Child and Adolescent Psychiatry, 36*, 980 - 988.

Kempton, S., Vance, A., Maruff, E., Luk, E., Costin, C., & Pantelis, C. (1999). Executive function and attention deficit hyperactivity disorder: Stimulant medication and better executive function performance in children. *Psychological Medicine, 29*, 527 - 538.

Kendall, R. E., & Gourlay, J. (1970). The clinical distinction between affective psychoses and schizophrenia. *British Journal of Psychiatry, 117*(261 - 266).

Keulers, E. H., Hendriksen, J. G., Feron, F. J., Wassenberg, R., Wuisman-Frerker, M. G., Jolles, J., & Vles, T. S. (2007). Methylphenidate improves reading performance in children with attention deficit hyperactivity disorder and comorbid dyslexia: An unblinded clinical trial. *European Journal of Paediatric Neurology, 11*(1), 21 - 28.

Kim, O. H., & Kaiser, A. P. (2000). Language characteristics of children with ADHD. *Communication Disorders Quarterly, 21*, 154 - 165.

Klee, S. H., & Garfinkel, B. G. (1983). The computerized continuous performance task: A new measure of inattention. *Journal of Abnormal Child Psychology, 11*(4), 487 - 496.

Kofler, M. J., Rapport, M. D., & Alderson, R. M. (2008). Quantifying ADHD classroom inattentiveness, its moderators, and variability: A meta-analytic review. *Journal of Child Psychology and Psychiatry, 49*(1), 59 - 69.

Kushnir, C. C., & Blake, J. (1996). The nature of the cognitive deficit in specific language impairment. *First Language, 16*, 21 - 40.

Lahey, M. (1990). Who shall be called language disordered? Some reflections and one perspective. *Journal of Speech and Hearing Disorders, 55*, 612 - 620.

Lazar, J. W., & Frank, Y. (1998). Frontal systems dysfunction in children with attention-deficit hyperactivity disorder and learning disabilities. *Journal of Neuropsychiatry and Clinical Neuroscience, 10,* 160 - 167.

Lee, S. I., Schachar, R., Chen, S. X., Ornstein, T. J., Charach, A., Barr, C., et al. (2008). Predictive validity of the DSM-IV and ICD-10 criteria for ADHD and hyperkinetic disorder. *The Journal of Child Psychology and Psychiatry, 49*(1), 70 - 78.

Leonard, L. (1998). *Children with specific language impairment*. Cambridge, MA: MIT Press.

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Lorch, E. P., Milich, R., & Sanchez, R. P. (1998). Story comprehension in children with ADHD. *Clinical Child and Family Psychology Review, 1*(3), 163 - 178.

Lorch, E. P., Milich, R., Sanchez, R. P., van den Brock, P., Baer, S., & Hooks, K. (2000). Comprehension of televised stories in boys with attention deficit hyperactivity disorder. *Journal of Abnormal Psychology, 109,* 321 - 330.

Losier, B. J., McGrath, P. J., & Klein, R. M. (1996). Error patterns of the Continuous Performance Test in non-medicated and medicated samples of children with and without ADHD: A meta-analytic review. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 37*, 971 - 987.

Love, A. J., & Thompson, M. G. (1988). Language disorders and attention deficit disorders in young children referred for psychiatric services: Analysis of prevalence and a conceptual synthesis. *American Journal of Orthopsychiatry, 58*(1), 52-64.

Lui, M., & Tannock, R. (2007). Working memory and inattentive behavior in a community sample of children. *Behavior and Brain Function, 3*, 12.

Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*(4), 377-384.

Martinussen, R., & Tannock, R. (2006). Working memory impairments in children with attention-deficit hyperactivity disorder with and without comorbid language learning disorders. *Journal of Clinical and Experimental Neuropsychology, 28*(7), 1073-1094.

Marton, K., & Schwartz, R. G. (2003). Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 46*(5), 1138-1153.

Max, J. E., Fox, P. T., Lancaster, J. L., Kochunov, P., Matthews, K., Manes, F. F., et al. (2002). Putamen lesions and the development of attention-deficit/hyperactivity symptomatology. *Journal of the American Academy of Child and Adolescent Psychiatry, 41*(5), 563 - 571.

McCandless, S., & O'Laughlin, L. (2007). The clinical utility of the Behavior Rating Inventory of Executive Function (BRIEF) in the diagnosis of ADHD. *Journal of Attention Disorders, 10*(4), 381 - 389.

McGee, R. A., Clark, S. E., & Symons, D. K. (2000). Does the Conners' Continuous Performance Test aid in ADHD diagnosis? *Journal of Abnormal Child Psychology, 28*(5), 415 - 424.

McInnes, A., Bedard, A. C., Hogg-Johnson, S., & Tannock, R. (2007). Preliminary evidence of beneficial effects of methylphenidate on listening comprehension in children with attention-deficit/hyperactivity disorder. *J ournal of Child and Adolescent Psychopharmacology, 17*(1), 35-49.

McInnes, A., Humphries, T., Hogg-Johnson, S., & Tannock, R. (2003). Listening comprehension and working memory are impaired in attention-deficit hyperactivity disorder irrespective of language impairment. *Journal of Abnormal Child Psychology, 31*(4), 427-443.

Mialet, J. P., Pope, H. G., & Yurgelun-Todd, D. (1996). Impaired attention in depressive states: A non-specific deficit. *Psychological Medicine, 26*, 1009 - 1020.

Miniscalco, C., Hagberg, B., Kadesjo, B., Westerlund, M., & Gillberg, C. (2007). Narrative skills, cognitive profiles, and neuropsychiatric disorders in 7-8-year-old children with late developing language. *International Journal of Language and Communication Disorders, 42*(6), 665 - 681.

Molho, C. E., & Silver, C. H. (1997). An investigation of the validity of the Children's Executive Functions Scale. *Archives of Clinical Neuropsychology, 12,* 370 - 371.

Montgomery, J. W. (2003). Working memory and comprehension in children with specific language impairment: What we know so far. *Journal of Communication Disorders, 36*, 221 - 231.

MTA Cooperative Group (1999). 14-month randomized clinical trial of treatment strategies for children with attention-deficit/hyperactivity disorder. *Archives of General Psychiatry, 56,* 1073 – 1086.

Naglieri, J. A. (1997). *Naglieri Nonverbal Ability Test - Multilevel Form*. San Antonio, TX: Harcourt Assessment.

Nass, R. D. (2006). Evaluation and assessment issues in the diagnosis of Attention Deficit Hyperactivity Disorder. *Seminars in Pediatric Neurology, 12*, 200 - 216.

Nichols, S. L., & Waschbusch, D. A. (2004). A review of the validity of laboratory cognitive tasks used to assess symptoms of ADHD. *Child Psychiatry and Human Development, 34*(4), 297 - 315.

Nicholson, C. L., & Hibpshman, T. L. (1996). *Slosson Intelligence Test Revised (SIT-R): For Children and Adults - Manual*. East Aurora, NY: Slosson Educational Publications, Inc.

Nigg, J. T. (2001). Is ADHD a disinhibitory disorder? *Psychological Bulletin, 127*, 571 - 598.

Nigg, J. T., Hinshaw, S. P., & Halperin, J. M. (1996). Continuous performance test in boys with attention deficit hyperactivity disorder: Methylphenidate dose response and relations with observed behaviors. *Journal of Clinical Child Psychology, 25,* 330 - 340.

Oram, J., Fine, J., Okamoto, C., & Tannock, R. (1999). Assessing the language of children with attention deficit hyperactivity disorder. *American Journal of Speech-Language Pathology, 8*, 72 - 80.

Oram, J., Fine, J., & Tannock, R. (1999). Assessing the language of children with attention deficit hyperactivity disorder. *American Journal of Speech-Language Pathology and Audiology, 8*, 72 - 80.

Paul, R. (Ed.) (1992). *Language and speech disorders*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Paul, R. (1995). *Language Disorders from Infancy through Adolescence: Assessment and Intervention*. St. Louis, MO: Mosby.

Pedigo, T. K., Scott, V. B., & Hughes, S. J. (2007). Implementing evidence-based practices in the assessment of ADHD, *5th Annual Conference American Academy of Clinical Neuropsychology*. Denver, CO.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37*(1), 51 - 87.

Pickering, S. J., & Gathercole, S. E. (2001). *Working Memory Test Battery for Children*. London: Psychological Corporation.

Plizka, S., Bennett, W., Bukstein, O., Walter, H., Arnold, V., Beitchman, J., et al. (2007). Practice parameters for the assessment and treatment of children and adolescents with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 46*(7), 894 - 921.

Porrino, L. J., Rappoport, J. L., Behar, D., Ismond, D. R., & Bunney, W. E. (1983). A naturalistic assessment of motor activity of hyperactive boys: II. Stimulant drug effects. *Archives of General Psychiatry, 40*, 688 - 693.

Porrino, L. J., Rappoport, J. L., Behar, D., Scerry, W., Ismond, D. R., & Bunney, W. E. (1983). A naturalistic assessment of the motor activity of hyperactive boys: Comparison with normal boys. *Archives of General Psychiatry, 40*, 681 - 687.

Prizant, B., Audet, L. R., Burke, G. M., Hummel, L. J., Maher, S. R., & Theadore, G. (1990). Communication disorders and emotional/behavioral disorders in children and adolescents. *Journal of Speech and Hearing Disorders, 55*, 179 - 192.

Purvis, K. L., & Tannock, R. (1997). Language abilities in children with attention deficit hyperactivity disorder, reading disabilities, and normal controls. *Journal of Abnormal Child Psychology, 6*(4), 133 - 144.

Rapin, I. (1996). Practitioner review: Developmental language disorders: A clinical update. *Journal of Child Psychology and Psychiatry, 37*(6), 643 - 655.

Rapin, I., & Allen, D. (Eds.). (1983). *Developmental Language Disorders: Nosologic Considerations*. New York: Academic Press.

Redmond, S. M. (2002). The use of rating scales with children who have language impairments. *American Journal of Speech-Language Pathology, 11*(2), 124 - 138.

Redmond, S. M. (2004). Conversational profiles of children with ADHD, SLI and typical development. *Clinical Linguistics and Phonetics, 18*(2), 107-125.

Redmond, S. M., & Rice, M. L. (1998). The socioemotional behaviors of children with SLI: Social adaptation or social deviance? *Journal of Speech, Language, and Hearing Research, 41*, 688 - 700.

Reynolds, C. R. (1997). Forward and backward memory span should not be combined for clinical analysis *Archives of Clinical Neuropsychology, 12*, 29 - 40.

Reynolds, C. R., & Kamphaus, R. W. (2006). *BASC-2: Behavior Assessment System for Children, Second Edition*. Shoreview, MN: AGS Publishing.

Riccio, C. A., & Hynd, G. W. (1993). Developmental language disorders in children: Relationship with learning disability and attention deficit hyperactivity disorder. *School Psychology Review, 22*(4), 696 - 710.

Riccio, C. A., Reynolds, C. R., Lowe, P., & Moore, J. J. (2002). The continuous performance test: A window on the neural substrates for attention? *Archives of Clinical Neuropsychology, 17*, 235 - 272.

Richardson, A. J. (2006). Omega-3 fatty acids in ADHD and related neurodevelopmental disorders. *International Review of Psychiatry, 18*(2), 155 - 172.

Rielly, N. E., Cunningham, C. E., Richards, J. E., Elbard, H. J., & Mahoney, W. J. (1999). Detecting Attention Deficit Hyperactivity Disorder in a communications clinic: Diagnostic utility of the Gordon Diagnostic System. *Journal of Clinical and Experimental Neuropsychology, 21*(5), 685-700.

Rosenthal, E. N., Riccio, C. A., Gsanger, K. M., & Jarratt, K. P. (2006). Digit Span components as predictors of attention problems and executive functioning in children. *Archives of Clinical Neuropsychology, 21*(2), 131-139.

Rowland, A., Lesesne, C., & Abramowitz, A. (2002). The epidemiology of attention-deficit/hyperactivity disorder (ADHD): A public health view. *Mental Retardation and Developmental Disabilities Research Reviews, 8,* 162 - 170.

Rueckert, L., & Grafman, J. (1996). Sustained attention deficits in patients with right frontal lesions. *Neuropsychologia*, *34*, 953 - 963.

Sandford, J. A., & Turner, A. (1995). *Manual for the Integrated Visual and Auditory (IVA) Continuous Performance Test*. Richmond, VA: BrainTrain.

Schachar, R., Logan, G., Wachsmuth, R., & Chajczyk, D. (1988). Attaining and maintaining preparation: A comparison of attention in hyperactive, normal, and disturbed control children. *Journal of Abnormal Child Psychology, 16*(4), 361 - 378.

Semel, E., Wiig, E., & Secord, W. A. (2003). *Clinical Evaluation of Language Fundamentals, Fourth Edition*. San Antonio, TX: Harcourt Assessment, Inc.

Shanahan, M. A., Pennington, B. F., Yerys, B. E., Scott, A., Boada, R., Willcutt, E. G., et al. (2007). Processing speed deficits in attention deficit/hyperactivity disorder and reading disability. *Journal of Abnormal Child Psychology*, *34*(5), 585 - 602.

Shaywitz, B., Fletcher, J., Holahan, J., Shneider, A., Marchione, K., Stuebing, K., et al. (1995). Interrelationship between reading disability and attention deficit hyperactivity disorder. *Child Neuropsychology, 1*, 170 - 186.

Shaywitz, S. E., & Shaywitz, B. A. (2008). Paying attention and reading: The neurobiology of reading and dyslexia. *Development and Psychopathology, 20*, 1329 - 1349.

Sheslow, D., & Adams, W. (2003). *Wide Range Assessment of Memory and Language, Second Edition (WRAML2)*. Lutz, FL: Psychological Assessment Resources, Inc.

Siegel, L. S., & Ryan, E. B. (1989). The development of working memory in normally achieving and subtypes of learning disabled children. *Child Development, 60*, 973 - 980.

Silva, P. A., Williams, S., & McGee, R. (1987). A longitudinal study of children with developmental language delay at age three: Later intelligence, reading and behavior problems. *Developmental Medicine and Child Neurology, 29*(5), 630-640.

Silver, C. H., Benton, S. B., Goulden, L. G., Molho, C. E., & Clark, J. P. (1999). Measurement of children's executive function by parent report. *The Clinical Neuropsychologist, 13*, 228.

Silver, C. H., Kolitz-Russel, S., Bordini, F., & Fairbanks. (1993). The Children's Executive Functions Scale: Unpublished rating scale.

Singer, B. D., & Bashir, A. S. (1999). What are executive functions and self-regulation and what do they have to do with language-learning disorders? *Language, Speech, and Hearing Services in Schools, 30*, 265 - 273.

Smyth, M. M., & Scholey, K. A. (1992). Determining spatial span: The role of movement time and articulation rate. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 45A*, 479 - 501.

Snowling, M. J., Bishop, D. V., Stothard, S. E., Chipchase, B., & Kaplan, C. (2006). Psychosocial outcomes at 15 years of children with a preschool history of speech-language impairment. *Journal of Child Psychology and Psychiatry, 47*(8), 759-765.

Spitzer, R. L., Davies, M., & Barkley, R. A. (1990). The DSM-III-R field trial of disruptive behavior disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 29*, 690 - 697.

Stanovich, K. (Ed.). (1993). *The construct validity of discrepancy definitions of reading disability*. Baltimore: Brookes.

Stanton-Chapman, T. L., Justice, L. M., Skibbe, L. E., & Grant, S. L. (2007). Social and behavioral characteristics of preschoolers with specific language impairment. *Topics in Early Childhood Special Education, 27*(2), 98 - 109.

Stark, R., & Tallal, P. (1981). Selection of children with specific language deficits. *Journal of Speech and Hearing Disorders, 46*, 114 - 122.

StatSoft. (2008). Electronic Statistics Textbook. Retrieved 3/2/2009, 2009, from www.statsoft.com/textbook/stathome.html

Stevenson, J. (Ed.). (1996). *Developmental changes in the mechanisms linking language disabilities and behavior disorders*. Cambridge: Cambridge University Press.

Stevenson, J., Richman, N., & Graham, P. (1985). Behavior problems and language abilities at three years and behavioral deviance at eight years. *Journal of Child Psychology and Psychiatry*, *26*(2), 215-230.

Still, G. (1902). The Coulstonian lectures on some abnormal physical conditions in children. *Lancet, 1*, 1008 - 1012.

Stins, J. F., Tollenaar, M. S., Slaats-Willemse, D., Buitelaar, J. K., Swaab-Barneveld, H., Verhulst, F. C., et al. (2005). Sustained attention and executive functioning performance in attention-deficit/hyperactivity disorder. *Child Neuropsychology, 11*, 285 - 294.

Swaab-Barneveld, H., de Sonneville, L., Cohen-Kettenis, P., Gielen, A., Buitelaar, J., & van Engeland, H. (2000). Visual sustained attention in a child psychiatric population. *Journal of the American Academy of Child and Adolescent Psychiatry, 39*, 651 - 659.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using Multivariate Statistics* (Fifth ed.). Boston: Pearson Education, Inc.

Tannock, R., Hum, M., Humphries, T., & Schachar, R. (2000, October). *Interviewing teachers about children's classroom behavior and academic performance.* Paper presented at the Proceedings of the 47th Annual Meeting of the American Academy of Child and Adolescent Psychiatry, New York, NY.

Tannock, R., Purvis, K. L., & Schachar, R. (1993). Narrative abilities in children with attention deficit hyperactivity disorder and normal peers. *Journal of Abnormal Child Psychology, 21*, 103 - 117.

Tannock, R., & Schachar, R. (1996). Executive dysfunction as an underlying mechanism of behavior and language problems in attention deficit hyperactivity disorder. In J. H. Beitchman, N. J. Cohen, M. M. Konstantareas, & R. Tannock (Eds.), *Language, learning, and behavior disorders: Developmental, biological, and clinical perspectives.* Cambridge, UK: Cambridge University Press.

Teicher, M. H. (1995). Actigraphy and motion analysis: New tools for psychiatry. *Harvard Review of Psychiatry, 3*, 8 - 35.

Teicher, M. H., Ito, Y., Glod, C., & Barber, N. I. (1996). Objective measurement of hyperactivity and attentional problems in ADHD. *Journal of the American Academy of Child and Adolescent Psychiatry, 35*(3), 334 - 342.

Teicher, M. H., Polcari, A., Anderson, C. M., Andersen, S. L., Lowen, S. B., & Navalta, C. P. (2003). Rate dependency revisited: Understanding the effects of methylphenidate in children with attention deficit hyperactivity disorder. *Journal of Child and Adolescent Psychopharmacology*, *13*(1), 41 - 51.

Teicher, M. H., Polcari, A., & McGreenery, C. E. (2008). Utility of objective measures of activity and attention in the assessment of therapeutic response to stimulants in children with attention-deficit/hyperactivity disorder. *Journal of Child and Adolescent Psychopharmacology, 18*(3), 265 - 270.

Teicher, M. H., Lowen, S. B., Polcari, A., Foley, M., & McGreenery, C. E. (2004). Novel strategy for the analysis of CPT data provides new insight into the effects of methylphenidate on attentional states in children with ADHD. *Journal of Child and Adolescent Psychopharmacology*, *14*(2), 219 - 232.

Tetnowski, J. A. (2004). Attention deficit hyperactivity disorder and concomitant communicative disorders. *Seminars in Speech & Language*, *25*(3), 215-223.

Tirosh, E., Berger, J., Cohen-Ophir, M., Davidovitch, M., & Cohen, A. (1998). Learning disabilities with and without attention-deficit hyperactivity disorder: Parents' and teachers' perspectives. *Journal of Child Neurology*, *13*(6), 270 - 276.

Tirosh, E., Cohen, A., Berger, J., Davidovitch, M., & Cohen-Ophir, M. (2001). Neurodevelopmental and behavioural characteristics in learning disabilities and attention deficit disorder. *European Journal of Paediatric Neurology, 5*(6), 253 - 258.

Tomblin, J. B., Records, N. L., Buckwalter, P., Zhang, X., Smith, E., & O'Brien, M. (1997). Prevalence of specific language impairment in kindergarten children. *Journal of Speech, Language, and Hearing Research, 40*(6), 1245-1260.

Tomblin, J. B., & Zhang, X. (Eds.) (1999). *Language patterns and etiology in children with specific language impairment*. Cambridge, MA: MIT Press.

Toppelberg, C. O., & Shapiro, T. (2000). Language disorders: A 10-year research update review. *Journal of the American Academy of Child and Adolescent Psychiatry, 39*(2), 143-152.

TOVA. (2007). *Test of Variables of Attention (TOVA)*. Los Alamitos, CA: Author.

Trommer, B. L., Hoeppner, J. A., Lorber, R., & Armstrong, K. J. (1988). The go-no-go paradigm in attention deficit disorder. *Annals of Neurology, 24*, 610 - 614.

Vallance, D. D., Im, N., & Cohen, N. J. (1999). Discourse deficits associated with psychiatric disorders and with language impairments. *Journal of Child Psychology and Psychiatry, 40*(5), 693 - 704.

van Daal, J., Verhoeven, L., & van Balkom, H. (2007). Behavior problems in children with language impairment. *Journal of Child Psychology and Psychiatry, 48*(11), 1139-1147.

van den Bosch, R. J., Rombouts, R. P., & van Asma, J. O. (1993). Subjective cognitive dysfunction in schizophrenic and depressed patients. *Comprehensive Psychiatry, 34*, 130 - 136.

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children - Fourth Edition*. San Antonio, TX: Harcourt Assessment, Inc.

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV)*. San Antonio, TX: Pearson Education, Inc.

Wechsler, D., Kaplan, E., Fein, D., Kramer, J., Morris, R., Delis, D., et al. (2004). *Wechsler Intelligence Scale for Children - Fourth Edition - Integrated*. San Antonio, TX: Harcourt Assessment, Inc.

Wechsler, D., & Naglieri, J. A. (2006). *Wechsler Nonverbal Scale of Ability* San Antonio, TX: Harcourt Assessment, Inc.

Weismer, S. E., Tomblin, J. B., Zhang, X., Buckwalter, P., Chynoweth, J., & Jones, M. (2000). Nonword repetition performance in school-age children with and without language impairment. *Journal of Speech, Language, and Hearing Research, 43*, 865 - 878.

Westby, C., & Watson, S. (2004). Perspectives on attention deficit hyperactivity disorder: Executive functions, working memory, and language disabilities. *Seminars in Speech and Language, 25*(3), 241-254.

Wiig, E., & Semel, E. (1988). *Test of Language Competence - Expanded Edition (TLC-EE)*. San Antonio, TX: Psychological Corporation.

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

Williams, D., Stott, C. M., Goodyer, I. M., & Sahakian, B. J. (2000). Specific language impairment with or without hyperactivity: neuropsychological evidence for frontostriatal dysfunction. *Developmental Medicine and Child Neurology, 42*(6), 368-375.

Wolraich, M. L. (1999). Attention deficit hyperactivity disorder: The most studied and yet most controversial diagnosis. *Mental Retardation and Developmental Disabilities Research Reviews, 5*, 163 - 168.

Wolraich, M. L., Lambert, W., Baumgaertel, A., Garcia-Tornel, S., Feurer, I. D., Bickman, L., et al. (2003). Teachers' screening for Attention Deficit/Hyperactivity Disorder: Comparing multinational samples on teacher ratings of ADHD. *Journal of Abnormal Child Psychology, 31*(4), 445 - 455.

Woodcock, R., & Johnson, M. (1989). *Woodcock-Johnson Psycho-Educational Battery - Revised*. Allen, TX: DLM Teaching Resources.

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

Ylvisaker, M., & DeBonis, D. (2000). Executive function impairment in adolescence: TBI and ADHD. *Topics in Language Disorders, 20*(2), 29 - 57.