ASSESSMENT OF ATTENTION AND MOTION IN CHILDREN WITH AN ORAL LANGUAGE DISORDER AND ATTENTION-DEFICIT/HYPERACTIVITY DISORDER FOLLOWING LANGUAGE INTERVENTION

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DEDICATION

I dedicate this work to Christ and my loved ones.

Your support, love, and encouragement

helped me achieve this amazing accomplishment.

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by

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ASSESSMENT OF ATTENTION AND MOTION IN CHILDREN WITH AN ORAL LANGUAGE DISORDER AND ATTENTION-DEFICIT/HYPERACTIVITY DISORDER FOLLOWING LANGUAGE INTERVENTION

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Children diagnosed with an oral language disorder (OLD) and attention deficit/hyperactivity disorder (ADHD) have been identified to have symptom overlap of core ADHD symptoms, thus misdiagnoses or true symptom overlap must be examined. Additionally, given that stimulant medication is the most popular treatment for children diagnosed with ADHD, the role of medication in remediating attention and movement in children with OLD and OLD/ADHD should be explored. Core ADHD symptoms in children with OLD and ADHD can be identified objectively using the Quotient™, an objective CPT designed to measure core symptoms of ADHD (i.e., inattention, impulsivity, and movement). In 2009, Baker found the Quotient™ to

be a useful diagnostic tool in the assessment of children with OLD and OLD/ADHD given its ability to discriminate OLD from OLD/ADHD children on variables of movement. The current study aimed to replicate the Baker (2009) findings by examining one year follow-up data. The current study also aimed to identify the effects of medication on attention and movement. The sample for the present study consisted of 35 children, between 6 and 13 years, with an oral language disorder. Twenty-two of the total sample also met diagnostic criteria for ADHD. Results of repeated measure analysis of variance (ANOVA) with a factor for groups (OLD vs. OLD/ADHD or On Meds/Off Meds), a factor for time (T1 and T2), and a factor that represents the interaction term (Groups by Time) revealed significant diagnostic group differences in movement, significant medication condition group differences for attention and movement, significant improvements in attention and body control over time (i.e., 1 year), and significant improvements over time in an attention variable and a movement variable for children on medication testing. Suggestions addressing limitations of the current study are discussed for future direction.

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PRIOR PUBLICATIONS

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LIST OF ABBREVIATIONS

ADHD	Attention-Deficit/Hyperactivity Disorder
APA	American Psychological Association
CPT	Continuous Performance Test
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
K-SADS-P/L	Schedule for Affective Disorders and Schizophrenia for School Age Children, Present/Lifetime Edition
LD	Learning Disability
LI	Language Intervention
MMAT	McLean Motion and Attention Test
MTS	Motion Tracking System
OLD	Oral Language Disorder
Quotient™	Quotient ™ ADHD System
TOVA	Test of Variables of Attention

CHAPTER ONE
Introduction

SIGNIFICANCE OF THE PROBLEM

Evident as early as 18 to 30 months old (American Speech-Language Hearing Association, 2008), 1 to 15% of preschool and school-age children are diagnosed with an oral language disorder (American Psychological Association, 2000; Boyle, Gillham, & Smith, 1996; Cohen, Davine, & Meloche-Kelly, 1989; Gibbs & Cooper, 1989; Law, Boyle, Harris, Harkness, & Nye, 2000; Love & Thompson, 1988; Tomblin, Smith, & Zhang, 1997). Of those with an oral language disorder (OLD), many will later develop other comorbid diagnoses (Cohen et al., 2000; Westby & Watson, 2004), including attention deficit/hyperactivity disorder (ADHD). Specifically, an estimated 50% of children with ADHD have a comorbid oral language deficit (Cohen, Barwick, Horodezky, Vallance, & Im, 1998; Cohen, Davine, Horodezky, Lipsett, & Isaacson, 1993; Gualtieri, Koriath, Van Bourgondien, & Saleeby, 1983).

Since children with both OLD and ADHD are expected to experience more academic difficulties (Bashir & Scavuzzo, 1992; Rescorla, Hadicke-Wiley, & Escare, 1993) and a wide variety of difficulties in language, coordination, attention, and perception, they are expected to suffer from more difficulties in their social skills and emotional well-being when these diagnoses are co-occurring (Pickering, 2004a). Given that children with OLD and ADHD may have some overlapping diagnostic symptoms (Cohen et al., 2000) that may present as attention deficits, the current study will aim to identify and differentiate specific attention variables (on and off medication) in children with OLD and OLD/ADHD before and after a language intervention. It is likely that children with these diagnoses have contrasting attention deficits that would warrant

different types of treatment approaches; therefore, it is imperative to understand the differences to better accommodate learning environments for children with language impairments and ADHD.

CHAPTER TWO
Literature Review

LANGUAGE IMPAIRMENT

Diagnosing an Oral Language Disorder

Language impairment (LI) or a language disorder is a deficit or delay in receptive language (the understanding of spoken language by others) and/or expressive language (the sharing of thoughts, ideas, and feelings). An assortment of terms have been used to refer to this LI condition, including specific language impairment (SLI), developmental language disorder, developmental dysphasia or aphasia (Toppelberg & Shapiro, 2000), and communication disorder (American Psychological Association, 2000; APA). The Diagnostic and Statistical Manual Fourth Edition (DSM-IV) uses the name *Communication Disorders* to categorize five language disorders: 1) Expressive Language Disorder, 2) Mixed Receptive-Expressive Language Disorder, 3) Phonological Disorder, 4) Stuttering, and 5) Communication Disorder Not Otherwise Specified (APA, 2000). For the purposes of this study and consistent with terminology used in the Shelton School Language Intervention program (LI), Expressive Language Disorder and Mixed Receptive-Expressive Language Disorder will be referred to as an oral language disorder (OLD).

PREVALENCE

There are discrepancies in the estimates of OLD, which may be due to variations in clinical and demographic characteristics of the samples, diagnostic criteria, and assessment procedures. Due to various in research methodology and diagnostic criteria, studies report different prevalence rates for OLD, ranging from 1 to 15% of children (APA, 2000; Boyle, Gillham, & Smith, 1996; Cohen, Davine, & Meloche-Kelly, 1989; Gibbs & Cooper, 1989; Law, Boyle, Harris, Harkness, & Nye, 2000; Love & Thompson, 1988; Tomblin, Smith, & Zhang, 1997). With regard to gender prevalence rates, there is some debate whether it is more commonly found in boys compared to girls. Most literature suggests a higher prevalence of OLD in boys than girls, with ratios ranging from 1.2:1 to 2.3:1 (Burden, Scott, Forge, & Goodyer, 1996; Randall, Reynell, & Curwen, 1974; Stevenson & Richman, 1976; Stewart, Hester, & Taylor, 1986; Tuomi & Ivanoff, 1977). Only two studies have found a higher prevalence in girls. Beitchman and colleagues (1986) found a 0.98:1 ratio of those with language disorders and a 0.46:1 ratio of those with speech and language diagnoses. In an epidemiological study of specific language disorders (SLI), Tomblin and colleagues (1997) suggested an underreporting of difficulties in girls in the existing data. Similar to Tomblin et al., Shaywitz and colleagues (1990) had previously reported this phenomenon with regard to the underreporting of girls with reading disabilities.

Data on prevalence rates by ethnicity are practically non-existent, perhaps due to non-diverse sampling. Only two studies found LI more prevalent among African-Americans (Hammer, Tomblin, Zhang, & Weiss, 2001; Tomblin et al., 1997). Tomblin and colleagues (1997) found increased rates of language delays in monolingual African-Americans when

compared with Caucasians. In another study, OLD was more common among children with African American mothers compared to children with Caucasian or Latin mothers (Hammer et al., 2001). To date, no other studies have examined ethnic differences in the diagnosis of LI.

ETIOLOGY

Nature: Neurological and Genetic

One of the most common issues in the clinical presentation of children between ages 3 and 16 years, regardless of their diagnosis, is problems in language (Shapiro, 1989). Despite the prevalence, the mechanism by which language disorders are caused is unknown. Different research perspectives provide support for biological and/or environmental influences. Some of the primary theories of etiology include a neurofunctional, neurostructural, genetic, and environmental risk factor approach to explain the etiology of language disorders.

The neurofunctional perspective of language disorders postulates developmental deficits in processing input and organizing output. Specifically the difficulty is processing brief components of information presented in rapid succession and organizing rapid sequential motor output. Tallal and colleagues (1993) argued that there is difficulty processing quick tonal changes responsible for the deficient phonemic discrimination. They also found that low phonological awareness was associated with poor reading skills.

Several studies have found structural differences or neurobiological defects in areas of the brain known to support language functioning. Semrud-Clikeman (1997) reviewed postmortem reports and four magnetic resonance studies and found asymmetry (asymmetric

measurement between the left and right hemispheres of the brain) in perisylvian and planum temporale regions. Plante and colleagues (1991) also found perisylvian asymmetries in boys with LI, their parents, and their siblings (Plante, 1991). Reversal of normal leftward asymmetry was also seen in other studies (Herbert et al., 2005; Jackson & Plante, 1996). In a more recent study, children with LI had narrower right hemispheres, smaller pars triangularis in the left hemisphere, and more rightward asymmetry of language structures than control children (Gauger, Lombardino, & Leonard, 1997). In addition to children with LI, atypical symmetry of the planum temporale has also been seen in children with dyslexia (Foster, Hynd, Morgan, & Hugdahl, 2002; Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990; Larsen, Høien, Lundberg, & Odegaard, 1990). Additionally, reduced brain size has also been identified in children with LI (Preis, Jancke, Schitter, Huang, & Steinmetz, 1998).

There is much support for the relationship between heredity and LI, including a specific genetic links. Language disorders have been found in higher numbers within families. More than 7 studies in the past decade indicate this familial pattern (Gilger, 1992). Additionally, Tomblin and colleagues (1997) found that, when compared to control children, fathers of children with LI were more likely to have histories of speech difficulties, learning difficulties, or mental retardation. Further support for heredity of LI includes findings of higher prevalence in siblings (Tomblin, 1989) and higher prevalence in fathers and siblings (29%) than mothers (7%) (Rice, Honey, & Wexler, 1998; Tallal, Ross, & Curtiss, 1989). Along with support for heritability, evidence for a single gene transmission for dysphasia, which is the difficulty in speaking and understanding spoken or written language, was found (Gopnik & Crago, 1991), but to date, a specific gene location study has not been published. In a more recent study, Bartlett

and colleagues (2002) found specific language impairment to be located on chromosomes 13 and 2.

Nurture: Environmental Risk Factors

In a review of language disorders research for the past decade, lower socioeconomic status was consistently associated with LI (Toppelberg & Shapiro, 2000). Tomblin and colleagues (1997) reviewed existing literature and found that parents with less education (no or incomplete college education) were more likely to have children with speech and learning problems. Additionally, they also identified parental smoking and drinking to be associated with LI. Other studies have also identified higher prevalence of language disorders in lower socioeconomic groups (Beitchman, Wilson, Brownlie, Walters, & Lancee, 1996; Horwitz, Irwin, Briggs-Gowan, Heenan, Mendoza, & Carter, 2003). Other environmental risk factors include children in bilingual homes (Horwitz et al., 2003) and maternal age below 18 years (Stanton-Chapman, Chapman, Bainbridge, & Scott 2002).

DEVELOPMENTAL TRAJECTORY

Academic functioning

Many studies have found that children with OLD are at risk for academic difficulties. More specifically, concurrent and longitudinal studies have found that reading and/or spelling problems occur more frequently in children with LI (Bird, Bishop, & Freeman, 1995; Bourdreau

& Hedberg, 1996; Catts, 1993; Scarborough, 1990; Tallal et al., 1989; Van der Lely & Stollwerk, 1996). Bishop and Adams (1990) further examined the relationship and found language to be the best predictor of reading achievement (around age 8.5 years).

Comorbidities

Children with an OLD are at risk later developing a psychiatric disorder (Baker & Cantwell, 1990; Beitchman, et al., 1996; Cantwell & Baker, 1991). Several researchers report that around 50% of children with Language-Learning Disorders also have an Axis I psychiatric disorder (Beitchman et al., 1986; Maag & Reid, 1994; Stanford & Hynd, 1994; Torgesen, 1990). The most frequently occurring comorbid diagnosis is ADHD (Beitchman et al., 1986; Biederman, Newcorn, & Sprich, 1991; Cohen et al., 1998; Cohen et al., 1993; Warr-Leeper, Wright, & Mack, 1994). The overlap of ADHD-like and language impairment symptoms is discussed in the section Attention-Deficit/Hyperactivity Disorder.

TREATMENT

Language Interventions

To date, early language interventions have shown to be the most effective measure to improve current language functioning in young children, thus preventing them from later developing more severe language deficits (Gillon, 2000; Menchaca, Arnold, & Smith, 1991; Whitehurst, Fischel, Lonigan, Valdez-). Without early intervention, young children with

language deficits may later struggle in school. Studies have shown associations between early language deficits and later development of learning disabilities (Bird et al., 1995; Bishop & Adams, 1990; Boudreau & Hedberg, 1999; Catts, 1993; Scarborough, 1990), difficulties with social skills (Cohen et al., 1998; Rutter & Casear, 1991), and psychiatric disorders (Baker & Cantwell, 1987; Beitchman et al., 2001; Benasich, Curtiss, & Tallal, 1993). Reports indicate that language intervention programs aimed to improve the child's academic language performance, so that it is within normal limits for his or her chronological age, should be the primary goal (Olswang, Rodriguez, & Timler, 1998).

Intervention for language disorders has proven effective for younger children for various reasons. Preschool-age children are at the highest risk for later developing an oral language disorder when they exhibit significant expressive and receptive language delays that last six or more months (Bishop & Edmundson, 1987; Thal & Tobias, 1992). Additionally, studies have indicated that preschool-age children with limited spoken vocabulary are also likely to be good candidates for intervention (Fischel, Whitehurst, Caulfield, & DeBaryshe, 1989; Olswang, Long, & Fletcher, 1997; Rescorla, Roberts, & Dahlsgaard, 1997). Furthermore, young children with delayed expressive and receptive language often display poor socialization skills compared to normally-speaking toddlers (Paul, Spangle-Looney, & Dahm, 1991). Moreover, preschoolers exhibiting socialization problems, including unwillingness to initiate and take part in conversations with peers, may benefit from early intervention (Craig & Washington, 1993; Hadley & Rice, 1991; Rice, Sell, & Hadley, 1991). These studies show the benefit of early intervention for language related impairments in children.

Shelton Language Intervention Program (LI)

The Shelton School, founded in 1976 by Dr. June Ford Shelton, serves to educate children with learning differences. The learning differences include written and oral language disorders. The specific language-based disabilities include OLD and written language disorders (Dyslexia). Related disorders are distinguished as a single or comorbid diagnoses or deficits, and these include Attention-Deficit Hyperactivity Disorder (ADHD), Mathematics Disorder, Motor Skills Disorder, Reading Comprehension Disorder, Written Expression Disorder, and Social Skills Deficits.

The course curricula for the Language Intervention Program (LI) at Shelton School have been developed for children ages 6 to 14 years. They include Montessori Applied to Children At-Risk and four language therapy programs. The four language therapy programs include Alphabetic Phonics, The DuBard Association Method, Sequential English Education (SEE), and Shelton Adolescent Reading Approach (SARA). The LI Program, aimed at remediating coordination, language, attention, and perceptual deficits, combines the Montessori Method Applied to Children At-Risk for preschool through grade 4 (Montessori, 1988; Pickering, 1988) and the DuBard Association Method (DuBard & Martin, 2000; McGinnis, 1939), specific to children with an OLD, with occupational therapy, and sensory-integration therapy. In grades 5 through 7, the program continues the intensive DuBard Association Method model. Children who participated in the LI Program will be included in the current study.

CHAPTER THREE
Attention-Deficit/Hyperactivity Disorder (ADHD)

DIAGNOSING ADHD

Over the past several decades, children with ADHD-like symptoms have been diagnosed with hyperkinetic disorder, hyperactive disorder, minimal brain dysfunction, and attention deficit disorder (Barkley, 1998). In the third edition of the Diagnostic and Statistical Manual (DSM) of Mental Disorders, the term attention deficit disorder (ADD) recognized attention deficits with or without features of hyperactivity (APA, 1980). Since then, the DSM has made modifications in the diagnosis of ADD and now uses the name Attention-Deficit/Hyperactivity Disorder.

DSM-IV suggests a diagnosis of ADHD when a persistent (lasting at least 6 months), developmentally inappropriate pattern of inattention and/or hyperactivity-impulsivity symptoms occurs before the age of 7 years and in at least two settings (e.g. at school [work] and at home) (APA, 2000). More specifically, DSM-IV categorizes an ADHD into the subtypes Predominately Inattentive Type, Predominately Hyperactive-Impulsive Type, Combined Type, or NOS (not otherwise specified). Specific diagnostic criteria for ADHD subtypes are shown in Table 1.

PREVALENCE

The American Academy of Child and Adolescent Psychiatry (AACAP; 2007) outlines practice parameters for assessment of ADHD and describes the disorder as one of the most common and researched childhood psychiatric disorders. It is also one of the most frequently

diagnosed psychiatric disorders in childhood, affecting between 2% and 18% of school-age children (Barbaresi et al., 2002; Centers for Disease Control and Prevention, 2005; Harel & Brown, 2003; Rowland, Lesesne, & Abramowitz, 2002; Woodruff, Axelrad, Kyle, Nweke, Miller, & Hurley, 2004) and 2% of preschool-aged children (Lavigne, Gibbons, Christoffel, Arend, Rosenbaum, & Binns, 1996). Follow-up studies indicate that 60-85% of children with ADHD will continue to have the disorder throughout their adolescent years (Barkley, Fischer, Edelbrock, & Smallish, 1990; Biederman et al., 1996; Claude & Firestone, 1995).

ADHD is found to continue into the teen years and adulthood, but there are some diagnostic issues regarding diagnoses in adulthood. In a follow-up study, Biederman, Mick, and Faraone (2000) found that 90% of adults who had ADHD in their childhood, continued to have at least five symptoms of ADHD. Of those interviewed, 40% met full diagnostic criteria for ADHD, giving rise to a diagnostic issue regarding self-reporting of symptoms. Literature suggests a discrepancy in prevalence rates due to sampling (age at which diagnosed) and diagnostic assessment procedures (symptoms based on self-report, clinician report, or teacher report). Other studies reported prevalence rates higher when a parent reported symptoms of his/her child, compared to a young adult retrospectively reporting his/her own symptoms (Barkley, Fischer, Fletcher, & Smallish, 2002).

ETIOLOGY

A neurological basis for the etiology of ADHD is highly supported by most neuropsychology studies (Bush, Valera, & Seidman, 2005; Castellanos, Lee, Sharp, Jeffries, Greenstein, and Clasen, 2002; Durston et al., 2004; Farone et al., 2005; Muenke, 2004; Nigg, 2006; Sowell,

Thompson, Welcome, Henkenius, Toga, & Peterson, 2003; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Genetic, neurological, and brain structure studies have investigated neurological causes of ADHD.

In a review of twin studies, Farone and colleagues (2005) found a 76% hereditability link. More recently, a genome study identified ADHD markers at chromosomes 4, 5, 6, 8, 11, 16, and 17 (Muenke, 2004). Further supporting a genetic link, brain imaging studies have identified gray matter deficits at higher rates in siblings of children with ADHD (Durston et al., 2004). Other imaging studies have identified reduced cortical white and gray matter volume (Castellanos et al., 2002) and decreased frontal and temporal lobe volume (Sowell et al., 2003) in children with ADHD. Other neurobiological etiological factors identified, although non-genetic, include maternal smoking during pregnancy (Mick, Biederman, Faraone, Sayer, & Kleinman, 2002), prenatal stress, low birth weight (Mick, Biederman, Prince, Fischer, & Faraone, 2002), and traumatic brain injury (Max et al., 1998).

DEVELOPMENTAL TRAJECTORY AND COMORBIDITIES

There is much co-occurrence of ADHD with other psychiatric diagnoses and academic difficulties in children, adolescents, and adults. Between 20 to 60% of children with ADHD have one or more learning disabilities or language problems (Pliszka, Carlson, & Swanson, 1999; Pliszka, 2000). Aside from the comorbidity of ADHD and OLD, discussed in depth in Chapter II, studies have also indicated that children with ADHD are at risk for learning problems or learning disorders (Kube, Peterson, & Palmer, 2002; Shapiro & Gallico, 1993; Shaywitz & Shaywitz, 2008).

Aside from academic difficulties, children with ADHD are also expected to have comorbid Axis I diagnoses. Around 75% of preschool children with ADHD have at least one comorbid psychiatric diagnosis (Wilens, Biederman, & Spencer, 2002), and many of these children are later diagnosed with behavioral disorders. An estimated 30 to 50% of all children with ADHD are likely to have an externalizing disorder, most likely oppositional defiant disorder (ODD; Spencer, Biederman, & Wilens, 1999; Pliszka, 2000). ODD is expected to occur in 54 to 84% of children with ADHD (Pliszka et al., 1999). Of those with comorbid ODD and ADHD, many are expected to later develop conduct disorder (CD; Barkely, 2005).

Aside from behavioral disorders, mood and anxiety disorders are also prevalent comorbid diagnoses in individuals with ADHD. Major depressive disorder is estimated to occur in 5 to 40% of adolescents with ADHD (Spencer et al., 1999; Pliszka et al., 1999), while bipolar disorder occurs at a prevalence of 10-20% (Faraone, Biederman, Wozniak, Mundy, Mennin, & O'Donnell, 1997; Wozniak, Biederman, Mundy, Mennin, & Faraone, 1995). At least one or more anxiety disorders are also found to co-occur in children with ADHD at a rate of 20 to 35% (Biederman et al., 1991; MTA Cooperative Group, 1999; Pliszka et al., 1999; Spencer et al., 1999; Tannock, 2000).

In addition to academic difficulties and comorbid diagnoses, many children with ADHD continue to have ADHD and other problems in their adolescence and adulthood. As many as 60-85% of children with ADHD will continue to have the disorder in their adolescence (Barkley et al., 1990; Biederman et al., 1996; Claude & Firestone, 1995), while as many as 90% will continue to have at least five symptoms of ADHD (Biederman et al., 2000). As adults, antisocial and criminal behaviors are seen at "higher than expected" rates (Barkley, Fischer, Smallish, & Fletcher, 2004). Compared to individuals without ADHD, adults with ADHD reportedly have

higher rates of employment, marital, and health problems (Barkley, Fischer, Smallish, & Fletcher, 2006), children out of wedlock (Johnston, 2002), and injuries and accidents (Barkley et al., 2004).

Because the presence of comorbid disorders puts children at risk for later development of additional disorders, it is important to recognize the prevalence of this issue in order to provide early treatments and interventions. Findings from the NIMH Multimodal Treatment Study of ADHD (MTA) and other studies provide strong support for the efficacy of early interventions to prevent the future development of comorbid diagnoses in children with ADHD (Jensen & Cooper, 2003; Wilens, et al., 2002).

TREATMENT

Medication

For children with ADHD, pharmacological intervention is the most popular treatment option to improve behavior problems, but there is much debate over its efficacy in remediating other specific deficits of ADHD, such as executive functioning (Tamm et al., in press). Although there is debate on its diagnosis and treatment, medication is the one of the most common approaches to treat ADHD symptoms in children (Rhodes, Coghill, & Matthews, 2006) and has successfully produced improvements in executive functioning (EF) in adults and EF and behavior control in children with ADHD. In an epidemiological study of children with ADHD (Rowland et al., 2002) and in a study of elementary school children with ADHD in Rhode Island, reports indicated that 6 to 7% of children with ADHD are likely to be treated with medication

(Harel & Brown, 2003). Of the medications utilized for treatment of ADHD in children, stimulants are the most frequently prescribed and studied (Rhodes et al., 2006) and are thought to block the reuptake of the neurotransmitters norepinephrine and dopamine (Pliszka, 2003). Various studies have shown stimulant medication to improve behavioral issues, such as self-regulation (Kerstin, Gunther, Hanisch, & Herpertz-Dahlmann, 2004; Rhodes, Coghill, & Matthews, 2006), while other researchers provide support for non-medication interventions to improve attention and executive functioning (Kerns, Eso, & Thompson, 1999; Tamm, et al., in press) in children with ADHD.

A myriad of studies have identified stimulant medication to improve executive functioning in adults and children with ADHD (Kempton, Vance, Maruff, Luk, Costin, & Pantelis, 1999; Kerstin et al., 2004; Mehta, Owen, Sahakian, Mavaddat, Pickard, & Robbins, 2000; Rhodes et al., 2006). For example, in a study of adults with significant difficulties in their working memory, those treated with the stimulant ADHD medication, methylphenidate, showed improvements in their cognitive performance (Mehta et al., 2000). In a study of children with ADHD/Combined Type, children's performance on EF tasks while on stimulant medication was associated with improved EF compared to children who were not treated with medication (Kempton, et al., 1999). In another study, improvements in self-regulation in boys with ADHD were found for children who were treated with stimulant medication (Rhodes et al., 2006). In a study indicating improvements in attention variables in children with ADHD, vigilance, sustained attention, and set shifting were shown to improve with stimulant medication while divided attention did not improve (Kerstin et al., 2004).

Non-Medication

While medication for ADHD has demonstrated improvements in behavior control and some areas of executive functioning, the utilization of effective non-medication treatment options is often preferred for children because of adverse side effects, such as increased stuttering (Burd & Kerbeshian, 1991; Lavid, Franklin, & Maguire, 1999; Riley & Riley, 2000), tics (Castellanos et al., 1997; Denckla, Bemporad, MacKay, 1976; Gualtieri & Patterson, 1986), obsessive/compulsive behaviors (Breggin, 1999; Castellanos et al., 1997), and "zombie" or lethargic/withdrawn behaviors (Fialkov & Hasley, 1984; Firestone, Musten, Pisterman, Mercer, & Bennett, 1998; Swanson, Cantwell, Learner, McBurnett, Pfiffner, & Kotkin, 1992).

Despite attention being one of the primary deficits in children with ADHD, few studies have investigated how to remediate attention without using medication. Some researchers have investigated specific areas of attention (sustained attention, selective attention, alternating attention, and divided attention) in children with ADHD and have successfully utilized a non-medication treatment or an attention training intervention (Tamm et al., in press; Kerstin et al., 2004). In a study of 23 school-aged children with ADHD who participated in 8 consecutive weeks of an attention training intervention (16 total sessions), the children demonstrated EF improvements (Tamm et al., in press). Specifically, neuropsychological assessments indicated improvements in fluid reasoning, cognitive flexibility, and working memory following the intervention. Additionally, 75% of the participants reported that at least one other person had remarked on progress in their attention.

CHAPTER FOUR
Symptom Overlap in OLD/ADHD & Assessment

ATTENTION DEFICITS IN CHILDREN WITH OLD AND ADHD

One of the most common comorbid diagnoses with OLD is ADHD (Beitchman et al., 1986; Biederman et al., 1991; Cohen et al., 1998; Cohen et al., 1993; Warr-Leeper, Wright, & Mack, 1994). Since OLD and ADHD are co-occurring at high rates and with detrimental developmental outcomes, tailoring treatment is very important, but can be challenging (Westby & Watson, 2004). While some studies have provided strong evidence for attention training and language interventions to remediate attention and language deficits in children with ADHD and OLD, few studies have investigated the role of attention in children with ADHD and comorbid OLD.

There is evidence of overlapping symptoms in inattention in children with ADHD and OLD (see Table 2). Two studies found that children with ADHD displayed deficits in their pragmatic language (i.e., excessive talking, insufficient information provided upon responding, poor turn-taking skills, and difficulty maintaining topics) (Humphries, Koltun, Malone, & Roberts, 1994; Tannock, Purvis, & Schachar, 1993; Tannock, Purvis, & Schachar, 1996). Camarata and Gibson (1999) confirmed a correlation between ADHD symptoms and their impact on pragmatics or the social use of language (Prutting & Kirchner, 1987; Searle, 1969), thus providing stronger evidence for underlying language deficit and behavior symptom overlap in children with ADHD and OLD. Additionally, one study found lower listening comprehension and working memory performance evident in children with a LI and comorbid LI and ADHD (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003). Given the symptoms displayed in

both groups, it would be expected that children with ADHD and OLD would present as inattentive. More specifically, if an observed child has difficulty comprehending what he/she has heard and holding information in short term memory, caregivers and/or clinicians might rate the child as inattentive. Fortunately, objective measures of attention can be used to discriminate between the groups.

OBJECTIVE ASSESSMENT OF ATTENTION

Continuous Performance Test

The Continuous Performance Test (CPT) has proven an effective, popular, and efficient means of objectively assessing attention (Greenberg & Waldman, 1993; Kanaka et al., 2008; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), especially in individuals with suspected ADHD (Nass, 2006; Nichols & Waschbusch, 2004; Pollak et al., 2009; Riccio, Reynolds, & Lowe, 2002; Wu, Huang, Chen, Chen, Chang, & Chao, 2007). The CPT excludes any aspect of self, parent, teacher, or clinician reporting of symptoms. CPTs are computer-based and in many versions the test-taker is instructed to respond to a "target" stimulus and inhibit responding to "non-target" stimuli (Corkum & Siegel, 1993; DuPaul, Anastopoulos, Shelton, Guevrement, & Metevia, 1992; Epstein, Conners, Sitarenios, & Erhardt, 1998; Greenberg & Waldman, 1993; Rosvold et al., 1956). Most CPTs use an English letter, number, or picture as the "target" stimulus, making them feasible for use in pediatric populations. The stimuli appear randomly, frequently, and over a period of 13 to 20 minutes (Kanaka et al., 2008), depending on the specific CPT version.

Efficacy of CPTs

Researchers report that children with ADHD perform worse on CPTs than normal controls (Losier, McGrath, & Klein, 1996; O'Dougherty, Neuchterlein, & Drew, 1984), thus supporting its use in the diagnostic battery for ADHD. The mechanism by which a CPT detects ADHD-like symptoms is by identifying the test-taker's response patterns. Inattentive and hyperactive/impulsive symptoms are two separate variables, tabulated by the amount of missed responses to "target" stimuli (inattention) and responses to "non-target" stimuli (hyperactivity/impulsivity) compared to a normative sample. Errors of omission are assumed to reflect symptoms of inattention (Barkley, 1991; Corkum & Siegel, 1993; Eliason & Richman, 1987; Epstein et al, 1998; Halperin, Sharma,Greenblatt, & Schwartz,1991; Inoue et al., 1998; Klee & Garfinkel, 1983; Lassiter, D'Amato, Raggio, Whitten, & Bardos,1994).

Most studies examining the psychometrics of various CPTs agree that it is a reliable and valid clinical tool for diagnosing ADHD (Gordon & Mettelman, 1988; Greenberg & Waldman, 1993; Halperin et al, 1991; Impara & Plake, 1998; Fischer, Newby, & Gordon, 1995; Seidel & Joschko, 1991). In 1991, Halperin and colleagues reported test-retest reliability of the traditional CPT, known as the "AX", ranging from 0.65 to 0.74 for hits, misses, hit reaction time, and the derived inattention and impulsivity scores. On the CPT named Seidel Continuous Attention Task (SCAT), Seidel and Joschko (1991) reported test-retest reliability ranging from 0.36 for commission errors to 0.82 for reaction time. In 1993, Greenberg and Waldman found test-retest reliability of 0.80 for response times, 0.50 for commission errors, and 0.14 for omission errors on the CPT called Test of Variables of Attention (T.O.V.A.). For the Gordon Diagnostic Systems

(GDS), test-retest reliability for commission errors ranged from 0.52 to 0.94 (Gordon & Mettelman, 1988; Impara & Plake, 1998).

Findings that do not support the use of the CPT in the diagnostic assessment of ADHD in children have reported small correlations with teacher ratings (Halperin, Wolf, Pascualvaca, & Newcorn, 1988; Lovejoy & Rasmussen, 1990; Seidel and Joschko, 1990) and correlations between omission and commission errors (Halperin, Wolfe, Greenblatt, & Young, 1991; Teicher, Lowen, Polcari, Foley, & McGreenery, 2004). Halperin and colleagues (1988) found a correlation between omission and commission errors with teacher ratings of inattention and hyperactivity ($r = 0.25$; $r = 0.37$ respectively). Seidel and Joschko (1990) also reported low correlations with teacher ratings of inattention and hyperactivity ($r = 0.35$; $r = 0.38$ respectively). Lovejoy and Rasmussen (1990) found very low correlations between teacher ratings of inattention and hyperactivity (both were $r = 0.01$). With regard to studies that found a correlation between omission and commission errors, interpreting responses to describe inattentive and hyperactive/impulsive symptoms should be done with caution (Halperin et al., 1991; Teicher et al., 2004).

Quotient™

Martin Teicher developed the Quotient™, a computer-based CPT that appears to be better suited for individuals with dyslexia or reading disorders due to the types of targets and non-targets (Behavioral Diagnostic Company [BioBdx], 2007). It is more sensitive to attention problems than other CPTs (Greenway, 2004). The Quotient™, used in the current study,

accounts for measures of movement, fluctuations in attention span, and measures of attention (Teicher et al., 2004).

First, a headband and motion reflector are placed on the child. The reflector faces the Motion Tracking System, located just above the computer monitor. The child is then instructed to respond to the "target" stimulus (which is a solid black, eight-point star) and inhibit responding to the "non-target" stimulus (which is a black, five-point star). Each stimulus flashes across a white computer screen as quickly as 180 milliseconds at a time, individually appearing in random locations across the screen. The task lasts 15 minutes for children (under age 13) or 20 minutes for adolescents and adults.

According to BioBdx (2007), the Quotient™ accurately measures motion and analyzes shifts in attention state to give a clear picture of the core symptom areas of ADHD. A printed, computerized report provides three major pieces of data: 1) motion analysis, 2) attention analysis, and 3) shift in attention state. Motion, attention, and attention state variables are further explained in Table 3. Motion is measured using data from a sensor or Motion Tracking System (will be described in the Method section). As the child moves during the task, type and distance of movement of the child's head is collected in intervals of fifty times per second. Attention is measured using data from response style which is represented by percentage of correct responses, omission errors, and commission errors. Attention state is identified as the type and the number of attention shifts based on response patterns at every thirty seconds. Specifically, every thirty seconds, responses are identified as on task, distracted, impulsive, random, minimal responding, and contrary, depending on percentage of certain combinations of correct and incorrect hits of targets and non-targets.

Researchers have proposed that the Quotient™ is a more reliable measure of ADHD-related variables than other CPTs because it can discriminate between children with ADHD compared to normal controls (Teicher, Ito, Gold, & Barber, 1996; Teicher et al., 2004). In a study using the Quotient™, data suggested that it was able to discriminate between ADHD and normal controls on variables of attention state. A higher number of attention state shifts were identified in children with ADHD compared to normal controls (Teicher et al., 2004).

As previously discussed, ADHD and language impairment symptoms have been identified in children diagnosed with an OLD and ADHD. Because there is debate over whether there is a true symptom overlap or possible misdiagnoses, using an objective measure of ADHD is important. Until recently, no study had investigated the utility of the Quotient™ to discriminate between OLD and OLD/ADHD children. Baker (2009) investigated attention and movement in children enrolled in the Shelton School LI program with OLD and OLD/ADHD. Using the Quotient™, Baker identified discriminating differences between children with OLD and OLD/ADHD. Specifically, children with OLD/ADHD had more overall movement (i.e., lower immobility duration, greater number of movements, more displacement, more area of movement, and higher temporal scaling) than children with OLD. Additionally, OLD/ADHD children's movements were more linear or simple in quality. Baker (2009) also identified that children with OLD/ADHD taking stimulant medication showed improvements in their attention (i.e., accuracy, fewer omission errors, quicker response time, more consistent response time), attention state (i.e., fewer attention shifts, more on task, and less distracted responding), and movements (i.e., more time sitting still, less movements, less displacement, less area of movement, less frequent movements, and more complex movements). For children with OLD-only, there was only one group difference in their on versus off medication testing. For the

children with OLD, they had lower response variability when tested on medication compared to their performance off medication. Given that the Quotient™ is an objective measure of various attention variables and has some psychometric support, it was used in the current study to measure attention and motion variables in children with OLD and ADHD.

CHAPTER FIVE
Summary of Literature Review

Children with language and attention deficits are expected to have academic and social difficulties and are at risk of developing other psychiatric disorders. Although studies report a high prevalence of comorbid ADHD and OLD in children, the co-occurrence of these disorders may be overrepresented. Various studies, including those previously mentioned, have identified core ADHD symptoms (inattention and hyperactivity-impulsivity) in children with OLD. Specifically, children with OLD have language impairments that can prevent them from understanding information presented to them in the classroom or at home and may cause them to refrain from social interactions that require receptive and/or expressive language abilities. Their lack of understanding and their lack of interaction with their peers may cause them to appear inattentive, and as they pursue activities other than what they were instructed to do, teachers and parents might assume they are hyperactive-impulsive.

Diagnostic assessment procedures of ADHD have traditionally relied upon parent and teacher ratings of the child's attention and hyperactivity-impulsivity. Using a more objective measure, such as the Quotient™, to discriminate children with ADHD from children who may appear to have ADHD (i.e., children with OLD) is a crucial piece of the assessment process in diagnosing ADHD. In a one year follow up from Baker's (2009) study investigating the diagnostic utility of the Quotient™, the current study re-tested the reliability of the Quotient™ at discriminating children with OLD from children with OLD/ADHD on variables of movement.

With regard to treatment, medication and non-medication interventions have shown some success in remediating attention and body control (i.e. motion variables to be discussed in "Study Rationale, Aims, and Hypotheses" section). As previously stated, it is also important to

investigate the role of medication to gain insight into the effectiveness of medication versus non-medication at improving attention and body control. Since stimulant medication has shown to improve core ADHD symptoms (inattention and hyperactivity-impulsivity), it is expected that children will have improved attention and body control (less motion/movement) when tested on medication compared to their performance off medication.

CHAPTER SIX
Study Rationale, Aims, and Hypotheses

STUDY RATIONALE

A review of the OLD and ADHD literature suggests that children with these diagnoses will experience detrimental academic, social, and emotional functioning throughout their lifetime. Given the unfavorable development they will suffer and symptom overlap of core ADHD symptoms in children with ADHD and OLD, better identification of true ADHD in both groups and the role of medication in children with OLD and OLD/ADHD should be explored. Further, utilizing objective assessments in the diagnostic process may be more accurate for better treatment planning.

Core ADHD symptoms in children with OLD and ADHD can be identified objectively using the Quotient™. Specifically, the Quotient™ is an objective CPT, designed to measure core symptoms of ADHD (i.e., inattention, impulsivity, and movement); thus it is able to discriminate children who appear to have ADHD (when subjectively assessed with rating scales) from children who actually have ADHD. Baker's (2009) findings demonstrated that the Quotient™ could be a useful diagnostic tool in the assessment of children with OLD and OLD/ADHD given its ability to discriminate OLD from OLD/ADHD children on variables of movement. Specifically, children with OLD/ADHD spent less time sitting still (lower immobility duration score), had more movements, the distance of their movements were greater in distance (higher displacement score), the space in their movement was greater (higher area score), and they had more linear movements (lower spatial complexity score). Although these findings were identified at baseline, it would be important to replicate the consistency of these

findings over time (i.e., one year). Additionally, because research suggests that stimulant medication improves attention and body control, the ability of the Quotient™ to objectively identify on versus off medication differences for attention and/or motion performance and/or identify improvement in attention and/or motion over time will be investigated. Specifically, attention gains and body control (i.e., fewer movements) will be examined across children with OLD and OLD/ADHD when children are tested on and off stimulant medication (over a one year period of enrollment in the Shelton School LI program). These objective results could support the role of the Quotient™ in the diagnostic assessment process and demonstrate the effects of stimulant medication treatment for children with comorbid OLD/ADHD. In summary, this study will use the Quotient™ measures in an attempt to replicate findings of the original Baker (2009) study a year later following further educational intervention (i.e., participants in the LI program) and to examine the role of stimulant medication in a subgroup of the OLD/ADHD subjects who are tested both on and off of their medications both at T1 and again at T2.

See Table 3 for a description of what each of the Quotient™ variables measures. The Quotient™ has three general domains of attention, attention state, and movement with each containing different sets of measurements. The attention variables include: 1) *accuracy*, 2) *omission errors,* 3) *commission errors*, 4) l*atency*, 5) v*ariability,* and 6) *Coefficient of Variance* (COV). The attention state variables include: 1) *attention shifts*, 2) *on task*, 3) *distracted*, 4) *impulsive*, 5) *random responding*, 6) *minimal responding*, and 7) *contrary*. The movement variables include: 1) *immobility duration*, 2) *movement,* 3) *displacement*, 4) *area*, 5) *spatial complexity,* and 6) *temporal*.

Repeated measure ANOVAs will be used that have a factor for groups (OLD vs. OLD/ADHD or On Meds/Off Meds), a factor for time (T1 and T2), and a factor that represents

the interaction term (Groups by Time). For Aim I emphasis will be placed on the mean differences at T2 for groups to see if they replicate the findings for T1 (time and interactions will also be examined if significant). Aims II-IV will also focus on group mean differences (On Med vs. Off Med) with an approach similar to Aim I. Although Aims II-IV will not be examining diagnostic group differences, Baker's (2009) findings for on versus off medication for OLD/ADHD children will be used as a guide for hypotheses. In sum, the emphasis will be on group differences, as there is no existing literature to support a strong finding for time and interaction with time to suggest meaningful hypotheses for this particular group of subjects.

AIMS AND HYPOTHESES

Aim I

The first study aim using the Quotient™, will test if children with OLD continue to have significantly less movements than those with OLD/ADHD after one year of participation in a language intervention program. The following hypotheses will compare OLD against OLD/ADHD children on *immobility duration* or time spent sitting still, total number of *movements*, *displacement* or amount of distance of movements, *area* or amount of space of the movements, *spatial complexity* or the complexity of the movement path, and *temporal scaling* or frequency of movement

Hypothesis I a

After one year of participation in the LI program, children with OLD will have a higher immobility duration score (i.e., OLD children will spend more time sitting still) than children with OLD/ADHD.

Hypothesis I b

After one year of participation in the LI program, children with OLD will have a lower movement score (i.e., OLD children will have fewer position changes) than children with OLD/ADHD.

Hypothesis I c

After one year of participation in the LI program, children with OLD will have a lower displacement score (i.e., OLD children's movements will be much shorter in distance) than children with OLD/ADHD.

Hypothesis I d

After one year of participation in the LI program, children with OLD will have a lower area score (i.e., OLD children will have a smaller amount of space in their movements) than children with OLD/ADHD.

Hypothesis I e

After one year of participation in the LI program, children with OLD/ADHD will have a lower spatial complexity score (i.e., OLD/ADHD children's movements will be qualitatively more simple or linear) than children with OLD.

Hypothesis I f

After one year of participation in the LI program, children with OLD will have a lower temporal scaling score (i.e., OLD children will move less frequently) than children with OLD/ADHD.

Aim II

As previously discussed, the research literature provides support that stimulant medication improves attention in children with ADHD. The second aim will be to investigate the role of stimulant medication (i.e., medicated children's performance on and off medication) on attention as measured by the Quotient™ (Hypotheses IIa-f). Specifically, it is expected that all children

(i.e., children with OLD and children with OLD/ADHD) who have been prescribed stimulant medication will consistently have better attention (i.e., a better accuracy score or more correct responses, a lower omission error score or fewer missed targets, a lower commission error score or fewer incorrect responses to non-targets, a lower latency score or lower response time, to lower variability score or lower standard deviation of response time, and a lower COV score or lower response consistency) when tested on medication compared to their performance off medication. This will be tested at both Time 1 and Time 2.

Hypothesis II a

Children who have been prescribed stimulant medication will have a better accuracy score when medicated compared to their off medication testing at both T1 and T2.

Hypothesis II b

Children who have been prescribed stimulant medication will have fewer omission scores (i.e., fewer missed targets) when medicated compared to their off medication testing at both T1 and T2.

Hypothesis II c

Children who have been prescribed stimulant medication will have fewer commission errors (or will have fewer incorrect responses to non-targets) when medicated compared to their off medication testing at both T1 and T2.

Hypothesis II d

Children who have been prescribed stimulant medication will have lower variability scores (or will have a lower standard deviation for response time) when medicated compared to their off medication testing at both T1 and T2.

Hypothesis II e

Children who have been prescribed stimulant medication will have a lower latency score (or will respond faster) when medicated compared to their off medication testing at both T1 and T2.

Hypothesis II f

Children who have been prescribed stimulant medication will have a lower COV score or faster response consistency when medicated compared to their off medication testing at both T1 and T2.

Aim III

The third aim will be to investigate the role of stimulant medication (i.e., medicated children's performance on and off medication) on attention state shifts as measured by the Quotient™ (Hypotheses IIIa-g). Specifically, it is expected that children who have been prescribed stimulant medication will have attention state shift profiles that reflect fewer shifts in attention and better accuracy when tested on medication compared to their performance off medication.

Hypothesis III a

Children will have fewer attention shifts during testing (i.e., a lower number of shifts in attention state which include on task, distracted, impulsive attention, random, minimal, and contrary states) on medication compared to their performance off medication.

Hypothesis III b

Children will spend more time with an on task attention profile (or will spend a higher percent of time hitting correct targets) when they are tested on medication compared to their performance off medication.

Hypothesis III c

Children will spend less time in a distracted attention state profile (or will spend a less time hitting correct and incorrect targets not due to chance) when they are tested on medication compared to their performance off medication.

Hypothesis III d

Children will spend less time in the impulsive attention state profile (or will spend a less time hitting both mostly correct targets and some incorrect targets) when they are tested on medication compared to their performance off medication.

Hypothesis III e

Children will spend less time in the random responding attention state profile or will spend less time hitting most targets and non-targets (accuracy of responding is as good as chance) when they are tested on medication compared to their performance off medication.

Hypothesis III f

Children will spend less time in the minimal responding attention state profile or will spend a less time missing most targets and non-targets (accuracy is about as good as chance) when they are tested on medication compared to their performance off medication.

Hypothesis III g

Children will spend less time in the contrary attention state profile or will spend a less time with response accuracy worse than chance when they are tested on medication compared to their performance off medication.

Aim IV

The following aim will be to investigate the role of stimulant medication (i.e., medicated children's performance on and off medication) on movement performance as measured by the Quotient™ (hypotheses IVa-e). Specifically, it is expected that children who have been prescribed stimulant medication will have fewer and smaller movements when tested on medication compared to their performance off medication.

Hypothesis IV a

Children will have a higher immobility duration score (i.e., will spend more time sitting still) when tested on medication compared to their performance off medication at both T1 and T2.

Hypothesis IV b

Children will have a lower movement score (i.e. will have fewer position changes) when tested on medication compared to their performance off medication at both T1 and T2.

Hypothesis IV c

Children will have a lower displacement score (i.e., movements will be much shorter in distance) when tested on medication compared to their performance off medication at both T1 and T2.

Hypothesis IV d

Children will have a lower area score (i.e., will have a smaller amount of space in their movements) when tested on medication compared to their performance off medication at both T1 and T2.

Hypothesis IV e

Children will have a higher spatial complexity score (i.e., movements will be qualitatively more complex) when tested on medication compared to their performance off medication at both T1 and T2.

Hypothesis IV f

Children will have a lower temporal scaling score (i.e., lower frequency of movements) when tested on medication compared to their performance off medication at both T1 and T2.

CHAPTER SEVEN
Method

PARTICIPANTS

Data, in a larger ongoing LI program study, were collected at two time intervals (Spring 2008 and Spring 2009) by a University of Texas Southwestern Medical Center (UTSW) Clinical Psychology Doctoral program graduate student, Kristine Baker, for a dissertation published in 2009. (Only Spring 2008 data were included in the Baker 2009 dissertation). Child participants, included in the study, attended a language intervention (LI) program at the Shelton School, a specialized private school for children with learning differences, in Dallas, Texas. Thirty-five participants, tested in Spring 2008 and Spring 2009, were between the ages of 6 and 13 years (17 = male; 18= female*)*.

Children who participated in the LI program and were included in the study, had a primary diagnosis of OLD (diagnosed by experienced speech-language pathologists, licensed psychologists, and educational diagnosticians at Shelton School) or OLD/ADHD (diagnosed by a clinical psychology doctoral program graduate student/research coordinator). Those participants with a comorbid ADHD diagnosis had one of the four subtypes of Predominantly Inattentive Type, Predominantly Hyperactive-Impulsive Type, Combined Type, or Disorder Not Otherwise Specified. Participants in the study were not excluded for taking ADHD medication (i.e., stimulant medication), but were asked to be able to be tested on and off their medication (i.e., parent and child provided consent and assent). Children at the Shelton School not enrolled in the LI program and students with history of head injury or neurological disorder, such as a seizure disorder, were excluded from this study.

Pattern 6

Children diagnosed with an OLD were evaluated by experienced speech-language pathologists, licensed psychologists, and educational diagnosticians at Shelton School. Those who met Pattern 6 categorization were enrolled in the LI program. Shelton School defines Pattern 6 as predominant Oral Language Disability or Dysphasia. Children with this profile have: (a) low average (85 – 89) or below average (< 85) verbal IQ, (b) below average (< 85) auditory processing, processing speed, visual perceptual ability, reading comprehension, spelling, or handwriting, and (c) average reading rate and accuracy (85 – 115). In addition, their receptive and expressive language performance is in the moderate to severe range of impairment or below 85.

K-SADS-P/L

Children in the study were diagnosed with ADHD using the Kaufman's Schedule for Affective Disorders and Schizophrenia in School Age Children, Present and Lifetime (K-SADS-P/L) (Kaufman et al., 1997). This 82-item semi-structured diagnostic interview is for children and adolescents aged 6 to 18 years. It has specific questions for any diagnosis, allowing the interviewer to proceed to diagnostic questions for other co-occurring disorders experienced in the lifetime of the child (current or past). The symptoms are coded as present (2) or below threshold, (1) or not present, and (0) or no information. The K-SADS-P/L uses the same diagnostic criteria as the DSM-IV-TR (Ambrosini, 2000). Specifically, to be diagnosed with ADHD, a participant must receive 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 will be diagnosed with ADHD NOS if ratings do not meet full symptom criteria (e.g., < 6 inattentive symptoms rated as a "three"), but prominent symptoms of inattention and/or hyperactivity/impulsivity are present and cause impairment.

Reliability studies of the K-SADS-P/L report high inter-rater reliability (range: 93% to 100%), excellent test-retest reliability with kappa coefficients in the excellent range for present and/or lifetime diagnoses of major depression, bipolar, generalized anxiety, conduct, and oppositional defiant disorder (.77 to 1.00), and good reliability for present diagnoses of posttraumatic stress disorder and attention-deficit/hyperactivity disorder (.63 to .67) (Kaufman et al. 1997).

MEASURES

Quotient™

The *Quotient™*, the CPT used in the study, was developed by Martin Teicher and the Developmental Biopsychiatry Research Program at McLean Hospital for individuals over age five. Prior to the *Quotient/ADHD System™*, Teicher developed the OPTAx. The OPTAx was later renamed the McLean Motion and Attention Test (MMAT; i.e., MMAT/ADHD System™) after the following were added: 1) movement assessment which included movement data for the head and legs (legs not included with the OPTAx), 2) updated normative data, 3) revised report format, and 4) revised scoring variables with age percentiles. To date, the BioBehavioral Diagnostics Company (BioBdx) has a licensing agreement with the McLean Hospital to make

this system commercially available. In 2008, the MMAT was renamed the Quotient™ after more user-friendly and visually appealing physical design changes were made and a revised report format was implemented.

The Quotient™ is an objective instrument thought to assess core symptoms of ADHD: (1) attention, (2) impulsivity, and (3) movement. The machine involves a Macintosh computer and an infrared optical tracking system (i.e., Motion Tracking System; MTS). Movement data are gathered from head and/or leg movements while the child participant wears a golf ball-sized sensor on a headband (children under 13 years) or on each leg, just below the knee (adolescents age 13 and over). The sensors communicate with the MTS, situated five feet in front of the participant. Movement greater than 0.4 mm is detected and recorded fifty times per second.

Specific procedures for the task involve the participant being seated in front of the computer and hitting the spacebar when he/she sees an eight-point star (the target) or inhibiting from hitting the spacebar when they see a five-point star (non-target). Before they begin the task, they must demonstrate understanding of the computer task by doing a tutorial of the test that lasts less than a minute. The target appears on the white computer screen, one at a time, randomly, and at different spots on the screen. The target and non-target appear at intervals of 2 seconds and stay on the screen for 100 milliseconds. The task lasts 15 minutes for child participants (age 6 through 13).

DESIGN AND PROCEDURE

Archival data were used for the current study. The previous study was reviewed and approved by the Shelton School Internal Review Board (IRB) and the University of Texas Southwestern Medical Center IRB to ensure ethical considerations and appropriate study designs. Before participation, a research study coordinator read participants and their legal guardians a description of the study, study aims, expectations, risks, and benefits. Additionally, participants' and their guardians' concerns and questions were addressed. Finally, both child and parent gave informed verbal and written assent and consent to participate in the study.

Baseline data or Time 1 (T1) data were collected for the previous study during the Spring of 2008 (Baker, 2009) and Time 2 (T2) data were collected again during the Spring of 2009. All testing was conducted at the Shelton School. Participants were tested one at a time before, during, or after school with the permission of the school teacher, child, and parent. Participants were walked by the research coordinator or research assistant to a testing room where the test administrator entered the participant's study identification code, date of birth, gender, school grade, and medication status (i.e., no medication or medication and time of last dosage). After entering the participant's demographic information, the participant sat in the designated Quotient^{TM} chair, facing the computer monitor. The participant was then given a disposable headband to wear around his/her head, above the temples. Then, the participant read the test instructions on the computer monitor and followed the computer prompts as stated. Before beginning the computer task, the test administrator ensured participants' understanding of the computer task by observing them successfully complete a tutorial of the test. At this time, participants were reminded to follow the computer instructions until the task was complete (i.e.,

they were encouraged not to talk, get out of their seat). During the 15 minute test, the administrator stayed in the testing room to notate observations, without talking to the participant. After completing the test, the child was walked back to class. Participants being tested off medication were taken to the school nurse for medication administration, and then they were taken back to class.

After participants completed the test, data were immediately submitted and analyzed by BioBdx using a central server. Data were then compared to a normative group (of around 3000) by age and gender. Later, the study coordinator used the Quotient™ report generator to produce a PDF file of Quotient™ data, including statistical and graphical information about attention and movement variables. Raw data was later entered and stored in a Statistical Package for the Social Sciences (SPSS) database on a secure, password-protected computer. In accordance with the Shelton School and UTSW IRB and Health Insurance Portability and Accountability Act of 1996 (HIPAA) standards, confidentiality of all participants was maintained. Codes based on letters in their first and last names were used, making their research data unidentifiable.

CHAPTER EIGHT
Statistical Analyses

The current study, which began in the Spring school semester of 2008, was modeled as a repeated measures Analysis of Variance (ANOVA) design. Demographic, diagnostic characteristics and Quotient™ data were double-entered into a database using the Statistical Package for the Social Sciences (SPSS) electronic software.

DEMOGRAPHIC AND CLINICIAL CHARACTERISTICS OF THE SAMPLE

Of the sixty-seven participants enrolled in the Shelton School Language Intervention program in 2008, thirty-five were included in the current study (see Table 4 below for a flow chart description of students excluded from the current study). Thirty-five participants, 18 females and 17 males, ranging in age from 6 to 13 (M =9.4 years, SD = 2.1) completed Quotient™ testing in the Spring of 2008 and the Spring of 2009. With regard to diagnostic characteristics, within the overall sample (N = 35), 22 (62.9%) children met criteria for a diagnosis of ADHD based on the K-SADS-P/L. Diagnostic group assignment was based on ADHD diagnostic status defined as OLD versus OLD/ADHD. Additionally, in a subgroup called *medication condition*, group assignment was based on stimulant medication status at the time of testing defined as On Meds versus Off Meds for the subgroup sample (n=16) who were prescribed stimulant medication at both T1 and T2. Demographic and clinical characteristics and stimulant medication status are described below in Table 5).

Table 5. Demographic Characteristics of the Study's Sample

	Total Sample (N = 35) N (%)	OLD (n = 13) n (%)	OLD/ADHD (n = 22) n (%)
Gender			
Male	17 (48.6%)	7 (53.8%)	10 (45.5%)
Female	18 (51.4%)	6 (46.2%)	12 (54.5%)
Ethnicity			
Caucasian	27 (77.1%)	11 (84.6%)	16 (72.7%)
Hispanic	3 (8.6%)	0 (0%)	3 (13.6%)
African American	1 (2.9%)	0 (0%)	1 (4.5%)
Asian	1 (2.9%)	0 (0%)	1 (4.5%)
Other	3 (8.6%)	2 (15.4%)	1 (4.5%)
ADHD Type			
Inattentive	7 (20%)	N/A	7 (31.8%)
Hyperactive-Impulsive	1 (2.9%)	N/A	1 (4.5%)
Combined	6 (17.1%)	N/A	6 (27.3%)
NOS	8 (22.9%)	N/A	8 (36.4%)
[ψ]Medication	22 (62.9%)	4 (30.8%)	18 (81.8%)

[ψ]Participants prescribed stimulant medication

RESULTS

Aim I: Movement Differences by Diagnostic Groups

To test the hypotheses in Aim I, a two group (OLD versus OLD/ADHD) repeated measures ANOVA was conducted at Time 1 (Spring 2008) and Time 2 (Spring 2009) **(**Green & Salkind, 2005**)**. The means and standard deviations for the various Quotient™ movement variables are reported in Table 6. Significance of ANOVAs was based on a *p* value of .05 or less. Significant statistical findings support predictions made in Hypotheses Ib - d and If. Statistical analyses did not support Hypotheses Ia and Ie.

Hypotheses I b: Movements

As predicted in Hypothesis I b, after one year of participation in the LI program, the OLD/ADHD group had a significantly greater number of movements at both Time 1 and Time 2 than the OLD group $F(1,29) = 8.54$, $p < .007$, $\eta^2 = .23$ representing a small effect size (Cohen, 1988). This finding was consistent with findings by Baker (2009).

Hypotheses I c: Displacement

As predicted in Hypothesis I c, after one year of participation in the LI program, children with OLD/ADHD had significantly greater distance in their movements at both Time 1 and Time 2 than the OLD group $F(1,29) = 7.76$, $p < .01$, $\eta^2 = .21$ representing a small effect size (Cohen, 1988). This finding was consistent with findings by Baker (2009).

Hypotheses I d: Area

As predicted in Hypothesis I d, after one year of participation in the LI program, children with OLD/ADHD had significantly greater space in their movements at both Time 1 and Time 2 than the OLD group $F(1,29) = 10.64$, $p < .003$, $\eta^2 = .27$ representing a small effect size (Cohen, 1988). This finding was consistent with findings by Baker (2009).

Hypotheses I f: Temporal Scaling

As predicted in Hypothesis I f, after one year of participation in the LI program, children with OLD/ADHD had a higher frequency of movements than at both T1 and T2 than the OLD group $F(1,29) = 8.30$, $p < .01$, $\eta^2 = .22$ representing a small effect size (Cohen, 1988). This finding was consistent with findings by Baker (2009).

Summary of Results for Hypotheses I a – f

In summary, results indicate that the when OLD children have a comorbid diagnosis of ADHD their overall body movements are greater compared to children with an OLD-only diagnosis. More specifically, using the Quotient™ to measure various types of movements in both children with OLD and OLD/ADHD, children with comorbid ADHD had more difficulty inhibiting their movements (i.e., behavior). The current study replicated four of the six findings by Baker (2009) on movement differences by diagnostic group and confirmed Hypotheses I b, I c, I d, and I f. Specifically, both studies found that children with comorbid OLD/ADHD had significantly more position changes and had more distance and space in their movements (i.e., had higher movement, displacement, area, and temporal scaling scores) than children with an OLD only diagnosis. Different from Baker's (2009) findings, the current study found that the OLD group did not spend significantly more time sitting still (i.e., higher immobility duration score for OLD group) or have more complex head movements (i.e., higher spatial complexity score for OLD group). Using a two group (OLD versus OLD/ADHD) repeated measures ANOVA, exploratory analyses indicated no interaction or effect of time.

Table 6. Two-Way Repeated Measures Analyses of Variance to Examine Quotient™ Movement Variables for Diagnostic Groups

	OLD (**n =12**) *M (SD)*		OLD/ADHD (**n = 19**) *M (SD)*						
	T1	T2	T1	T2	Statistic		Value	*p*	η^2
Immobility Duration	213.58(116.84)	222.25 (159.82)	115.11 (122.70)	118.32 (110.82)	Group	*F(1,29)*	5.49	.26	
					Time	*F(1,29)*	0.12	.73	
					Interaction	*F(1,29)*	0.03	.86	
Movements	2032.67(1020.75)	2458.25 (2086.34)	4837.84 (2746.45)	4457.68 (2646.04)	Group	*F(1,29)*	8.54	.01*	.23
					Time	*F(1,29)*	0.01	.96	
					Interaction	*F(1,29)*	2.10	.16	
Displacement	2.73 (1.58)	3.82 (4.22)	8.70 (6.15)	8.11 (6.61)	Group	*F(1,29)*	7.76	.01*	.21
					Time	*F(1,29)*	0.11	.74	
					Interaction	*F(1,29)*	1.25	.27	
Area	66.17 (50.41)	107.67 (153.53)	265.37 (154.55)	266.11 (229.09)	Group	*F(1,29)*	10.64	.003*	.27
					Time	*F(1,29)*	0.50	.46	
					Interaction	*F(1,29)*	0.47	.50	
Spatial Complexity	1.20 (.10)	1.20 (.13)	1.12 (.14)	1.11 (.14)	Group	*F(1,29)*	0.10	.09	
					Time	*F(1,29)*	0.59	.81	
					Interaction	*F(1,29)*	0.00	.96	
Temporal Scaling	.60 (.24)	.59 (.37)	.98 (.42)	.98 (.42)	Group	*F(1,29)*	8.30	.01*	.22
					Time	*F(1,29)*	0.02	.90	
					Interaction	*F(1,29)*	0.04	.84	

*significant *p-value* alpha level of .05

Aim II: Attention Differences by Medication Condition

To test the hypotheses in Aim II, a two group (On Medication versus Off Medication) repeated measures ANOVA was conducted at Time 1 (Spring 2008) and Time 2 (Spring 2009) **(**Green & Salkind, 2005**)**. The means and standard deviations for the various Quotient™ attention variables are reported in Table 7. Significance of ANOVAs was based on a *p* value less than .05. Significant statistical findings support predictions made in Hypotheses IIa – b and IId – f. Statistical analyses did not support Hypothesis II c.

Hypothesis II a: Accuracy

As predicted in Hypothesis II a, compared to their performance when tested off medication, at both T1 and T2 children had a better accuracy score or would respond more accurately while medicated $F(1,15) = 8.14$, $p < .01$, $\eta^2 = .35$, representing a small effect size (Cohen, 1988). With regard to effect of time, overall, children responded more accurately at their follow-up/T2 testing compared to their baseline/T1 testing $F(1,15) = 6.08$, $p < .03$, $\eta^2 = .29$ representing a small effect size (Cohen, 1988).

Hypothesis II b: Omission Errors

As predicted in Hypothesis II b, at both T1 and T2 children who were prescribed stimulant medication had fewer omission scores (i.e., fewer missed targets) when tested on medication

compared to their performance off medication $F(1,15) = 9.90$, $p < .01$, $\eta^2 = .40$ representing a small effect size (Cohen, 1988).

Hypothesis II c: Commission Errors

Following statistical analyses, Hypothesis II c was not confirmed. Statistical analyses indicated no significant group difference or interaction for commission errors. With regard to effect of time, overall, children responded made significantly more incorrect responses to non-targets at their intial/T1 testing compared to their follow-up/T2 testing $F(1,15) = 5.33$, $p < .04$, $\eta^2 = .26$ representing a small effect size (Cohen, 1988).

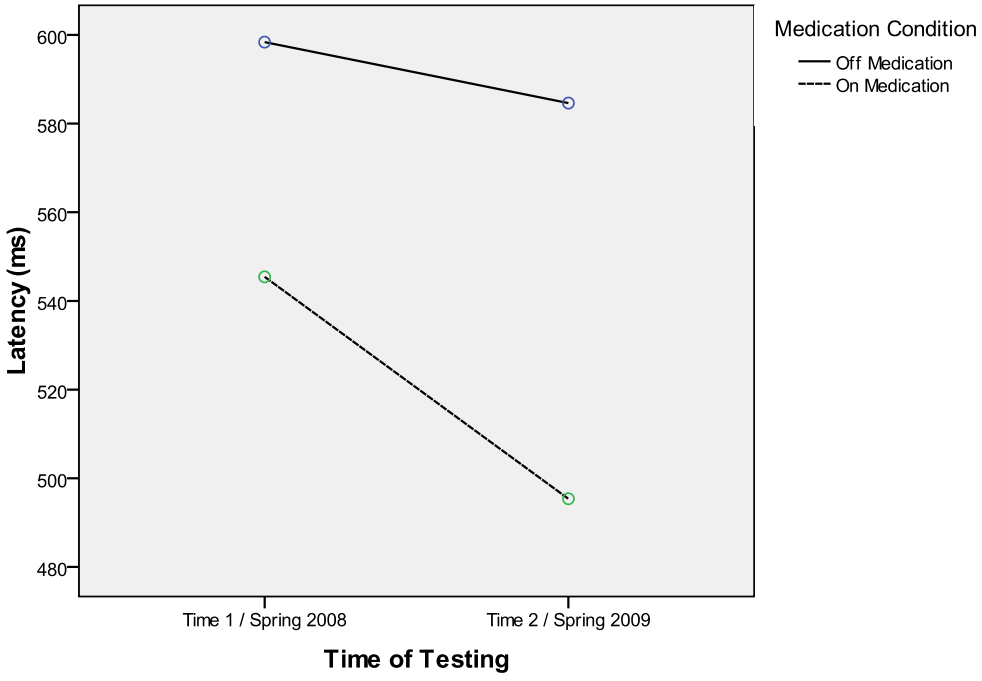
Hypothesis II d: Variability

As, predicted in Hypothesis II d, variability, defined as the standard deviation of response time to target, was significantly lower at Time 1 and Time 2 when children were tested on medication compared to their performance off medication $F(1,15) = 33.62$, $p < .00$, $\eta^2 = .69$ representing a medium effect size (Cohen, 1988). With regard to effect of time, overall, children's standard deviation of response time to target was lower at their follow-up/T2 testing compared to their baseline/T1 testing $F(1,15) = 7.57$, $p < .02$, $\eta^2 = .34$ representing a small effect size (Cohen, 1988).

Hypothesis II e: Latency

As predicted in Hypothesis II e, for latency, children responded significantly faster when they were on medication compared to their performance off medication $F(1,15) = 28.03$, $p < .00$, $\eta^2 = .65$ representing a medium effect size (Cohen, 1988). Regarding the interaction effect, over time, children responded significantly faster on medication at T2 compared with T1 $F(1,15) = 5.04$, $p < .04$, $\eta^2 = .25$ representing a small effect size (Cohen, 1988) (see Figure 1).

Figure 1. Interaction of Latency Scores Over Time When Children (n=16) were Tested On and Off Medication



Latency is the mean time, in milliseconds, to respond to target (ms)

Hypothesis II f: COV

As predicted in Hypothesis II f, for COV, time to respond (using a more stringent measure of response consistency) was significantly faster when children were tested on medication compared to their performance off medication $F(1,15) = 32.28$, $p < .00$, $\eta^2 = .68$ representing a medium effect size (Cohen, 1988). With regard to effect of time, overall, children's COV was lower at their follow-up/T2 testing compared to their baseline/T1 testing $F(1,15) = 5.80$, $p < .03$, $\eta^2 = .28$ representing a small effect size (Cohen, 1988).

Summary of Results for Hypotheses II a - f

In summary, results indicate that stimulant medication improves attention performance in OLD and OLD/ADHD children during a fifteen minute continuance performance task. As predicted, using the Quotient™ to measure attention in OLD and OLD/ADHD children on and off medication at both T1 and T2, children had significantly better accuracy, fewer omission errors, faster response time, and less variability when tested on medication compared to their performance off medication. There was no significant difference in medication condition for commission errors (i.e., inhibition in responding to non-targets).

As previously stated, the emphasis in Aim II was on effects of being on and off medication, as there is no existing literature to support a strong finding for time and interaction. With regard to the effect of time, after of year of a language intervention children had overall improved attention per Quotient™. Over time, children had improved percentage of correct responses, fewer incorrect responses to non-targets (i.e., better inhibition in their responding), less variability, and more consistent responding. There was no significant effect of time on

omission errors or latency. With regard to interaction of time and medication condition for latency, over time, children taking medication responded significantly faster compared to their performance a year earlier while children off medication were only faster slower at T2 compared to T1.

Table 7. Two-Way Repeated Measures Analyses of Variance to Examine Quotient™ Attention Variables for Medication Condition

	Off Medication (**n=16**) *M (SD)*		On Medication (**n =16**) *M (SD)*						
	T1	T2	T1	T2	Statistic		Value	*p*	η^2
Accuracy	81.14 (13.81)	85.91 (12.09)	86.44 (12.40)	89.83(6.30)	Group	*F(1,15)*	8.14	.01*	.35
					Time	*F(1,15)*	6.08	.03*	.29
					Interaction	*F(1,15)*	.29	.6	
Omission Errors	14.19 (14.49)	11.11 (15.11)	4.08 (5.88)	3.89 (5.37)	Group	*F(1,15)*	9.90	.01*	.40
					Time	*F(1,15)*	.96	.34	
					Interaction	*F(1,15)*	1.73	.21	
Commission Errors	23.56 (16.27)	16.96 (13.33)	23.14 (19.74)	16.46 (8.94)	Group	*F(1,15)*	.06	.81	
					Time	*F(1,15)*	5.33	.04*	.26
					Interaction	*F(1,15)*	.00	.99	
Variability	217.44 (81.27)	198.00 (88.15)	153.63 (76.77)	122.75 (55.26)	Group	*F(1,15)*	33.62	.00*	.69
					Time	*F(1,15)*	7.57	.02*	.34
					Interaction	*F(1,15)*	.41	.53	
Latency	598.37 (105.77)	584.63 (89.17)	545.44 (81.50)	495.37 (80.31)	Group	*F(1,15)*	28.03	.00*	.65
					Time	*F(1,15)*	3.92	.07	
					Interaction	*F(1,15)*	5.04	.04*	.25
COV	35.50 (11.42)	32.25 (10.06)	27.13 (10.91)	23.69 (7.49)	Group	*F(1,15)*	32.28	.00*	.68
					Time	*F(1,15)*	5.80	.03*	.28
					Interaction	*F(1,15)*	.01	.95	

*significant *p-value* alpha level of .05

Aim III: Attention State Differences by Medication Condition

To test the Hypotheses in Aim III, a two group (On Medication versus Off Medication) repeated measures ANOVA was conducted at Time 1 (Spring 2008) and Time 2 (Spring 2009) **(**Green & Salkind, 2005**)**. The means and standard deviations for the various Quotient™ attention state variables are reported in Table 8. Significance of ANOVAs was based on a *p* value less than .05. Significant statistical findings support predictions made in Hypotheses IIIb, c, and f. Statistical analyses did not support Hypothesis IIIa, d, e, and g.

Hypothesis III b: On Task Attention State

As predicted, children spent more time responding "on task" when they were tested on medication at Time 1 and Time 2 compared to their performance off medication $F(1,15) = 4.66$, $p < .05$, $\eta^2 = .24$ representing a small effect size (Cohen, 1988).

Hypothesis III c: Distracted Attention State

As predicted, children spent a lower percentage of time in a distracted attention state (i.e., a response style of hitting some targets and some non-targets, where accuracy was not by chance or random) when they were tested on medication at Time 1 and Time 2 compared to their performance off medication $F(1,15) = .97$, $p < .01$, $\eta^2 = .39$ representing a small effect size (Cohen, 1988).

Hypothesis III f: Minimal Responding Attention State

As predicted, children spent less time in the minimal responding attention state profile (i.e., children were less likely to make both omission and commission errors) when they were tested on medication at Time 1 and Time 2 compared to their performance off medication $F(1,15) = 4.92$, $p < .04$, $\eta^2 = .25$ representing a small effect size (Cohen, 1988).

Summary of Results for Hypotheses III a- g

In summary, results indicate better accuracy and less distracted attention state responding patterns for children at both T1 and T2 when tested on stimulant medication. As predicted, using the Quotient™ to measure attention state in children on and off medication at both T1 and T2, children had a significantly higher percentage of time on task (i.e., mostly responding accurately, lower percentage of time distracted (i.e., response style of hitting some targets and some non-targets, where accuracy was not by chance), and lower percent of time in a minimal responding pattern (i.e., response style of missing most targets and non-targets, where accuracy is about good as chance). There were no significant group differences for number of attention shifts, impulsive responding, random responding, and contrary attention states. There was no interaction or effect of time for any of the attention state variables.

Table 8. **Two-Way Repeated Measures Analyses of Variance to Examine Quotient™ Attention State Shift Variables for Medication Condition**

	Off Medication (**n=16**) *M (SD)*		On Medication (**n =16**) *M (SD)*						
	T1	T2	T1	T2	Statistic		Value	*p*	η^2
Attention shifts	14.13 (5.01)	13.87 (4.30)	10.38 (4.38)	13.56 (6.24)	Group	*F(1,15)*	2.37	.14	
					Time	*F(1,15)*	1.18	.29	
					Interaction	*F(1,15)*	3.12	.10	
On Task	42.75 (30.81)	55.06 (26.89)	59.38 (30.17)	59.75 (25.97)	Group	*F(1,15)*	4.66	.05*	.24
					Time	*F(1,15)*	1.35	.26	
					Interaction	*F(1,15)*	1.87	.19	
Distracted	18.69 (15.31)	14.69 (13.01)	3.90 (6.35)	8.65 (12.66)	Group	*F(1,15)*	.97	.01*	.39
					Time	*F(1,15)*	.02	.88	
					Interaction	*F(1,15)*	4.32	.06	
Impulsive	23.53 (17.39)	18.80 (10.78)	26.25 (17.88)	28.19 (15.51)	Group	*F(1,15)*	1.87	.19	
					Time	*F(1,15)*	.10	.76	
					Interaction	*F(1,15)*	1.29	.27	
Random Responding	7.08 (14.24)	8.98 (15.79)	8.96 (19.35)	2.49 (5.37)	Group	*F(1,15)*	1.73	.30	
					Time	*F(1,15)*	3.24	.09	
					Interaction	*F(1,15)*	.63	.44	
Minimal Responding	5.16 (7.71)	4.38 (10.23)	.83 (3.33)	.41 (1.13)	Group	*F(1,15)*	4.92	.04*	.25
					Time	*F(1,15)*	.20	.66	
					Interaction	*F(1,15)*	.06	.82	
Contrary	2.50 (6.95)	.83 (3.33)	.21 (.83)	.21 (.83)	Group	*F(1,15)*	2.49	.14	
					Time	*F(1,15)*	.74	.41	
					Interaction	*F(1,15)*	1.30	.27	

*significant *p-value* alpha level of .05

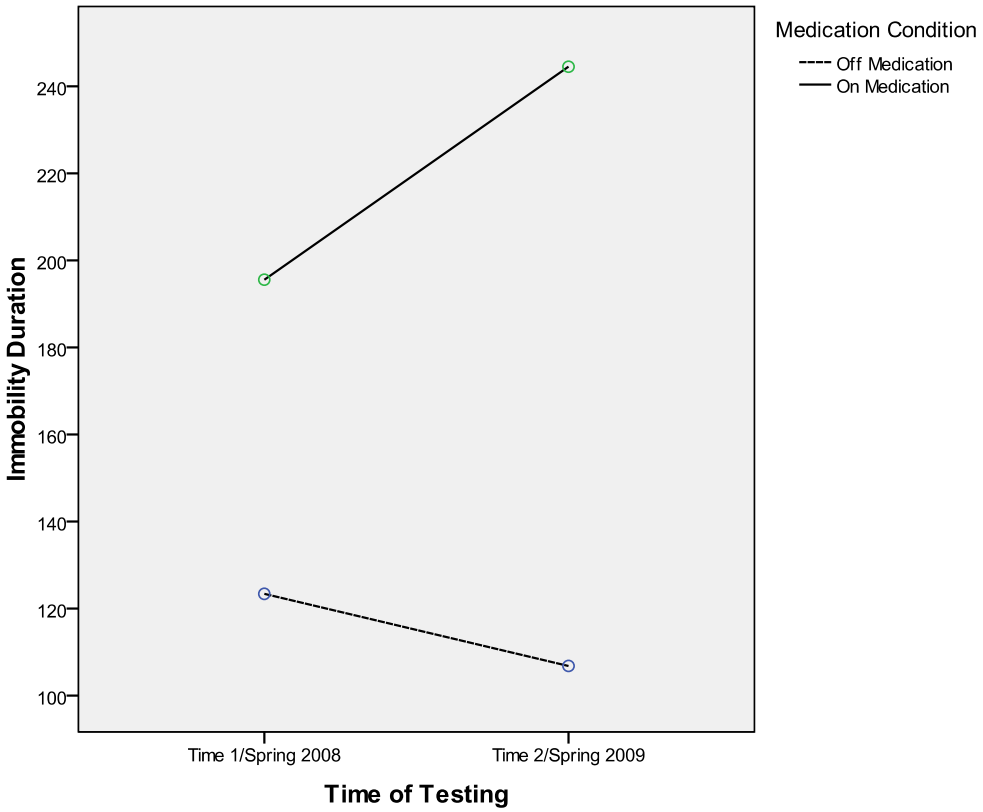
Aim IV: Movement Differences by Medication Condition

To test the hypotheses in Aim IV, a two group (On Medication versus Off Medication) repeated measures ANOVA was used for Time 1 (Spring 2008) and Time 2 (Spring 2009) **(**Green & Salkind, 2005**)**. The means and standard deviations for the various Quotient™ movement variables are reported in Table 9. Significance of ANOVAs was based on a *p* value less than .05. A Tukey HSD post hoc was used for any significant interaction (Hinkle, Wiersma, & Jurs, 2002). Significant statistical findings support predictions made in Hypotheses IVa-f.

Hypothesis IV a: Immobility Duration

As predicted in Hypothesis IV a, children spent more time sitting still when tested on medication compared to their performance off medication at both T1 and T2 $F(1,15) = 20.54$, $p < .00$, $\eta^2 = .58$ representing a medium effect size (Cohen, 1988). For interaction of time and medication condition, over time, children tested on medication spent significantly more time sitting still at T2 compared to T1 while children off medication spent less time sitting still at T2 compared to T1, $F(1,15) = 5.37$, $p < .04$, $\eta^2 = .26$ representing a small effect size (Cohen, 1988) (see Figure 2).

Figure 2. Interaction of Immobility Duration Scores Over Time When Children (n=16) were Tested On and Off Medication



Hypothesis IV b: Movement

As predicted in Hypothesis IV b, children had fewer position changes when tested on medication compared to their performance off medication at both T1 and T2 $F(1,15) = 26.10$ $p < .00$, $\eta^2 = .64$ representing a medium effect size (Cohen, 1988).

Hypothesis IV c: Displacement

As predicted for Hypothesis IV c, at T1 and T2, when children were tested on medication their total distance of movements was shorter compared to the distance they moved when tested off medication $F(1,15) = 22.45$ $p < .00$, $\eta^2 = .60$ representing a medium effect size (Cohen, 1988).

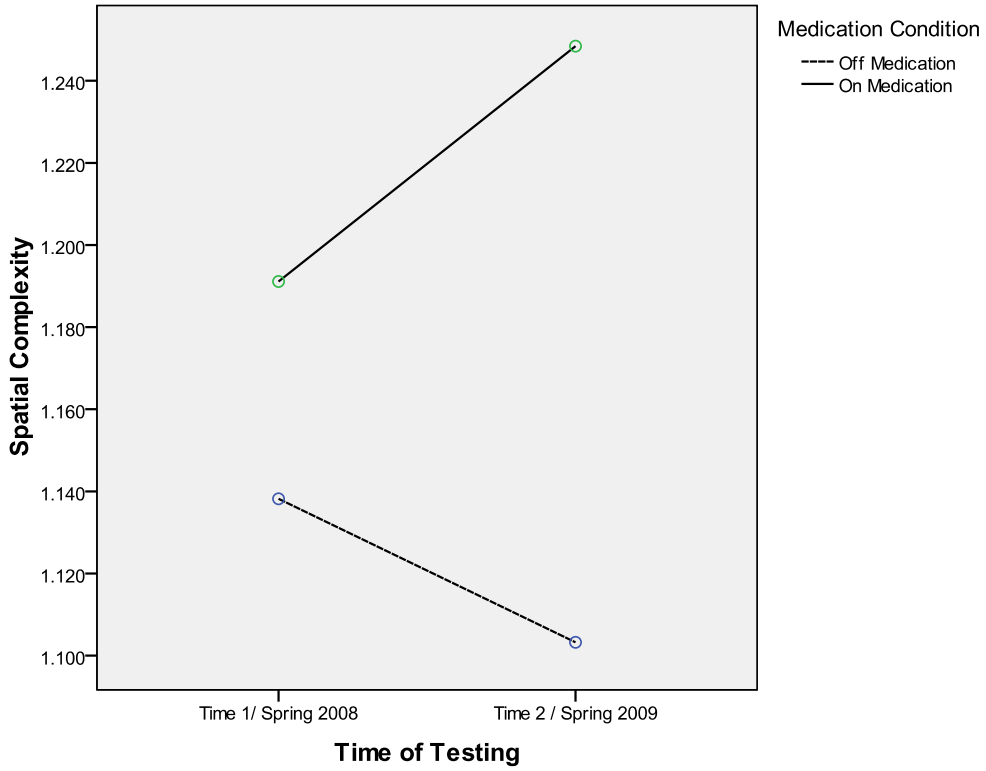
Hypothesis IV d: Area

As predicted in Hypothesis IV d, children had a lower area score (i.e., the space they moved in were smaller) when tested on medication compared to their performance off medication at both T1 and T2 $F(1,15) = 31.08$ $p < .00$, $\eta^2 = .67$ representing a medium effect size (Cohen, 1988).

Hypothesis IV e: Spatial Complexity

As predicted in Hypothesis IV e, children had a higher spatial complexity score (i.e., movements were qualitatively more complex) when tested on medication compared to their performance off medication at both T1 and T2 $F(1,15) = 17.54$, $p < .00$, $\eta^2 = .54$ representing a medium effect size (Cohen, 1988). For interaction of time and medication condition, over time, children tested on medication had significantly more complex movements at T2 compared to T1 while children off medication had more linear movements at T2 compared to T1, $F(1,15) = 17.27$, $p < .00$, $\eta^2 = .54$ representing a medium effect size (Cohen, 1988) (see Figure 3).

Figure 3. Interaction of Spatial Complexity Scores Over Time When Children (n=16) were Tested On and Off Medication



Hypothesis IV f: Temporal Scaling

As predicted in Hypothesis IV f, when children were tested on medication their movements were significantly less frequent at both T1 and T2 compared to more frequent movements when tested off medication $F(1,15) = 24.49$ $p < .00$, $\eta^2 = .62$ representing a medium effect size (Cohen, 1988).

Summary of Results for Hypotheses IV a - f

In summary, results indicate that stimulant medication helps OLD and OLD/ADHD remain still children during a fifteen minute continuance performance task. As predicted, using the Quotient™ to measure movement, OLD and OLD/ADHD children tested on medication spent significantly more time sitting still, had fewer position changes, traveled less distance in their movements, had smaller area of movement, had less frequent movements, and had more complex movements at both T1 and T2.

As previously stated, the emphasis in Aim IV was on effects of being on and off medication, as there is no existing literature to support a strong finding for time and interaction. With regard to time, there was no significant effect of time for any of the movement variables. With regard to interaction of time and medication condition, for immobility duration, over time, children tested on medication spent significantly more time sitting still at T2 compared to T1 while children off medication spent less time sitting still at T2 compared to T1. Additionally, there was an interaction of time and medication condition for spatial complexity. Over time, children tested on medication had significantly more complex movements at T2 compared to T1 while children off medication had more linear movements at T2 compared to T1. There was no interaction of time for movements, displacement, area, or temporal scaling.

Table 9. Two-Way Repeated Measures Analyses of Variance to Examine Quotient™ Movement Variables for Medication Condition

	Off Medication (**n=16**) *M (SD)*		On Medication (**n =16**) *M (SD)*						
	T1	T2	T1	T2	Statistic		Value	*p*	η^2
Immobility Duration	123.38 (129.02)	106.81 (106.56)	195.56 (130.51)	244.50 (189.01)	Group	*F(1,15)*	20.54	.000*	.58
					Time	*F(1,15)*	1.56	.23	
					Interaction	*F(1,15)*	5.37	.04*	.26
Movements	4841.56 (3007.52)	4916.62 (2768.34)	2342.44 (1409.24)	2343.56 (1930.90)	Group	*F(1,15)*	26.10	.000*	.64
					Time	*F(1,15)*	.01	.92	
					Interaction	*F(1,15)*	.04	.84	
Displacement	8.83 (6.76)	9.23 (7.06)	3.44 (2.64)	3.54 (3.57)	Group	*F(1,15)*	22.45	.000*	.60
					Time	*F(1,15)*	.07	.80	
					Interaction	*F(1,15)*	.106	.75	
Area	250.25 (172.73)	300.13 (255.54)	87.25 (84.52)	91.06 (113.39)	Group	*F(1,15)*	31.08	.000*	.67
					Time	*F(1,15)*	.62	.44	
					Interaction	*F(1,15)*	1.31	.27	
Spatial Complexity	1.14 (.15)	1.10 (.12)	1.19 (.14)	1.25 (.19)	Group	*F(1,15)*	17.54	.001*	.54
					Time	*F(1,15)*	.33	.58	
					Interaction	*F(1,15)*	17.27	.001*	.54
Temporal Scaling	.99 (.44)	1.07 (.42)	.67 (.30)	.65 (.39)	Group	*F(1,15)*	24.49	.000*	.62
					Time	*F(1,15)*	.35	.56	
					Interaction	*F(1,15)*	1.67	.22	

*significant *p-value* alpha level of .05

CHAPTER NINE
Discussion

CONCLUSIONS AND CLINICAL IMPLICATIONS

As previously discussed in the review of the OLD and ADHD literature, an overlap of core ADHD symptoms (see Table 2 for specific descriptions of overlap) in children with OLD make it difficult to accurately discriminate OLD from OLD/ADHD children using traditional rating scales. Utilizing objective assessments in the diagnostic process may be more accurate. Specifically, CPTs have been found to objectively identify children with ADHD from normal controls (Losier, McGrath, & Klein, 1996; O'Dougherty, Neuchterlein, & Drew, 1984). Additionally, CPTs have proven to be a reliable and valid clinical tool for diagnosing ADHD (Gordon & Mettelman, 1988; Greenberg & Waldman, 1993; Halperin et al, 1991; Impara & Plake, 1998; Fischer, Newby, & Gordon, 1995; Seidel & Joschko, 1991). Specifically, traditional CPTs (such as the TOVA and the SCAT) have found errors of omission to be an objective measure of symptoms of inattention (Barkley, 1991; Corkum & Siegel, 1993; Eliason & Richman, 1987; Epstein et al, 1998; Halperin, Sharma,Greenblatt, & Schwartz,1991; Inoue et al., 1998; Klee & Garfinkel, 1983; Lassiter, D'Amato, Raggio, Whitten, & Bardos,1994). Unlike traditional CPTs, the Quotient^{TM} is a CPT designed to measure core symptoms of ADHD, including movement and attention shifts. Despite questionable ADHD symptom overlap in OLD and ADHD children due to the use of subjective assessment protocol, few studies has investigated the diagnostic utility of CPTs for discriminating ADHD

symptoms between OLD versus OLD/ADHD children. For this reason, the current study sought to replicate the Baker (2009) study.

To date, only one other study has used the Quotient™ to examine ADHD symptoms of inattention and body control in OLD versus OLD/ADHD children. In 2009, Baker found the Quotient™ to discriminate children with OLD from OLD/ADHD on six movement variables. Findings from the current study supported the Baker (2009) study. Specifically, four of the six movement variables discriminate children with OLD from OLD/ADHD. For Aim I, findings suggest that the Quotient™ could be a useful diagnostic tool in the assessment of children with OLD and OLD/ADHD given its ability to objectively and consistently identify distinct movement differences between OLD and OLD/ADHD. Additionally, for Aim I, findings suggest that OLD/ADHD children are qualitative different from OLD children in that comorbid-ADHD seems to be related to more body movement.

In addition to examining replicating Baker's (2009) findings, the current study also sought to use the Quotient™ to investigate the role of medication on improving core symptoms of ADHD (i.e., attention and body control). For Aims II-IV, findings suggested that children (both OLD/ADHD) have better body control (all six movement variables) when on stimulant medication. The current study's findings were consistent with other studies identifying stimulant medication to improve body control in children with ADHD (Kerstin, Gunther, Hanisch, & Herpertz-Dahlmann, 2004; Rhodes, Coghill, & Matthews, 2006). Additionally, for Aims II-IV, findings suggested that stimulant medication may also improve attention performance (all six attention variables improved when children were tested on medication). This finding supports Kerstin and colleagues (2004) finding that showed improved sustained attention in children with ADHD treated with stimulant medication. With regard to attention state, medication seemed to

improve on task, distracted, and minimal responding patterns. Additionally, over time, some areas of attention (i.e., accuracy, commission errors, variability, and COV) seemed to improve at children's on medication testing, while latency decreased over time during testing on medication. Over time, the interaction of time and medication condition significantly impacted immobility duration and spatial complexity.

Aim I

The first Aim of the current study was to replicate findings from Baker (2009) while examining the utility of the Quotient™ in the ADHD diagnostic assessment process. Using archival data from Baker (T1) along with one year follow-up data (T2), the current study was able to replicate Baker's findings that showed the Quotient™ as a measure able to discriminate children with OLD from children with OLD/ADHD. Like Baker (2009), the current study found that children with comorbid ADHD performed significantly different from those with an OLD-only diagnosis based on more movements (i.e., position changes), larger displacement (i.e., total distance traveled), larger area of movement, and more temporal scaling (i.e., frequency of movement). Dissimilar to Baker's (2009) findings, children with OLD/ADHD did not differ from OLD children on immobility duration (i.e., time spent sitting still) or spatial complexity (i.e., complexity of movement path; lower value indicating more linear or back and forth movements). Although raw data seemed to suggest that OLD children spent more time sitting still than OLD/ADHD children, there were no statistically significant differences. Additionally, raw data also seemed to indicate that OLD children had more back and forth movements compared to OLD/ADHD children, but there were no statistically significant differences. Lack

of significance may be attributed to a small study sample (OLD = 12; ADHD = 19). With regard to effect of time and interaction of time and diagnoses, there were no significant findings.

Aim II

While research suggests that stimulant medication improves attention and body control, the role of medication on attention and movement in children with OLD and OLD/ADHD has not been explored in terms of 1) does medication improve attention and/or movement, and 2) does medication improve attention and/or movement over time. The purpose of Aim II was to investigate role of medication (on medication versus off medication) on attention performance in OLD and OLD/ADHD children using the Quotient™. Specifically, it was expected for children to have better attention performance when tested on medication. Results indicated that stimulant medication did improve overall attention performance in OLD and OLD/ADHD. Specifically and as predicted, in OLD and OLD/ADHD children had significantly better accuracy, fewer omission errors, better response consistency, faster responding, and less variability when tested on medication compared to their performance off medication. With regard to inhibition, as in Baker's (2009) study, the current study did not find differences between on versus off medication for commission errors (i.e., inhibition in responding to non-targets). It is noted that the current study did not examine diagnostic subgroups for the on versus off medication analyses due to small sample size.

With regard to the role of medication and the effect of time on attention, after one year of a language intervention, children had overall improved attention per Quotient™. Compared to their performance at T1, by T2 children made gains in their attention exemplified by higher

percentage of correct responses, fewer incorrect responses to non-targets (i.e., better inhibition in their responding), less variability, and more consistent responding. Unexpectedly, time did not significantly impact performance on omission errors or latency. Although there were no significant differences over time for latency, there was a significant interaction of time and medication condition. Over time children responded significantly faster on medication compared to their performance a year earlier while children off medication were only slightly faster at T2 compared to T1.

AIM III

The purpose of Aim III was to investigate role of medication (on medication versus off medication) on attention state in OLD and OLD/ADHD children using the Quotient™. It was predicted that children tested on medication would have fewer attention shifts and more on task, less distracted, less impulsive, less random, less minimal, and less contrary attending. Results indicated that medication improved on task (i.e., mostly responding accurately), distracted (i.e., less time hitting some targets and some non-targets), and minimal (i.e., less time missing most targets and non-targets) responding patterns. Unexpectedly, there were no significant differences in on versus off medication performance on attention shifts, impulsive responding, random responding, and contrary attention states. Additionally, the interaction of time and medication condition and effect of time did not significantly differ for any of the attention state variables. Perhaps if the sample size were large enough to divide into diagnostic subgroups as in Baker's (2009) study, there might have been enough variation in attention performance to yield significant differences by medication condition.

AIM IV

The purpose of Aim IV was to investigate role of medication (on medication versus off medication) on movement in OLD and OLD/ADHD children using the Quotient™. Given research previously cited, it was predicted that children tested on medication would have more behavior/movement control compared to their performance off medication. As predicted, results showed that stimulant medication helped OLD and OLD/ADHD remain still longer, with fewer movements, less displacement, less area in their movements, and less frequent movements compared to their performance off medication during the fifteen minute continuous performance task. As predicted, children off medication had more linear or back and forth movements at both T1 and T2 compared to children on medication who had more complex movements.

The emphasis in Aim IV was on group differences, since no existing literature supported a strong finding for time and interaction. However, it was expected that children tested on medication would have improved body control over time. With regard to interaction of time and medication condition, for immobility duration, over time, children tested on medication spent significantly more time sitting still at T2 compared to T1 while children off medication spent less time sitting still at T2 compared to T1. Additionally, there was an interaction of time and medication condition for spatial complexity. Over time, children tested on medication had complex movements at T2 compared to T1 while children off medication had linear movements at T2 compared to T1. There was no interaction of time and medication condition for movements, displacement, area, or temporal scaling. Additionally, with regard to time, there was no significant effect of time for any of the movement variables. Given insufficient exiting literature for the role of medication over time for attention or movement differences, time and

interaction findings from the current study are considered to conservatively supplement the existing literature.

METHODOLOGICAL LIMITATIONS AND FUTURE RESEARCH

Despite significant findings for diagnostic and medication condition as identified by the Quotient™, some limitations for the current study are considered. With regard to future research, prospective studies should aim to address limitations of the current study. As noted earlier, the small sample size may not have detected important group, time, and interaction differences. Future studies with larger samples, should retest differences for both diagnostic group and medication condition by diagnostic group on attention, movement, and attention state variables.

A second limitation suggests caution in generalizing findings. With regard to representativeness, children in the study were not randomly chosen, but were selected from a pool of participants enrolled in a language intervention at a private school for children for learning differences in the Dallas-Fort Worth metropolis. Because of the regional location and presumed socioeconomic factors for attendees of private school, cultural exclusivity of this group would not be representative of the general population. Future studies would have more generalizable findings if random sampling were used.

Third, a normal control group was not used, thus significant findings cannot be considered causal but correlational. Additionally, a normal control group comparison would be able to give additional identifying information on deficits of OLD and OLD/ADHD children.

Finally, reliability and validity of the Quotient™ variables used in the current study are limited. Although standardized and normative scores are currently available, these "scaled scores" for overall Inattention, Motion, and a combined index (i.e., Global ADHD) were not available for the current, thus comparisons were not possible. Additionally, published means and standard deviations within the community sample, or among ADHD subjects, are unavailable for the "scaled scores," preventing individual or group comparisons with normal or clinical populations. For future direction, researchers should continue to investigate psychometric properties of the Quotient™.

TABLES

Table 1.

DSM-IV Criteria for ADHD (APA, 2000)

A. Either (1) or (2):

(1) Six (or more) of the following symptoms of **inattention** have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

Inattention

(a) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities
(b) often has difficulty sustaining attention in tasks or play activities
(c) often does not seem to listen when spoken to directly
(d) often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions)
(e) often has difficulty organizing tasks and activities
(f) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)
(g) often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)
(h) is often easily distracted by extraneous stimuli
(i) is often forgetful in daily activities

(2) Six or more of the following symptoms of **hyperactivity-impulsivity** have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

Hyperactivity

(a) often fidgets with hands or feet or squirms in seat
(b) often leaves seat in classroom or in other situations in which remaining seated is expected
(c) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restless)
(d) often has difficulty engaging in leisure activities quietly
(e) is often "on the go" or often acts as if "driven by a motor"
(f) often talks excessively

Impulsivity

(a) often blurts out answers before questions have been completed
(b) often has difficulty awaiting a turn
(c) often interrupts or intrudes on others (e.g., butts into conversations or games)

A. Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before age 7 years.

B. Some impairment from the symptoms is present in two or more settings (e.g. at school [work] and at home).

C. There must be clear evidence of significant impairment in social, school, or occupational functioning.

D. The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder).

Code based on type:

314.01 ADHD, Combined Type:	if both criteria A1 and A2 are met for the past 6 months
314.00 ADHD, Predominantly Inattentive Type:	if criterion A1 is met but criterion A2 is not met for the past 6 months
314.01 ADHD, Predominantly Hyperactive-Impulsive Type:	if Criterion A2 is met but Criterion A1 is not met for the past 6 months

Note:

314.9 Attention-Deficit/Hyperactivity Disorder Not Otherwise Specified	This category is for disorders with prominent symptoms of A1 or A2 that do not meet criteria for ADHD. Examples include: 1. Individuals whose symptoms and impairment meet the criteria for ADHD, Predominately Inattentive Type but whose age at onset is 7 years or after. 2. Individuals with clinically significant impairment who present with inattention and whose symptom pattern does not meet the full criteria for the disorder but have a behavioral pattern marked by sluggishness, daydreaming, or hypoactivity

Table 2.

ADHD Inattention Symptom Overlap in Children with OLD

ADHD	7 Inattention Symptoms Overlap in OLD	OLD: Research and Rationale for Symptom Overlap
Inattentive Type: 6 or more Inattention criteria *Inattention* (a) fails to give attention to details or makes careless mistakes (b) difficulty sustaining attention (c) does not listen when spoken to (d) does not follow through on instructions and fails to finish schoolwork, chores (e) difficulty organizing (f) avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (g) loses things necessary for tasks or activities (h) easily distracted by extraneous stimuli (i) forgetful in daily activities	*Inattention* (a) */**child does not understand instruction and makes careless mistakes (b) */**/*** child does not appear to sustain attention on tasks that are not understood & when spoken to (c) ***child does not listen when spoken to because of deficits in pragmatic language (d) */**child is unable to complete tasks due to lack of understanding or memory of instructions (e) ---------- (f) */** child does not complete task due to lack of understanding (g) ---------- (h) * because child has deficits in listening comprehension, he/she may appear tune out and pay attention to "extraneous stimuli" (i) **child is forgetful due to impaired working memory	* <u>lower listening comprehension</u> in children with language disorder (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003) may effect child's understanding verbal instructions: ** <u>impaired working memory</u> in children with language disorder (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003) may impact child's ability to keep information or instructions in working memory and therefore unable to follow through with instructions ***<u>pragmatic language difficulties</u> in children with language disorders (Adams and Lloyd 2005; Bishop and Norbury 2002; Botting, 2003) may impact their ability to communicate with peers, teachers, and parents in an age-appropriate manner

Table 3.

Definitions of Quotient™ Variables: Attention, Attention State, and Motion

Quotient™, Attention Variables	
Variable	**Definition**
Accuracy	Percentage of correct responses
Omission Errors	Percentage of missed targets
Commission Errors	Percentage of incorrect responses to non-target
Latency	Mean time, in milliseconds, to respond to target (ms)
Variability	Standard deviation of response time to target
Coefficient of Variance (COV)	A more stringent measure of response consistency: (100 x variability) / latency
Quotient™, Attention State Variables	
Attention Shifts	Number of shifts in attention state
On Task (A)	Percent of time hit many targets and few non-targets
Distracted (D)	Percent of time hits some targets and some non-targets; accuracy is better than chance
Impulsive (I)	Percent of time hits many targets and some non-targets
Random Responding (R)	Hits most targets and non-targets; accuracy of responding is as good as chance
Minimal Responding (M)	Misses most targets and non-targets; accuracy is about as good as chance
Contrary (C)	Response accuracy is significantly worse than chance

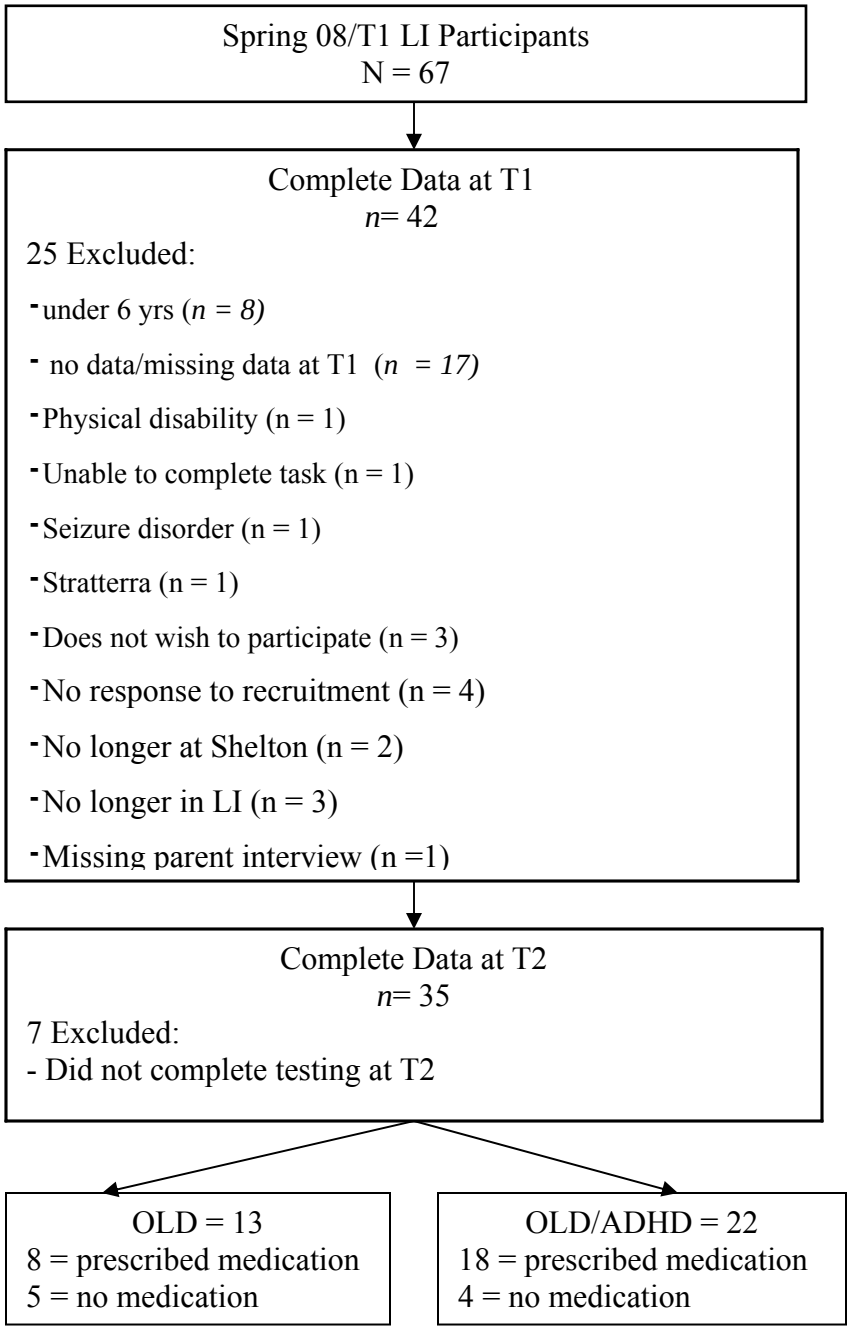
Table 3. (continued)

Quotient™, Motion Variables	
Immobility Duration	Average amount of time, in seconds, spent sitting still (moving less than 1 mm)
Movements	Average number of position changes (movement greater than 1 mm), measured in total meters
Displacement	Total distance traveled (in meters) by the marker
Area	Size and shape, measured in cm^2, of the space covered by the marker
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
Temporal Scaling	Frequency of movement (scale from 0 to 1; 0 = no movement and 1 = constant movement)

Quotient™, Scaled Scores	
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).
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).
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).

Table 4.

LI Participant, Quotient™ Data Collection Flow Chart for Spring 2008 (Time 1; T1) and Spring 2009 (Time 2; T2) (N = 35)



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