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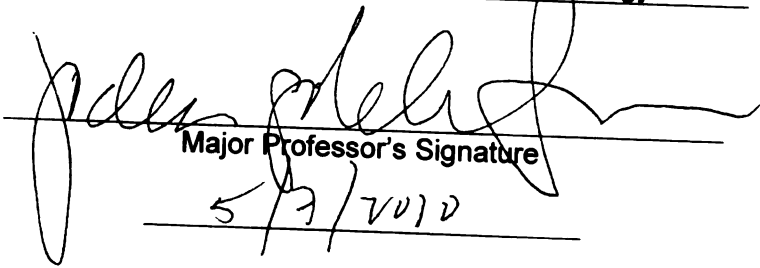
THE INFLUENCE OF INATTENTION ON
RAPID AUTOMATIZED NAMING AND READING SKILLS

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Andy V. Pham

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THE INFLUENCE OF INATTENTION ON
RAPID AUTOMATIZED NAMING AND READING SKILLS

By

Andy V. Pham

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ABSTRACT

THE INFLUENCE OF ATTENTION ON RAPID AUTOMATIZED NAMING AND READING SKILLS

By

Andy V. Pham

The purpose of this study is to determine how behavioral symptoms of inattention predict rapid automatized naming (RAN) performance and reading skills in typically developing children. Participants included 104 third- and fourth-grade children from different elementary schools in mid-Michigan. RAN performance was assessed using the four Rapid Naming subtests from the CTOPP. Oral reading fluency and comprehension were assessed using the GORT-IV, and inattention was assessed using the SNAP-IV rating scale. Hierarchical regression analyses revealed that all four RAN stimuli, particularly letter RAN, predicted reading fluency and comprehension. Ratings of inattention predicted RAN performance and reading fluency, but not comprehension after controlling for age, gender, ethnicity, working memory and estimated IQ. After controlling for RAN performance, overall inattention did not significantly predict reading skills. Further analyses suggest that RAN performance mediated the relation between inattention and reading skills. Findings highlight the need to recognize the influence of phonological awareness, RAN, and attention when understanding typical reading development.

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CHAPTER 1 INTRODUCTION

Literacy is the one of the most basic fundamental skills needed to succeed in modern society. It is essential for academic, social, and economic advancement (Snow, Burns & Griffin, 1998). However, reading difficulties are also a common problem experienced by many school-aged children. A recent study conducted by the National Assessment of Educational Progress (NAEP) found that at least one-third of all fourth-grade students in the United States scored below the basic grade level in reading achievement in 2007 (The Coalition of Education, 2008). Many school districts are implementing preventative programs, early intervention, and evidence-based practices in order to aid struggling students. Currently, teachers are placing emphasis on providing direct instruction of basic literacy skills for all students during their early elementary school years.

There is general consensus that phonological awareness deficits are the primary cause of early reading difficulties (e.g., Schatschneider et al., 2002). However, there is evidence that deficits in rapid automatized naming are also correlated with reading difficulties, especially in older elementary school children (Denckla & Rudel, 1976; Wolf & Bowers, 1999). Rapid automatized naming (RAN) is described as an underlying reading component which allows the child to quickly access letter and word patterns, or orthographic representations, established in the lexicon during reading acquisition (Savage, Pillay & Melidona, 2007). RAN performance is typically assessed by presenting the child with arrays of letters, digits, objects, or colors, which the child is asked to name quickly. It requires multiple sub-skills including attention, perception, conceptual knowledge, lexical retrieval, processing speed, and articulation (Wolf, Bowers, & Biddle,

2000). While the RAN measure seems to have strong predictive ability of reading skills, the specific nature of the cognitive processes underlying RAN performance have not been clearly determined or agreed upon by researchers (Vukovic & Siegel, 2006).

Why would a relatively simple task that requires naming of familiar symbols be associated with reading? Though RAN is correlated with processing speed (Shanahan et al., 2006), it is not identical to it, since it has been shown to correlate with word recognition and connected-text reading. Mostly for young readers, RAN performance contributes sizable variance to the accuracy and latency of word reading even when phonological awareness and IQ are controlled (Ackerman & Dykman, 1993). In addition, phonological awareness and RAN show differing patterns of relationships with specific reading skills. Compared to RAN, phonological awareness is strongly associated with real and nonsense word decoding accuracy, while RAN is more strongly associated with word recognition and oral reading fluency than phonological awareness (Bowers & Wolf, 1993; Manis, Doi, & Bhadha, 2000). Unfortunately, there has been less research exploring RAN in predicting reading comprehension, especially compared with phonological processing.

Reading is a complex process which involves attention and effort to learn, especially for beginning readers. Children with attention problems will struggle with reading fluency and comprehension if these tasks are too demanding for them. Many studies have revealed a relatively high rate of comorbidity between Attention-Deficit Hyperactivity Disorder (ADHD) and reading disabilities (Aaron, Joshi, Palmer, Smith, & Kirby, 2002; Pennington, Grossier, & Welsh, 1993), and researchers have been exploring various cognitive risk factors in both disorders to explain this relation. Interestingly

enough, specific RAN tasks, such as variations of the Stroop task, have been used to study attention problems since children with these deficits also exhibit difficulties in naming familiar visual stimuli rapidly (Stroop, 1935). Considering that many researchers often conduct group differences of children labeled as having a reading disability, ADHD, or both, there is relatively little research investigating how varying levels of inattention contribute to RAN performance and reading skills in typically developing children. Most studies overlook the fact that reading and attention occurs on a continuum, since many children with minor reading difficulties or delays in elementary school do not necessarily have a reading disability, or that children with inattentive symptoms do not necessarily have ADHD.

The purpose of the present study is to clarify and understand how inattention is implicated in the relation between RAN performance and higher-level reading skills in typically developing elementary school children. By understanding this relation, a specific plan of assessment and intervention can be created for children who are potentially at risk of reading difficulties. Different RAN stimuli have been used in both clinical and research settings, but due to differences in methodology, there has been debate among practitioners whether certain stimuli are better in predicting reading difficulties or inattention than others. Even though research studies have cited the important role of RAN in reading fluency, there has been little research investigating how both attention and RAN contribute to reading comprehension. Examining this relation will prompt the development of reading interventions which address specific processes including attention, processing speed, and phonological awareness.

CHAPTER 2 LITERATURE REVIEW

Developmental Pathways of Reading

Reading development occurs as early as the child can hear sounds in language. Many research studies looking at reading development from a cognitive processing or neurodevelopmental perspective have suggested that readers at various developmental stages use different reading components and processes to meet their needs and goals (National Reading Panel, 2000; Shaywitz, Morris, & Shaywitz, 2008; Torgesen et al., 2001). For example, beginning readers, who are learning how to read, use specific strategies to analyze and decode a word correctly. Advanced readers, on the other hand, are reading to learn by accumulating knowledge from and understanding the text. Their basic literacy skills are fully developed and becoming automatic; thus, they are reading more fluently and spending more of their cognitive, attentional, and memory resources for reading comprehension.

Even before entering preschool, infants and toddlers are able to develop sound awareness, as they can distinguish their mother's and father's voices from other voices or noises around them (Hart & Risley, 1995). As they grow older, children attain skills in phonological awareness, which allows them to understand that sentences, words, and syllables are made up of individual sounds, called phonemes (NRP, 2000). Phonological awareness therefore uses verbal and auditory language processes that are needed for distinguishing sounds at the phoneme level. Without adequate phonological awareness, children would not be able to blend sounds together to form words or to segment words into their individual sounds. Phonological awareness is considered not only a strong

predictor of future reading ability, but also as a primary cause of word-level reading difficulties (Torgesen, Wagner et al., 1997).

In addition to phonological awareness, beginning readers learn the alphabetic principle by discriminating and recognizing specific letters of the alphabet and associating the correct sound with the corresponding letter (i.e., grapheme-phoneme or letter-sound association). Studies have clearly demonstrated that direct instruction in blending, segmenting, rhyming, and elision (i.e., deleting sounds), as well as the alphabetic principle result in improved word attack skills, allowing the child to decode words accurately (Torgesen, Alexander et al., 2001). Once emerging readers see words written on a page, their skills in phonological awareness and the alphabetic principle allow them to associate each letter with the appropriate sound, blend them together, and produce the word. After repeated exposure of words, they eventually become automatic with sight words. When readers master these basic literacy skills, they can retrieve sight words from long-term memory without having to decode the words again.

A reading component thought to be essential in this process is rapid automatized naming (RAN), which refers to the ability to name visual stimuli (e.g., letters) quickly and automatically (Wolf & Bowers, 2000). Many researchers agree that RAN is highly correlated with reading fluency (Denckla & Rudel, 1976; Savage, Pillay, & Melidona, 2007; Wolf & Bowers, 2000). Even though beginning readers use RAN to aid them in recognizing and recalling letters and phonemes automatically, it is a stronger predictor of reading fluency than phonological awareness, as skilled readers are recalling words at a rapid rate when reading connected text (Manis, Doi, & Bhadha, 2000). Thus, RAN has been investigated more thoroughly with upper elementary school grades, where oral

reading fluency and reading comprehension are emphasized. Through repeated exposure and use of letter-sound associations, skilled readers use orthographic knowledge to discern letter- and word-patterns easily (Barker, Torgesen, & Wagner 1992). Thus, they are able to read connected text more fluently without having to decode familiar words. In other words, advanced readers rely less on phonological awareness and more on rapid naming (and orthographic skills) for word recognition and fluent reading. Even though these cognitive reading components appear distinct from each other as parallel developmental processes, phonological awareness and rapid naming are suspected to be interrelated and to improve specific reading skills (Bowers & Newby-Clark, 2002). Figure 1 provides a developmental process of the relation between these cognitive reading components, reading outcomes, and the instructional foci needed to enhance these components and improve outcomes.

The developmental pathways of reading allow teachers, practitioners, and researchers to understand that beginning readers learn how to read differently from advanced readers. Once readers establish basic literacy skills in phonological awareness to decode words accurately, they are able to quickly recall these words after repeated exposure and readings experiences. Numerous studies from cognitive neuroscience, educational psychology, reading research, and learning disabilities support the notion of these pathways, including empirical studies that look at differences of these pathways at a neurological level.

Neurodevelopmental Correlates of Reading

Within the past decade, cognitive neuroscience has made strides in attempting to understand brain-behavior relationships in many areas of learning and education; one in

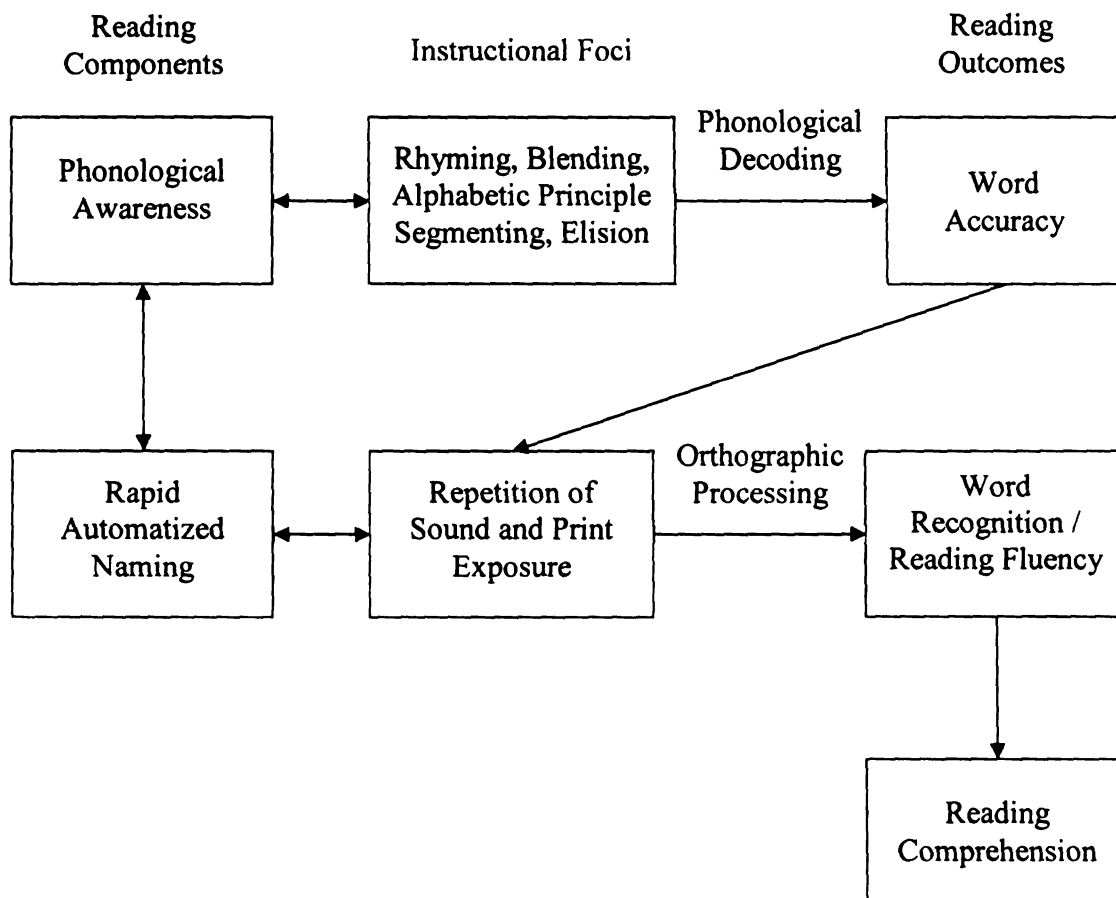


Figure 1. Developmental model of reading components, instructional foci, and reading skills.

particular is reading, which is one of the most studied areas today. While there is no specific “reading area” in the brain, studies have shown that there exists a set of several brain regions that are activated when normally developing children and adults read (e.g., Shaywitz et al., 2003). Some of these regions are particularly involved in phonological processing, while others appear to be support more advanced skills in reading, including rapid naming and orthographic processing. Children with reading difficulties, in particular, show atypical activation in these brain regions compared with typically developing children. The following paragraphs describe the research behind the neurodevelopmental perspective of reading.

Using functional magnetic resonance imaging (fMRI), researchers suggest that beginning readers use different neurological pathways than skilled readers (Shaywitz et al., 2003). For example, the *word-analysis system*, localized within the left parieto-temporal region of the brain, allows the novice reader to “analyze” the word by carefully associating the letters with their corresponding phonemes, a crucial process for decoding. The inferior frontal gyrus, located near Broca’s area in the frontal lobe, is also linked with the word-analysis system and is involved in language processing and speech production. Therefore, children hearing sounds and rhymes as a fundamental pre-literacy skill are also starting to establish phonological awareness by activating these neural regions whenever they analyze, decode, and produce new words accurately.

For advanced readers, the *word-form system*, localized within the left occipito-temporal region of the brain, allows the reader to recognize and retrieve whole words quickly (Shaywitz et al., 2003). Skilled readers do not necessarily need to decode words once they have frequent exposure to them; that process has become automatic. Thus,

words that had been analyzed from the left parietal-temporal system are now transferred to the left occipito-temporal system. The child now becomes a fluent reader, and is able to associate the phonemes and written components of the words quickly and easily. Because less effort is required for the child to read text fluently due to this repeated exposure, the inferior frontal gyrus plays a relatively minor role in assisting this region. As the occipital-temporal region becomes more effective at recognizing words forms, the child's reading skill levels rises dramatically (Shaywitz, Morris, & Shaywitz, 2008).

Additionally, evidence from fMRI scans suggest that these specific neural systems are implicated in children with severe reading problems, particularly developmental dyslexia, which has been consistently defined as a reading disorder with a neurobiological basis (Lyon, Shaywitz & Shaywitz, 2003). In individuals with developmental dyslexia, fMRI scans show a failure of left hemisphere posterior brain systems during reading activities (Shaywitz, Morris, & Shaywitz, 2008). Evidently, individuals with developmental dyslexia demonstrate a relative underactivation in both the parieto-temporal and the occipito-temporal regions of the brain. Thus, these studies focusing on the mechanisms of reading indicate that struggling readers rely more on word analysis rather than quick word recognition.

Shaywitz's finding (2008) also suggests that the neural regions implicated in dyslexic readers are very similar to the neural mechanisms of beginning readers, as they rely more on decoding. Many bright but struggling readers are slow to recognize words in connected text and will try to compensate by decoding slowly or even by inaccurate rote memory, without achieving quick word recognition (Nakamura et al., 2005). Disruption in this system for skilled reading has definite practical implications for the

dyslexic or beginning reader; for example, it provides the neurodevelopmental evidence for the necessity of additional time as an accommodation during high stakes testing.

Several fMRI studies have demonstrated that neural systems of reading are indeed malleable and that the disruption in these systems in children with reading difficulties can be modified through intensive reading interventions. Shaywitz and colleagues (2003) implemented a year-long evidence-based reading intervention focusing on phonological skills of elementary-school children with reading disabilities. Results following the implementation of the intervention showed that the experimental group made significant gains in reading and demonstrated increased activation within the left hemisphere and occipito-temporal regions of the brain, areas implicated in skilled reading. This suggests that neural plasticity still occurs in children with profound reading deficits, and that interventions intensively target these neural pathways to improve children's reading skills.

When children are learning how to read, neural connections are established between the word-analysis and word-form systems. Although researchers have come to understand the neural pathways of reading decoding, less is known about how children attain fluency and comprehension. These higher-level reading skills are the signature of mature readers. The next section discusses the specific reading skills children need to master in order to become mature readers.

Reading Skills

Many studies have explored beginning reading skills such as phonological awareness, decoding, and sight word recognition. Developmentally, both reading fluency and comprehension are higher-level reading skills that are essential in understanding text,

especially when learning various subject areas in school, such as mathematics, science, and social studies. The purpose of this section is to describe the cognitive processes of reading fluency and comprehension.

Reading Fluency

Reading fluency broadly refers to the ability to read words in connected text effortlessly, accurately, and with prosody (National Reading Panel, 2000; Wolf & Katzir-Cohen, 2001). Fluent readers are individuals whose decoding processes are automatic and require no conscious attention when reading orally (LaBerge and Samuels; 1974). Thus, they can maintain this reading performance for long periods of time and can generalize across texts. In order for fluency to occur, readers initially need to develop phonological, orthographic, and morphological processes at the sound, letter, and word levels, as well as semantic and syntactic processes at the word and connected-text levels (Moats, 1998; Wolf & Katzir-Cohen, 2001). When basic literacy skills are mastered, fluent readers will then be able to reserve and allocate much of their cognitive resources to understanding the meaning of a reading passage (Stanovich, 1986; Torgesen et al., 2001). Therefore, the outcome of comprehending material often depends on the ability to read fluently.

Assessment of reading fluency. When assessing oral reading fluency, two variables are measured: *reading rate* and *reading accuracy* (e.g., Kame'enui & Simmons, 2001; Shinn et al., 1992; Torgesen et al., 2001). According to Kame'enui & Simmons (2001) both rate and accuracy are equally important indicators, because fluency as an index of speed without accuracy is a "reckless indicator of cognitive processing, and determining accuracy without speed invariably exposes accuracy as an inflated construct"

(p. 206). For example, a child who reads 80 words per minute with twenty errors is a different reader from another child who reads 80 words in the same passage for five minutes without any errors.

One type of informal literacy measure of oral reading fluency is curriculum-based measurement (CBM) (Fuchs & Fuchs, 1999). Students are asked to read grade-level passages aloud, and fluency is quantified as the number of words read correctly in a minute (Shinn et al., 1992; Torgesen et al., 2001). However, a given low fluency score can be obtained either by reading accurately but slowly or by reading less accurately but quickly. When children are asked to read quickly, they may exhibit the *speed-accuracy tradeoff*, which refers to the behavior of reading quickly at the cost of making errors, or reading accurately at the cost of a slower rate (Snowling, Hulme, & Goulandris, 1994). Thus, a low fluency score does not clarify if the problem is rate, accuracy, or a combination of both. It is important for practitioners and researchers to calculate both the reading rate (typically measured as the number of total words read correctly per minute) and accuracy (percent of words read correctly) when measuring a student's oral reading fluency.

Children with reading difficulties in fluency, especially those in the upper elementary school grades, attempt to compensate by focusing on accuracy rather than speed. Young and Bowers (1995) compared fluency rates of average readers and poor readers in fifth grade. They found that poor readers were significantly slower than average readers on the easiest stories, meaning that when accuracy is addressed, their reading rate is still slow for these impaired readers. In another study, Torgesen and colleagues (2001) measured reading fluency of students with severe reading problems

after an intense one-on-one reading curriculum. The study included children from 8 to 10 years of age who were asked to read passages at 98% accuracy, with fewer than two errors. Following the eight-week intervention, these students' reading rate increased from 78 correct words per minute to 122 words per minute. Despite the significant gains in reading rate, it is unknown whether their reading comprehension improved following this intensive intervention.

Reading Comprehension

Reading comprehension is considered the ultimate goal of reading. Researchers have found that understanding a story or text requires a series of complex processes (Torgesen, 2007; Hudson, Lane, & Pullen, 2005). Reading comprehension broadly refers to the process of extracting and constructing meaning through the reciprocal interaction of ideas between the reader and the message of a particular text (Chard, Vaughn, & Tyler 2002; Rand Reading Study Group, 2007). Within this reader-text dyad, the reader possesses the background skills in phonemic awareness, alphabetic principle, accuracy and fluency, vocabulary, as well as prior knowledge and inference-making abilities. The text provides the discourse, genre, and the print or linguistic structure, which the reader must readily interpret (Rand Reading Study Group, 2007). When many factors are not matched with the reader's skills, prior knowledge, and learning experiences, the text becomes too difficult for optimal comprehension to occur. Therefore, reading comprehension requires active and deliberate cognitive processes readers must engage in while they interact with the text.

Many studies have shown that children who have problems with reading fluency and accuracy have also shown difficulties in comprehension (Fuchs, Fuchs, Hosp, &

Jenkins, 2001; Torgesen et al., 2007). Because reading comprehension requires higher-level cognitive processes that are not initially automatic, basic literacy skills such as word recognition and fluency must become an automatic process prior to understanding text (Torgesen et al., 2007). However, children with reading difficulties or beginning readers frequently attempt to switch attention rapidly back and forth from identifying words on the page to constructing meaning, thus limiting their ability to do either process well (Hudson, Lane, & Pullen, 2005). Thus, focused attention is also a necessary skill that must be maintained in both fluency and comprehension tasks in order to succeed in reading.

Assessment of reading comprehension. One informal way of assessing reading comprehension is to give readers access to material and have them retell or paraphrase what they have just read (Salvia & Ysseldyke, 2004). Retold passages may be scored on the basis of the number of words or phrases recalled. Retelling may be conducted in an oral or written format. Another method of assessing reading comprehension is to ask students questions about what they have just read. Questions can address main ideas, important relationships, specific characters, conflicts/events, and other relevant details (Salvia & Ysseldyke, 2004). Often, answers to questions are open-ended in order to assess their recall of details; however, if a child has difficulty responding to a question, an alternative method is to provide multiple choices to determine whether the child recognizes the correct answer.

The significant relation between reading fluency and reading comprehension has been found in both correlational studies and in treatment outcome studies in elementary school (Torgesen, Alexander et al., 2001). Correlations found between reading fluency

and reading comprehension range from .50 to .91, with most falling around .70 (Fuchs, Hosp, & Jenkins, 2001; Torgesen et al., 2007). In a study by Schatschneider and his colleagues (2005), 200 children in each of three grade levels (3rd, 7th, and 10th) were given the Florida Comprehensive Assessment Test (FCAT), which assessed their reading fluency and comprehension. Results revealed that those who performed substantially below average in reading fluency also obtained below average scores in reading comprehension in children at all grade levels. In a treatment outcome study, Torgesen, Alexander et al. (2001) found that, after an intensive intervention, the reading rate of the impaired readers improved when the passages were well below grade level. However, even at an independent level, these children read below the average number of words per minute, and their reading comprehension scores still fell below the average range when they were assessed using longer reading passages.

Reading fluency and comprehension are important indicators to academic success in elementary school. They are often described as higher-level reading skills once decoding and other pre-requisite literacy skills have been mastered. This understanding of reading development has implications for assessment, instruction, and early intervention. Despite its importance, many children struggle to learn how to read. The following section describes reading difficulties among elementary school children.

Reading Difficulties

Reading can be a very complex task for many individuals as it requires substantial cognitive effort and attention to learn and improve. When children fail to achieve typical gains in reading, there are many different components of the reading process that may be deficient within the reader. Some children may be at the lower end of the normal curve of reading development, while others are demonstrating evidence of a specific learning

disability in basic reading skills, especially when these problems are prolonged and significant. These issues are discussed in the following sections.

Reading Disabilities and Poor Readers

Children with severe reading difficulties in decoding, word recognition, fluency, or comprehension are said to have “reading disability” or “reading disorder,” despite receiving adequate instruction within the general education classroom (APA, 2000). Reading disabilities are considered the most common of the learning disabilities, affecting over 80% of school-aged children and adolescents who are identified with a specific learning disability (Lichtenstein, 2008; Lyon, Shaywitz, & Shaywitz, 2003). A pure reading disability is presumed to be neurologically based, and includes but is not limited to developmental dyslexia (Lyon, Shaywitz, & Shaywitz). Children with developmental dyslexia are at risk of experiencing poor scholastic achievement, grade retention, school drop out, low self-esteem, and/or poor post-school outcomes (e.g., unemployment).

On the other hand, poor readers are characterized by some reading researchers as having a developmental lag rather than a neurological deficit (Francis et al., 1996). Poor readers still exhibit deficiencies in one or more cognitive processes, whether it is phonological awareness, attention, RAN, or processing speed. Even though the source of learning problems may be developmental or neurological, the emphasis on understanding the processes behind reading development may aid in treatment.

Prevalence and Incidence

Prevalence estimates for reading disabilities are approximately 4% (APA, 2000), whereas for poor readers, the prevalence is approximately 17% or higher (Foorman,

Fletcher, & Francis, 1997). In regards to incidence, *The International Book of Dyslexia* (Smythe, Everatt, & Salter, 2004) revealed statistics from 14 different countries and cited the incidence of developmental dyslexia ranged from 1% to 11%. Because researchers around the world have varied terminology, definitions, and methods in assessing children with reading disabilities, these estimates are rough at best.

In the United States, even though 60-80% of individuals with reading disabilities are male, it is estimated to occur at equal rates between males and females when more careful assessment and diagnoses are used rather than biased school-based referral procedures (APA, 2000). However, the ratio of males to females increases as a function of severity (Olson, 2002). Because boys are generally more active and impulsive, they are more likely to be identified by parents or teachers for learning and/or behavioral problems. On the other hand, girls with reading problems are likely to be more passive than boys, and thus go unnoticed. With the relatively high prevalence of children diagnosed as having a reading disability, research has focused on whether these difficulties are environmentally or genetically based. The following sections discuss the heritability and genetic factors behind reading difficulties.

Genetic Bases of Reading Difficulties

Reading disabilities have a strong genetic influence. It is found in 25% to 65% of the children of parents who have a reading disability, and approximately 40% of siblings of children with a reading disability are also affected (Pennington & Gilger, 1996). Interestingly, a higher heritability for reading disabilities has been reported in children with higher IQ scores (Olson, et al., 1999; Wadsworths et al., 2000). The researchers suggested that because children with lower IQ tended to have parents with less education

and fewer reading opportunities at home, these environmental influences may have been more responsible for their children's reading difficulties compared to those with mothers who have more education and reading opportunities. In contrast, children who read poorly despite having a high IQ may have had more genetic constraints on their reading growth. Genetic factors account for over 50% of the variance in reading, while the remaining variance is attributed to environmental factors (Olson & Byrne 2005). Based on these statistics, if a child has a parent or sibling with a reading disability, that child is considered at risk for future reading difficulties.

Because reading difficulties are a high incidence problem for many school-aged children, development of good assessment protocols that can identify such children early is essential. The literature has primarily indicated the importance of teaching and monitoring phonological awareness in children who may be considered at risk of developing reading problems. However, in recent years, studies have also explored other cognitive processes which contribute to reading skills; one in particular is rapid automatized naming (RAN). The importance of RAN in reading development is discussed below.

Rapid Automatized Naming (RAN)

Rapid automatized naming, also known as *naming speed* or *speed of lexical access* (Wolf & Bowers, 1999), refers to the speed at which children can name a series of familiar visual stimuli. Researchers and literacy experts have used RAN tasks to assess children who have or are at risk of reading problems. The following sections describe the literature behind RAN and how it is used in assessment of reading skills, particularly in the areas of fluency and comprehension.

Utility and Assessment

Denckla and Cutting (1999) and Wolf (1997) believe that RAN represents a microcosm of reading, in which these tasks involve a quick and precise integration of different cognitive systems. For example, successful completion of a RAN task requires (1) focused attention to the stimuli, (2) assimilation of visual information with stored orthographic (or pictographic in the case of color and object stimuli) and phonological representations, (3) automatic retrieval of phonological labels, and (4) articulation (Wolf & Bowers, 2000). In other words, the overall demand of the RAN task requires that the phonological and symbolic associations be jointly activated, in addition to the motor skills needed for quick articulation of the label.

Rapid naming of visual stimuli has been shown to be a useful clinical tool for probing brain functions which underlie fluency in speech production and long-term word retrieval (Wolf & Bowers, 1999). Performance on RAN tasks is primarily measured by the total time needed to complete the naming task (rate); however, supplemental data such as the percent of correctly named items (accuracy), or by response latency for single items can also be determined. Difficulties in RAN are often a broad indication of lack of automaticity or fluency caused by interference or word-finding difficulties (Denckla & Rudel, 1976). Severe deficits in this process, as demonstrated by many researchers, may also indicate slow processing speed and disruptions of precise timing mechanisms that negatively influence the accessibility and connections between phonological and symbolic information (Manis, Doi, & Bhadha, 2000).

RAN tasks are structured and presented as matrices of symbols (e.g., letters, numbers, colors, and objects) in which the reader would quickly name each symbol in

each row from left to right (Wolf, O'Rourke, Gidney, Lovett, Cirino, & Morris, 2002). One of the best known measures of RAN is the *Rapid Automatized Naming and Rapid Alternating Stimulus Test* (RAN/RAS; Wolf & Denckla, 2005). Visual arrays of fifty stimuli consisting of high-frequency digits, letters, colors, or objects are presented ten times in randomized order. The Rapid Alternating Stimulus (RAS) tests are structured in a similar format to the RAN tasks except that they alternate from one stimulus to another (e.g., letter-digit-color). Another measure, the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999), contains the Rapid Naming subtest which is described as a measure of phonological retrieval from long-term memory, and assesses the ability to execute mental operations quickly and repeatedly. Both these tests primarily have been used as either research or clinical tools to identify students as early as preschool who are at risk of reading failure. Other common measures of RAN used in predicting reading skills are listed in Table 1.

RAN and Reading Fluency

Over a century ago, Cattell (1886) first suggested letter and word naming speed as an important determinant of reading skills. RAN has been hypothesized to be an early measure of reading fluency or an extension of reading fluency (e.g., Kame'enui & Simmons, 2001; Schatschneider, Carlson et al., 2002). The theory and research support related to deficits in RAN might provide some insight in the specific mechanisms pertaining to word recognition and reading fluency. For example, the theory that a familiar monosyllabic word can be named as rapidly as the name of letter or digit may indicate that the letters in the word are processed all at once and in parallel with each other (Joshi & Aaron, 2000). Therefore, the ability to name a word by sight is similar to

the ability to decode all the letters in the word simultaneously. For this reason, sight word reading skill or speeded processing can be viewed as an improvement to decoding. Once word recognition is mastered, children can focus on reading fluency. The literature has consistently shown RAN to predict reading both concurrently (Plaza & Cohen, 2003; Wolf & Bowers, 2000) and also longitudinally (Kirby, Parilla, & Pfeiffer, 2003; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Although researchers have found that discrete naming tasks also predict reading (Bowers & Swanson, 1991), RAN measures are considered to be more reflective of connected-text reading because of their heightened timing demands and also integration of phonological and lexical processes (Bowers, 1995).

Table 1. Common measures of RAN used to assess reading skills.

Measure	Authors	Subtest	Age/Grade	Stimulus
<i>Clinical Evaluation of Language Fundamentals (CELF-4)</i>	(Semel, Wiig, & Secord, 2003)	Rapid Automatic Naming	Ages: 5-21	Color Shape
<i>Comprehensive Test of Phonological Processing (CTOPP)</i>	(Wagner, Torgesen, & Rashotte, 1999)	Rapid Naming	Ages: 5-6 Ages: 7-24	Color Object Letter Digit
<i>Differential Abilities Scale, Second Edition (DAS-II)</i>	(Elliott, 2006)	Rapid Naming	Ages: 5-17	Color Object
<i>Dynamic Indicators of Basic Literary Skills (DIBELS)</i>	(Good & Kaminski, 2007)	Letter Naming Fluency	Grades: K-1	Letter
<i>Kaufman Test of Educational Achievement, Second Edition (KTEA-II)</i>	(Kaufman & Kaufman, 2003)	Naming Facility (RAN)	Ages: 4-25	Letter Color Object
<i>Developmental Neuropsychological Assessment (NEPSY-II)</i>	(Korkman, Kirk, & Kemp, 2007)	Speeded Naming	Ages: 3-16	Letter Digit Color Shape Size
<i>Process Assessment of the Learner-Second Edition (PAL-II)</i>	(Berninger, 2007)	Rapid Automatic Naming	Grades: K-6	Letter Word Digit
<i>Rapid Automatized Naming and Rapid Alternating Stimulus Tests (RAN/RAS)</i>	(Wolf & Denckla, 2005)		Ages: 5-18	Letter Digit Color Object
<i>Woodcock Johnson III Test of Cognitive Abilities (WJ-III-Cog)</i>	(Woodcock, McGrew, & Mather, 2001)	Rapid Picture Naming	Ages: 5-90+	Object

Several studies have explored the differences between the stimuli used in RAN measures and how well they correlate or predict reading fluency. There has been general consensus that alphanumeric RAN tasks tend to be better predictors of reading fluency than non-alphanumeric RAN tasks (Savage & Frederickson, 2005; Wolf & Bowers, 2000). For example, Savage and Frederickson (2005) found that while phonological tasks predicted reading accuracy, digit RAN tasks predicted reading fluency better than object RAN tasks. In a later study using all four stimuli (i.e., letters, digits, colors, and object), Savage and colleagues (2007) discovered that poorer performance on alphanumeric RAN (i.e., letters and digits) were stronger correlates of reading difficulties than non-alphanumeric RAN (i.e., colors and object). Tannock and colleagues (2006) believe that since letters and digits refer to categories with sharp, clear, and non-overlapping boundaries, they easily tap into phonological cues and lexical retrieval much faster than colors and objects, which refer to categories with unclear, variable, and overlapping boundaries.

Developmental dyslexia. Wolf and Bowers (1999) suggested that RAN tasks can differentiate poor readers from skilled readers. There has been accumulating research involving RAN deficits in individuals who have severe reading difficulties, such as developmental dyslexia (Wolf et al., 2000; Shaywitz, 2003). Many studies suggest that there are specific groups with reading disabilities who have single deficits in either phonological awareness or RAN. Phonological awareness broadly refers to the general understanding of sound structure of language, which includes onsets, rimes, syllables, in addition to phonemes, also described as *phonemic awareness* (Yopp & Yopp, 2000). Wolf and colleagues (2000) found that individuals with the most severe reading

disabilities, particularly within the area of reading fluency, are those who have deficits in both phonological awareness and RAN, commonly referred to as the *double deficit hypothesis*. In one study, children who had both deficits in phonological awareness and RAN in Kindergarten made slower progress in reading development and were more likely to suffer from reading difficulties by fifth grade (Kirby, Parrila, & Pfeiffer, 2003). The double deficit group exhibited the most significant negative reading outcomes even though that group did not possess lower levels of either phonological awareness or RAN than the single-deficit groups. Children with RAN deficits are often difficult to diagnose in early preschool years, but will likely develop reading problems throughout childhood. RAN deficits associated with developmental dyslexia may even persist into adolescence and adulthood especially if these problems are not assessed or remediated during the first several years of elementary school (Denckla & Rudel, 1976; Francis et al., 1996, Wolf & Bowers, 1999).

Previous literature has demonstrated the relation between RAN performance and reading fluency. RAN focuses on the speed of phonological or lexical access, and this speed is similar to how quickly and fluently children are able to read familiar text. Several researchers have also found that RAN tasks utilize different sub-skills that can potentially differentiate poor readers from typically developing readers. If this assertion is true, then RAN may be associated with reading comprehension, since this higher-level reading skill is suggested to be dependent on reading fluency.

RAN and Reading Comprehension

There have been few studies which have investigated the relation between RAN and reading comprehension (e.g., Holland, McIntosh and Huffman, 2004). It appears

logical that RAN would have an indirect influence on reading comprehension, especially if individuals have poor reading fluency. Wolf & Bowers (1999) found that RAN deficits were related to lower reading comprehension scores especially in poor readers. One hypothesis explaining this relation between RAN and reading comprehension is the role working memory plays in reading comprehension. If RAN measures the efficiency and speed of lexical access, it may therefore be an index of how much and how quickly information may be entered into working memory. Because reading comprehension depends on the integration of text and prior knowledge held in working memory (Bowers & Newby-Clark, 2002; Holland et al., 2004), those with slower RAN are less able to comprehend lengthier and more difficult reading material, even if they can readily identify words. This hypothesis is an interpretation based on studies exploring reading fluency (Wolf & Katzir-Cohen, 2001), whereby a specific reading speed is required for adequate reading comprehension.

Several investigators suggest that while RAN contributes to reading comprehension, the relation is evidently not as strong as with reading fluency (Johnston & Kirby 2006; Joshi & Aaron, 2000; Kirby, Parrila, & Pfeiffer, 2003). Joshi and Aaron (2000) conducted a study looking at how reading comprehension can be predicted by the relation between word decoding and listening comprehension of third-grade children. They hypothesized that the addition of RAN would also significantly improve the prediction of reading comprehension. Their analysis showed that even though much of the variance in reading comprehension was explained by the product of decoding and listening comprehension (48%), rapid letter naming explained nearly an additional 10% of the variance.

Johnston and Kirby (2006) attempted to replicate Joshi and Aaron's findings in a longitudinal study with children in third, fourth and fifth grades. However, instead of using rapid letter naming measures, they used rapid picture naming (i.e., animals). Using an overall sample of both poor and skilled readers, their results indicated that phonological awareness significantly contributed 2-4% to the third and fourth grade reading comprehension measures from the *Gates-MacGinitie Test* and *Woodcock Reading Mastery Tests—Revised* while rapid picture naming contributed approximately 1-3% of the additional variance, especially in the fourth- and fifth-grade reading measures in the overall sample. Despite the relatively low additional variance found, the researchers suggested that RAN measured in third graders added significantly to the prediction of fourth and fifth grade reading comprehension after controlling for phonological awareness. However, when separating the groups of poor readers from skilled readers, Johnston and Kirby (2006) reported the amount of unique variance attributable to RAN among poor readers ranged from 4-11%. This finding further demonstrates the predictive value of RAN in individuals who are struggling with reading tasks.

As mentioned previously, RAN deficits have a more profound effect with struggling readers. Kirby and colleagues (2003) also found significant relations between those with RAN performance deficits and low reading comprehension scores when using color and object stimuli. Their rationale for administering these stimuli was to use measures that minimized school-related content. Though weaker effects have been found for color and object RAN (van den Bos et al., 2002) than for letter and digit RAN, the non-alphanumeric RAN apparently still contributes to reading comprehension, with a

small effect found. These differences in performance between stimuli beg the question regarding the specific nature of the difficulties that underlie RAN. The following section discusses a few of these potential cognitive processes.

Assumed Cognitive Processes Associated with RAN

Phonemic awareness and phonological processing. Many studies have directly compared the predictive power of phonemic awareness and RAN (Allor, Fuchs, & Mathes, 2001; Schatschneider, Fletcher, Francis, Carlson, and Foorman, 2004). For example, Schatschneider and colleagues (2004) conducted a longitudinal study to examine the relative importance of phonemic awareness, rapid naming of letters and objects, vocabulary, and visual discrimination measured in Kindergarten in predicting reading accuracy, fluency, and comprehension at the end of first and second grades. The combination of phonemic awareness and rapid naming of letters was a significant predictor of all three outcomes at both grades. However, in this study, letter RAN was a stronger predictor of fluency than was phonemic awareness when the variables were considered separately. This may indicate that letter recognition may be a stronger indicator of future reading skills than phonemic awareness, because Kindergarten children are now developing both automaticity of letters and sound-symbol correspondence.

Some researchers have suggested that the significance of individual differences in phonemic awareness may diminish because other factors become more important in predicting reading fluency (e.g., Allor, Fuchs, & Mathes, 2001; Bowers & Wolf, 1993; Catts, Gillispie, Leonard, Kail, & Miller, 2002). Allor's (2001) review of 16 studies that included both phonemic awareness and rapid naming measures found mixed results as to

whether both contributed uniquely with the other in the predictive model. However, his review also indicated that RAN tasks were better predictors of reading fluency than measures of phonemic awareness primarily with poor readers in second to fourth grade. One possibility in these longitudinal and predictive studies is that RAN tasks assess the speed of fundamental cognitive processes required for construction of sight word representations, while phonemic awareness tasks have measured only the accuracy of these processes (Kirby, Parrila, & Pfeiffer, 2003). In addition, many of these studies recruited children who were assumed to have only reading difficulties; however, researchers did not take into account or control for other related factors, such as attention deficits.

For some researchers, RAN is included as an index of *phonological processing*, in addition to phonological awareness and phonological memory (Berninger & Wagner, 2008; Wagner & Torgesen, 1987). In this definition of phonological processing, RAN measures the speed of access to phonological codes and is necessary for successful recoding of written symbols into their phonological representations. Thus, in this view, RAN may be considered phonological in nature because it is included in the definition of phonological processing (Berninger & Wagner, 2008). However, other evidence suggests that alphanumeric RAN is more closely associated with reading (e.g. Compton, 2003; Levy et al., 1997; Manis & Freedman, 2001; Savage & Fredrickson, 2005) while non-alphanumeric RAN is more closely associated with attentional processes (e.g. Ackerman & Dykman, 1993; Rucklidge & Tannock, 2002;).

Processing speed. Given the fact that performance on RAN tasks is dependent on how quickly the reader completes the task, Kail and colleagues (1999) argued that

RAN measures specific aspects of processing speed. There has been considerable debate, however, about whether RAN reflects either phonological skills or pure processing speed (e.g., Savage et al., 2006). Researchers who believed that RAN is a measure of processing speed also claimed that RAN is not phonological in nature because it has consistently accounted for variance in reading after controlling for the effects of phonological awareness (Kail, Hall, & Caskey, 1999). The relation between reading and processing speed was explored by Cutting and Denckla (2001) and Powell and colleagues (2007), who found that processing speed did relate indirectly to reading through its influence on both phonological awareness and RAN tasks. However, both studies use single word reading as their outcome reading measure instead of reading fluency or comprehension.

There is also growing evidence that general processing speed is a strong and reliable predictor of a wide range of developmental difficulties including, but not limited to, reading difficulties (Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). If RAN were a measure of global processing speed rather than an early literacy measure, one would expect that whichever stimuli were used in the RAN tasks would not make a difference. However, as mentioned previously, several studies suggest that rapid naming of alphanumeric stimuli (i.e., letters and digits) are more highly correlated with reading fluency than non-alphanumeric stimuli (i.e., colors and objects) (Wolf et al., 2000; Schatschneider et al., 2002). These common findings evidently do not support the hypothesis that RAN's relationship to reading is based solely on general processing speed.

Orthographic processing. RAN has been described as a precursor to orthographic processing abilities in children (Wolf & Bowers, 1999). Orthographic processing refers to visual reading skills and relies on memory for letter clusters, letter chunks, words, and other patterns of written language that are typically larger than a phoneme (Barker, Torgesen, & Wagner, 1992). Therefore, some researchers assumed that orthographic processing is closely related to reading fluency, in that readers may acquire orthographic skills through repeated practice and successful experiences of decoding words (Manis et al., 2000) (See Figure 1). RAN may affect the rate at which children can make connections between letter patterns, the quality of the orthographic codes in long-term memory and retrieval, and the amount of practice needed to ensure orthographic coding of letter patterns. Therefore, readers with poor RAN do not register letter sequences quickly enough to “chunk” them into orthographic units and instead process the letters independently for an extended period of time (Bowers & Newby-Clark, 2002), resulting in difficult acquisition of orthographic processing.

Even though there have been relatively few research studies exploring the relationship between RAN and orthographic processing, available studies have provided evidence for the association (Holland et al, 2004; Manis et al., 2000). For example, Manis and colleagues (2000) found that letter and digit RAN predicted orthographic knowledge, accounting for 6-17% of the variance after controlling for vocabulary knowledge and phonological awareness. In addition, while it may be true that RAN is associated with orthographic processing and reading fluency, non-alphanumeric RAN stimuli (e.g., colors and objects) are not considered orthographic in nature. This assertion may partially explain why alphanumeric stimuli (e.g., letters and numbers) are better predictors of

reading ability than non-alphanumeric stimuli (Cutting & Denckla, 2001; Manis et al., 2000).

Genetic and Neurological Bases of RAN

There have been few genetic studies exploring the heritability of RAN. (Compton, Davis, DeFries, Gayan, & Olson, 2001). Compton and colleagues (2001) obtained reading data as part of the Colorado Twin Study of Reading Disability from 324 monozygotic and 263 same-sex dizygotic twins (ages 7-20 years). They found that RAN accounted for 5% of the genetic influence on word reading after controlling for genetic influence of phonemic awareness. Using the same data from the twin study, Davis and colleagues (2001) conducted a phenotypic analysis which suggested that the correlation between reading and RAN performance for the low-range group (i.e., at least one twin of each pair has a reading disability) was significantly higher ($r = .58$) than that for the normal-range sample (i.e., no history of a reading disability in either twin of the pair) ($r = .32$), suggesting that the relation between reading performance and RAN may differ for children with reading difficulties and normally-developing readers. When the researchers partitioned the phenotypic model to include estimates of additive genetic, shared environmental, and non-shared environmental contributions to the variance in RAN factors, results showed that both latent variables are highly heritable in low-range ($r = .57$) and normal-range twin groups ($r = .62$). However, the genetic correlation between reading and RAN was significantly higher for children with reading difficulties ($r = .71$) than for the normal-range group ($r = .35$). Though the researchers suggested that there is some genetic heritability involved in RAN performance, these RAN tasks may be a better

indicator of later reading skills for individuals who have reading difficulties rather than for skilled readers.

Neuroimaging. There has been only one empirical neuroimaging study which explored the neurological basis of RAN. Misra, Katzir, Wolf, and Poldrack (2004) conducted an fMRI study with average adult readers to evaluate the neural substrates that might underlie RAN performance. The adult participants were asked to rapidly name letter and object stimuli. For both RAN tasks compared with control tasks, activation was found in neural regions associated with eye movement control and attention as well as regions previously implicated in reading tasks, including the inferior frontal cortex, temporal-parietal areas, ventral visual stream. Future research should also explore the neural activation in children, both average and dyslexic readers, performing RAN and reading tasks.

Individuals with profound reading difficulties will do more poorly on RAN tasks than typically developing readers. As with reading fluency, impairment in RAN performance results in increased attention to the retrieval process, so that less attention will be left for reading comprehension. Along with the recent neuro-anatomical evidence of neural pathway specificity described above, this body of evidence suggests that RAN performance and attention have a unique role beyond phonological processing and processing speed in predicting reading skills. The following section discusses the literature on how inattention influences reading skills.

Inattention

Like reading, attention is a critical skill necessary for academic success. However, young children often exhibit difficulties in sustaining attention either at home or at

school. When these behaviors are persistent and appear at levels that are not age-appropriate, they may be displaying signs of Attention-Deficit Hyperactivity Disorder (ADHD). The purpose of this section is to provide a brief overview of ADHD, and to discuss how one of its core symptoms, inattention, is implicated in specific reading difficulties and RAN performance.

Attention-Deficit Hyperactivity Disorder (ADHD)

ADHD is one of the most common childhood psychiatric disorders in the United States, affecting approximately 3-7% of school-aged children (American Psychiatric Association [APA], 2000). This condition is characterized by a persistent pattern of inattention and/or hyperactivity and impulsivity that interferes with developmentally appropriate academic, social, or emotional functioning. However, there has been an ongoing debate about whether children showing problems only in the area of inattention are truly considered ADHD, since children who have predominantly inattentive symptoms have different neuropsychological and behavioral profiles from those who have predominantly hyperactive and impulsive symptoms (Barkley, 1996; Willcutt et al., 2005).

In previous versions of the Diagnostic and Statistical Manual (APA, 1987), Attention-Deficit Disorder was classified as a distinct disorder, separate from ADHD, and Barkley (1996) had suggested that more emphasis should be given to the impulsive and hyperactive characteristics of the disorder rather than to inattention when conceptualizing ADHD. Nevertheless, many studies that recruit child participants with ADHD do not distinguish these two profiles of “attention disorders” (Pennington et al., 1993). Separating inattentive symptoms from hyperactive-impulsive symptoms would

likely yield differing results between the two subtypes within the academic, cognitive, and behavioral domains, especially when understanding reading skills in this population.

Inattention and Reading

Inattention is described as a multi-dimensional construct in which children exhibit behavioral and cognitive difficulties in sustaining attention and executing goal-directed tasks (Barkley, 1997). In the case of reading, a child may have problems in selectively attending to many parts of the text anywhere from the individual phoneme to the semantic level. They may be slow readers, as they may exhibit less attention to specific phonological or semantic details of the text. Though skilled readers are believed to have attained automaticity in basic reading skills, higher-level reading such as comprehension still requires a substantial amount of attention. Even with the extensive literature on reading acquisition and development, Reynolds and Besner (2006) believed that attention is still an overlooked component in assessment and research, and is integral for translating print into speech, as well as achieving fluent reading and comprehension.

There is a relatively high comorbidity between reading disabilities and ADHD, ranging from 15% to 50% (Aaron, Joshi, Palmer, Smith, & Kirby, 2002; APA, 2000). However, many studies often do not separate differences between inattentive and hyperactive-impulsive symptoms. Phenotypic analyses from the Colorado Learning Disabilities Research Center suggested that reading difficulties or general learning difficulties are more strongly associated with inattention than hyperactivity-impulsivity (e.g., Willcutt & Pennington, 2001). Similarly, twin studies suggest that whereas the phenotypic correlation between reading difficulties and inattentive symptoms is primarily explained by common genetic influences, these common genes play a smaller role in the

correlation between reading deficits and hyperactive-impulsive symptoms (Willcutt, Pennington et al., 2005). Previous studies indicate that in addition to higher ratings of inattention symptoms from parents and teachers, children with reading difficulties also report greater problems with inattention than children without reading difficulties on self-report measures (Willcutt & Pennington, 2001).

Rabiner, Coie and the Conduct Problems Prevention Research Group, (2000) conducted a five-year longitudinal study with elementary school children (starting in Kindergarten) and discovered that inattention was associated with reading difficulties after controlling for prior reading achievement, IQ, and behavioral problems up through fifth grade. Hyperactivity, as rated by teachers, did not significantly correlate with reading achievement. They also found that inattentive first graders with average reading scores after Kindergarten were at risk for developing poor reading outcomes, and thus suggested that a primary symptom of inattention was associated with secondary symptoms of reading difficulties. However, Rabiner's study did not explore specific reading skills, such as reading fluency or comprehension, or parent ratings of inattention in each of the grade levels. It was also possible that some of the children indeed had a primary reading problem, but their reading difficulties were not severe enough to be considered reading disabled until they reached first grade.

Rabiner's findings were not fully consistent with those of Pennington and colleagues (1993), who had hypothesized that a primary reading difficulty was correlated with secondary symptoms of ADHD in children with comorbid ADHD and reading disability. Pennington's study also revealed a double dissociation between children with only ADHD and children with only reading disabilities, suggesting that children with

ADHD displayed deficits only on measures of executive functioning, whereas those with reading disabilities showed deficits only on measures of phonological processing.

However, Pennington's study used a clinically diagnosed sample, while Rabiner's study did not. In addition, participants in Pennington's study were slightly older and were all male, and the children with ADHD included those with a diagnosis of hyperactive-impulsive type and thus were not restricted to the inattentive type (Pennington et al., 1993). Because of these findings, researchers are now suggesting that there may be a shared cognitive risk factor underlying both disorders that may explain their comorbidity (Willcutt et al., 2005; Shanahan et al., 2006).

In summary, research suggests attention is critical to reading development, and this finding primarily comes from research exploring the comorbidity between reading disabilities and ADHD that are frequently observed in the same individual (Dykman & Ackerman, 1991; Shaywitz, Fletcher, & Shaywitz, 1994; Willcutt & Pennington, 2000). Even though this finding has been shown in clinical samples, typically developing children can also exhibit mild attention deficits that negatively influence reading performance. There have also been assertions about whether inattention is associated with a different neuropsychological and behavioral profile than hyperactivity-impulsivity (Barkley, 1996; Willcutt et al., 2005). Genetic and phenotypic studies suggest that inattentive behaviors negatively influence reading development, more so than hyperactive-impulsive behaviors. It is also very likely that the specific cognitive processes underlying reading skills are affected by inattention, such as RAN. The following section discusses this association.

Inattention and RAN

RAN deficits have been shown to be significantly correlated with reading difficulties (Wolf et al., 2000). However, RAN deficits have been found in children with attention problems as well, primarily studied in children with ADHD (Carte, Nigg and Hinshaw, 1996; Rucklidge and Tannock, 2002; Semrud-Clikeman et al., 2000; Tannock, Martinussen & Fritjers, 2000; Willcutt et al., 2001). Because of this finding, Waber and colleagues (2001) have argued, that unlike phonological awareness tasks, RAN performance does not differentiate children who have learning difficulties in other areas. They argued that these difficulties reflect common brain-based problems with timing or rapid processing that occur across all forms of learning impairment. For example, Shanahan and colleagues (2006) suggested that processing speed deficits may be a shared cognitive risk factor that would explain the comorbidity between reading disabilities and ADHD. When looking specifically at the different RAN stimuli of letters, digits, objects, and colors, they found significant differences in RAN performance between children with reading disabilities and the control group on all measures. Similarly, children with inattentive behaviors performed more slowly on RAN tasks than the control groups as well.

In regards to their behavioral performance, children with ADHD may carelessly make errors due to their difficulties with response inhibition or sustaining focus (APA, 2000). However, observations and results from previous studies do not appear to support this assertion when exploring error rates on specific RAN tasks across different groups of children. In a study conducted by Semrud-Clikeman and colleagues (2000), children with ADHD did not differ from the control group in number of errors made across all four RAN stimuli (i.e., letter, digit, color, and objects). Studies by Shanahan and

colleagues (2006) and Rucklidge & Tannock (2002) also did not find any differences in error rates between ADHD groups and control groups across RAN measures. On the other hand, children with reading difficulties did exhibit a significantly higher error rate on rapid letter-naming tasks than both the ADHD group and control group (Semrud-Clikeman et al, 2000). However, this finding has been described as a phonological processing problem, and not an issue relating to inattention or response inhibition.

Even though children with attention problems may not commit as many errors as typically developing children, their performance is often characterized by marked dysfluency (e.g., false starts, self-corrections, and hesitation) and overt manifestation of behavioral symptoms of ADHD (e.g., fidgeting, squirming in seat, and standing up from seat) during these very brief tasks each of which normally takes one to two minutes to complete (Tannock, 2003). However, there are no studies that observed or recorded number of self-corrections made on different RAN tasks or between different groups of children, as this behavior is often implied and reflected in a lower score or a slower time for task completion. With these observable patterns in mind, children with attention problems who also have reading difficulties, will likely struggle with classroom tasks where they are expected to sit and listen for long periods of time.

Assessment of inattention. Inattention can be assessed via clinical interviews, behavioral observations, continuous performance tests (CPT), or information gathered from teacher and/or parental rating scales. There are only a few specific measures assessing inattention that require rapid naming, particularly using color and word stimuli. The well-known *Stroop* task, for example, includes control conditions in which participants rapidly name words and colors (Stroop, 1935). Barkley (1997) reported that

9 out of 10 studies found that individuals with ADHD were impaired on the Stroop test. Pennington and colleagues (1993) argued that the Stroop test is sensitive to the attentional dysfunction that characterizes ADHD. However, the use of word stimuli as an attentional measure would not be reliable with children who have reading or language problems. Similar variations of the measure are found on the *Delis-Kaplan Executive Functioning System (D-KEFS*; Delis, Kaplan, & Kramer, 2001), a series of neuropsychological tests for assessing executive functioning and behavioral inhibition. Unlike the original Stroop where the number of colors or words read in a given time limit is recorded as the score, the D-KEFS uses the actual time required to read through all the colors or words as the score. Details about these specific attentional measures using RAN are listed in Table 2.

Table 2. Common measures of RAN used to assess inattention.

Measure	Authors	Subtest	Age/Grade	Stimulus
<i>Cognitive Assessment System (CAS)</i>	(Naglieri & Das, 1997)	Expressive Attention	Ages: 8 to 17	Color Word
<i>Delis-Kaplan Executive Functioning System (D-KEFS)</i>	(Delis, Kaplan, & Kramer, 2001)	Color Naming Word Reading	Ages: 8 to 89	Color Word
<i>Stroop Color and Word Test: Children's Version</i>	(Golden, Freshwater, & Golden, 2002)	Color Page Word Page	Ages: 5 to 14	Color Word

Color- and object-naming deficits. Several studies have reported distinct differences in RAN performance across different stimuli in clinical populations, particularly in children with ADHD. Findings revealed that children with ADHD demonstrated slower performance on non-alphanumeric RAN tasks than alphanumeric RAN tasks (e.g., Carte, Nigg & Hinshaw, 1996; Semrud-Clikeman et al., 2000). Meta-analyses of cognitive deficits in children, adolescents, and young adults with ADHD also revealed that color-naming deficits show moderate to large effect sizes ($d = .58-.62$) across the developmental lifespan with little evidence of age-related changes (van Mourik et al., 2005). Rucklidge and Tannock (2002) also found significant differences in color and object RAN tasks in children with ADHD compared with typically developing children. One possible psychological explanation for this finding is that slow color and object naming is associated with developmental delays in effortful semantic processing, which is typically associated with right hemisphere function (Tannock, Martinussen, & Frijter, 2000). In other words, naming colors and objects are thought to require more effortful, perceptual and semantic processing than naming letters and digits (Denckla & Rudel, 1976). Often, there is more than one plausible name for a given color or object, and asymmetries may likely exist between the labels. For example, color names may differ in word frequency leading to increased attention and the necessity of more careful and detailed processing. Impairments in semantic processing have been implicated in children with attention difficulties.

Even though children with inattention may not commit as many errors on RAN tasks compared with typically developing children, they are likely to exhibit dysfluency, such as self-corrections or hesitations, which would behaviorally explain their slower

performance on RAN measures and reading tasks. Future research should record and analyze these specific dysfluent behaviors on both RAN and reading measures, as it may be indicative of behaviors related to inattention. Additionally, future research should continue to explore whether colors and objects require more attention and semantic processing than letters or digits, especially as children get older. This assertion has implications for practice in assessment and monitoring of reading difficulties. However, additional factors need to be taken into account in order to establish this association. The following section describes these variables.

Additional Variables Affecting Reading and Inattention

Previous studies have presented a number of complex methodological issues when studying the relation between reading and inattention. For example, the criteria used to assess reading difficulties and levels of inattention are an important methodological issue. Furthermore, complicating studies of how reading difficulties and inattention develop and interrelate is the fact that a number of other possible factors can also be associated with these constructs including gender, intelligence, socio-economic status, and verbal ability (Hinshaw, 1992). As such, controlling for these additional variables is necessary when studying children's academic and behavioral outcomes.

Gender. One variable that deserves consideration when assessing reading skills is gender. Boys have been known to exhibit more reading difficulties than girls, especially when severity is taken into account (Olson, 2002). However, the gender ratio depends on the criteria used to define reading difficulties as well as the population studied. As stated earlier, male students are more likely to be referred in school and clinical facilities and identified with a reading disability than females because of a higher incidence of co-

occurring externalizing behaviors (APA, 2000; Lyon et al, 2006). Although school and clinics report a high male-to-female ratio, longitudinal and epidemiological studies indicate that there is a slight to no significant gender differences in reading disabilities (Badian, 1999; Lyon et al, 2006). For example, in an epidemiological study of reading disabilities (Shaywitz, Shaywitz, Fletcher, & Escobar, 1990), the male-to-female ratio was 1.2:1.

Intelligence quotient (IQ). General intelligence and verbal ability have been shown to be associated with reading achievement, especially since reading is considered a language-based skill (Rutter, 1978; Stanovich, 1988). As a result, most definitions of reading disability have required that the child display poor reading skills that could not be accounted for by low intelligence (Fletcher et al., 2002). Verbal ability also has an impact on reading skill and is traditionally controlled statistically in studies of reading disabilities in order to assess factors contributing to reading achievement independent of general intellectual ability (Bowers & Newby-Clark, 2002).

Socio-economic status (SES). Other contributors to reading achievement are parental occupation and level of education, which are thought to be equivalent to parent SES (Hollingshead, 1975). Studies have shown that parental occupation and level of education are positively correlated to the child's reading achievement since parents who have higher levels of education and SES are able to provide more academic opportunities and produce language-rich and supportive reading environments than those who have lower parent education and SES (Davis-Kean, 2005). In addition, parents who have a higher level of education are also likely to become more involved in their child's

education and schooling, which can indirectly influence reading achievement (Rabiner et al., 2000).

Working memory. Over the past few decades, many studies (e.g., Swanson & Jerman, 2007), have reported a strong association between verbal working memory and reading performance. As mentioned previously, poor readers who struggle with reading decoding have fewer residual cognitive, attentional, or memory resources for reading comprehension. Even with normal phonological awareness, slow reading fluency can still occur and may hinder comprehension because information will be lost before it is fully stored. However, not all reading comprehension problems are the result of poorly developed reading fluency, since working memory also makes a direct contribution to reading comprehension (Seigneuric & Ehrlich, 2005). As children mature and progress through school, their working memory capacity improves, mainly due to the elevated demands and increasing length and complexity of texts. In first grade, decoding skills explain most of the variance in children's reading comprehension; however, by the end of third grade, working memory becomes a significant contributor, providing more of the variance in reading comprehension than decoding (Cain, Bryant & Oakhill, 2004).

Purpose of Present Study

Extant research does not provide a detailed picture of how behavioral symptoms of inattention relate to RAN performance and reading skills in children. The majority of the research on children with ADHD does not separate the inattentive dimension from the hyperactive-impulsive dimension, nor make distinctions between specific reading skills when investigating the comorbidity between ADHD and reading disabilities. In addition, there are no studies that used both parent and teacher ratings when exploring inattentive

behaviors, though agreement between raters is moderate at best. By conducting a closer examination on how inattention is associated with higher-level reading skills in typically developing children, researchers are able to develop a more precise model of how the domains of inattention, RAN, reading fluency, and reading comprehension are interrelated and why. In addition, researchers and practitioners may be able to assess and intervene early with children who are at risk for developing reading difficulties or inattention during the elementary school years before they become worse.

It is evident that RAN tasks contribute to children's reading skills, particularly to those with pervasive reading difficulties. However, estimates on how much RAN contributes to reading varies from study to study (Johnston & Kirby, 2006; Joshi & Aaron, 2000; Schatschneider et al., 2002). The wide range of estimates is partly due to differences in methodology across studies, such as the different RAN stimuli and reading measures used, the variations in diagnostic criteria of reading disabilities and ADHD, the lack of consideration regarding the co-occurrence of inattention on reading skills, and the inability to control for other related variables such as the child's estimated IQ or parent SES.

Currently, there are no studies in the literature which assessed the specific relation between reading fluency and reading comprehension, across all four common RAN stimuli: letters, digits, colors, and objects. The majority of studies that explore RAN and reading ability have used single word reading measures. Considering that each stimulus likely requires variable amount of attention, perceptual and semantic processing needed to name the stimulus, there may be significant timing differences between each RAN stimulus based on the naming rate and accuracy recorded, and how these differences

relate to performance on reading outcome measures. In addition, behavioral data on self-corrections along with errors have not been collected in the literature to explain the potentially slower performance on these tasks across stimuli. Thus, using various RAN stimuli will allow researchers to understand how specific behaviors during RAN tasks may likely contribute to reading fluency and comprehension skills.

The primary goal of the present study was to determine how behavioral symptoms of inattention predict RAN performance across stimuli and higher-level reading skills in elementary school-aged children. Rather than assessing inattention and reading as categorical variables, both were treated as continuous variables, since a majority of the previous literature had been conducted with clinical populations. With this design, the relation between the two constructs, inattention and reading, could be examined in a broad sample of typically developing third- and fourth-grade children. Some of the children may likely be on the lower end of the norm in behaviors related to attention or in reading performance, which would have definite practical implications for children who are deemed at risk of being diagnosed with ADHD or a reading disability.

Research Questions

1.) Is RAN performance related to reading fluency and reading comprehension?

Hypothesis 1a: Yes, RAN performance is related to children's reading fluency after controlling for estimated IQ, gender, parent SES, parent and teacher ratings of inattention, working memory, and prior reading achievement.

Hypothesis 1b: Yes, RAN performance is related to children's reading comprehension after controlling for estimated IQ, gender, parent SES, parent and teacher ratings of inattention, working memory and prior reading achievement.

Rationale. There has been substantial literature to support the association between RAN performance and reading fluency (Denckla & Rudel, 1976; Wolf & Bowers, 2000) in elementary school-age children. Though RAN performance has not been found to be as strong a predictor for reading comprehension as it is for reading fluency, RAN is likely to play a significant role in comprehension considering its association with fluency. A regression model will be used to determine the influence of RAN on reading outcomes in the study sample.

2.) *Which RAN task is most related to reading fluency and reading comprehension?*

Hypothesis 2a: Letter RAN tasks will be most related with reading fluency.

Hypothesis 2b: Letter RAN tasks will be most related with reading comprehension.

Rationale. Previous studies suggest that RAN tasks that use alphanumeric stimuli, particularly letter-naming tasks, are significantly related to reading fluency (Wolf and Bowers, 1999). However, there has been little research that would suggest this will hold true for reading comprehension. Given the strong association between fluency and comprehension measures, it is likely that letter RAN tasks will contribute most of the variance in reading fluency and comprehension than color or object RAN tasks.

3.) *Is there an influence of parent and teacher ratings of inattention on RAN performance?*

Hypothesis 3a: Yes, parent ratings of inattention contribute to children's RAN performance after controlling for gender, ethnicity, parent SES, working memory, estimated IQ, and prior reading achievement.

Hypothesis 3b: Yes, teacher ratings of inattention contribute to children's RAN performance after controlling for gender, ethnicity, parent SES, working memory, estimated IQ, and supplemental reading achievement.

Rationale. Even though children with symptoms of ADHD tend to do poorly on RAN measures, there has not been extensive data regarding whether the inattentive domain specifically contributes to lower RAN performance. However, several studies in the ADHD literature indicate that children with attention deficits tend to do more poorly on color and object RAN tasks than the alphanumeric RAN tasks (e.g., Tannock, Banaschewski, & Gold, 2006). It is unclear whether typically developing children will perform similarly. Regression analyses will be used to test the hypothesis and determine how inattentive behaviors, as rated by both parents and teachers, contribute to RAN performance.

4.) *Do parent and teacher ratings of inattention uniquely contribute to reading skills after controlling for RAN performance?*

Hypothesis 4a: Yes, parent ratings of inattention will influence reading fluency after controlling for RAN performance.

Hypothesis 4b: Yes, parent ratings of inattention will influence reading comprehension after controlling for RAN performance.

Hypothesis 4c: Yes, teacher ratings of inattention will influence reading fluency after controlling RAN performance.

Hypothesis 4d: Yes, teacher ratings of inattention will influence reading comprehension after controlling RAN performance.

Rationale. Since children with inattention are likely to struggle with RAN tasks that require mental effort, this may indirectly affect their reading fluency and reading comprehension (Semrud-Clikeman et al., 2000; Tannock, Martinussen & Fritjers, 2000; Willcutt et al., 2001). Inattention likely contributes to RAN performance, though attention deficits may have a stronger link with reading difficulties among typically developing readers. Multiple regression analyses were used to determine whether inattention significantly contributes to reading skills after controlling for RAN performance. If not, additional analyses were performed to determine whether RAN mediates the relation between inattention and reading.

Table 3. Summary of hypotheses 1 and 2

Hypotheses	Questions	Variables	Analyses
Hypotheses 1a and 1b	Relation between RAN performance and reading skills	RAN (independent variable)	Multiple Regression
		Gender (independent control)	
		Ethnicity (independent control)	
		SES (independent control)	
		Estimated IQ (independent control)	
		Working Memory (independent control)	
Hypotheses 2a and 2b	Which RAN task is most related to reading skills?	Fluency and Comprehension (dependent variable)	Multiple Regression
		Prior Reading Achievement (independent control)	
		RAN (independent variable)	
		Gender (independent control)	
		Ethnicity (independent control)	
		SES (independent control)	
Hypotheses 2a and 2b	Which RAN task is most related to reading skills?	Estimated IQ (independent control)	Multiple Regression
		Working Memory (independent control)	
		Fluency and Comprehension (dependent variable)	
		Prior Reading Achievement (independent control)	

Table 4. Summary of hypotheses 3 and 4.

Hypotheses	Questions	Variables	Analyses
Hypotheses 3a and 3b	Relation between Inattention and RAN performance	RAN (dependent variable)	Multiple Regression
		Gender (independent control)	
		Ethnicity (independent control)	
		SES (independent control)	
		Estimated IQ (independent control)	
		Working Memory (independent control)	
		Ratings of Inattention (independent variable)	
Hypotheses 4a, 4b, 4c, 4d	Unique contribution of inattention on RAN performance and reading skills	Prior Reading Achievement (independent control)	Multiple Regression
		RAN (independent variable)	
		Gender (independent control)	
		Ethnicity (independent control)	
		SES (independent control)	
		Estimated IQ (independent control)	
		Working Memory (independent control)	
		Ratings of Inattention (independent variable)	
		Fluency and Comprehension (dependent control)	
		Prior Reading Achievement (independent control)	

Chapter 3: Methods

Participants

Children. There were 104 third- and fourth-grade children recruited from three elementary schools in a suburban school district in Michigan. All children were enrolled in general education classrooms, with classroom participation rates ranging from 5 to 48%. The sample included 56 female (54%) and 48 male (46%) children between the ages of 8 and 11 (mean age = 9.13). Thirty-nine children (38%) were enrolled in third grade, and 65 children (62%) were enrolled in fourth grade. All children spoke English as their primary language. Gender and ethnicity of the sample was reflective of the school district. Table 5 outlines the demographic data regarding the distribution of gender and ethnicity of the sample compared with the school district.

Parents. Out of 104 parents who provided consent to participate in the study, 99 were female (95%). Parents' socio-economic status were generally middle class (mean Hollingshead index score = 42.80, $SD = 11.63$, median = 44.00) (Hollingshead, 1975), although there was some variability in scores ranging from 14 (low SES) to 66 (high SES). One-hundred children had at least one parent who graduated high school (96%). Out of those, 63 children had at least one parent who graduated college (61%).

Teachers. Out of the 18 third- and fourth-grade teachers available in the three elementary schools, 15 teachers agreed to participate in the study. Six were third-grade teachers (40%), and nine were fourth-grade teachers (60%). Three teachers were male. Out of the 15 teachers, eight had completed a Master's degree or higher. The average number of years teaching elementary school was 17.1 years. When comparing gender, male teachers taught an average of 2.3 years, while female teachers taught an average

Table 5. Demographic characteristics of sample and school district

	Sample N	Sample %	School District %
Gender			
Male	48	46.2	48.4
Female	56	53.8	51.6
Ethnicity			
Caucasian	82	78.8	81.3
African-American	6	5.8	9.0
Latino/Hispanic	6	5.8	4.6
Asian-American	2	1.9	3.3
American Indian	2	1.9	< 0.1
Biracial/Multiracial	5	4.8	1.8
Total	104		

of 21.1 years. The average class size was 22 students, with a range from 18 to 26.

Exclusion criteria. Children with any learning, physical, social-emotional, or behavioral disorder were excluded from the study. The exclusions included children receiving special education services at their school for a reading disability, autistic spectrum disorder (ASD) or ADHD. Additional exclusion criteria included individuals who had a diagnosis of a psychological disorder (e.g., depression), a neurological disorder (e.g., traumatic brain injury), or cognitive impairment (i.e., mental retardation).

Sample size. In regards to sample size needed for the study, a statistical power approaching .80 is considered adequate for rejecting the null hypothesis if it were false.

For multiple regression procedures with six independent variables, given an alpha level of .05, assuming a medium effect size, and statistical power level of .80, the total recommended sample size was at least 100 participants. Due to geographic limitations for this study, a convenience sample was used.

Variables and Measures

Rapid automatized naming (RAN). Four rapid naming subtests were administered from the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999). The stimuli from the four subtests were presented individually: digits, letters, colors, and objects. Each participant was asked to name the stimuli as quickly as possible. The Rapid Digit Naming subtest consisted of numerals 2, 3, 4, 5, 7 and 8. Seventy-two numerals were presented on two pages in four rows on each page. The Rapid Letter Naming subtest consisted of the letters *a, c, k, n, s, and t*. Seventy-two letters were presented on two pages in four rows on each page. The Rapid Color Naming subtest consisted of colored squares: red, blue, yellow, green, and brown, and black. The colored squares were presented in four rows of nine colors in each row, totaling 72 colored squares on both pages. Lastly, the Rapid Object Naming subtest consisted of pictures of common objects: boat, chair, fish, key, pencil, and star. The objects were presented in four rows of nine pictures, totaling 72 items on both pages. Prior to exposing the test pages, each child was presented with practice items to determine ability to discriminate the stimuli. No participant was unable to name the stimuli or experienced difficulty in understanding the task.

Completion time, number of errors, and number of self-corrections were recorded for each RAN subtest. Scaled scores by age were determined based on the speed at

which each participant completed the task. The Rapid Naming Composite standard score was based on the performance of the two alphanumeric RAN tasks, while the Alternate Rapid Naming Composite standard score was based on the performance of the two non-alphanumeric RAN tasks. Reliability coefficients for the RAN subtests on the CTOPP are respectively: .79 for objects, .87 for digits, and .82 for both color and letter subtests.

Reading Skills. Children's oral reading fluency and comprehension of the text were measured using the *Gray Oral Reading Test-Fourth Edition* (GORT-4; Wiederholt & Bryant, 2001). The reading measure is an individually administered, norm-referenced measure of oral reading fluency and comprehension, used to assess individuals from 6- to 18-years of age. The GORT-4 was administered for this study to look at how reading comprehension is dependent on reading fluency, since both are assessed using the same reading passages. Children were asked to read aloud paragraphs of increasing difficulty, and respond to five comprehension questions for each passage. Deviations from the text, such as self-corrections, omissions, substitutions, insertions, and loss of place, were noted as errors.

Multiple scaled scores by age were derived from the child's oral reading including rate (speed) and accuracy (errors), which is used to determine reading fluency. A single score was derived for reading comprehension. An *oral reading quotient (ORQ)* was determined based on the sum of the fluency and comprehension scaled scores. The psychometric properties of the GORT-4 are summarized in the test manual (Wiederholt & Bryant, 2001). The internal consistency ranged from .87 to .98, suggesting good to excellent reliability. Specifically, internal consistency for fluency was greater than .90, while comprehension was greater than .95. Test-retest reliability ranged from .78 to .95,

suggesting moderate to excellent reliability. The reliability for fluency was greater than .90, while the reliability for comprehension was lower when alternate forms are used ($r = .78$), but still within acceptable range. Correlations between the GORT-4 and other measures of reading have resulted in high coefficients, with median correlations of .63-.75 for fluency, indicating acceptable criterion-prediction validity, whereas for comprehension, the correlation was lower ($r = .41$).

Inattention. Data regarding behavioral symptoms of inattention were collected using a section of the *Swanson, Nolan and Pelham, Version Four (SNAP-IV), Rating Scale*. The *SNAP-IV* was among the first *DSM-IV* symptom-based rating scale of ADHD, originally based on the Swanson and Pelham Rating Scale (Atkins et al., 1985). It was used in many treatment studies, including the Multimodal Treatment Study for ADHD (Multimodal Treatment Study of Children With ADHD, 1999) and also in genetic studies (Willcutt, Pennington, Chhabildas, Friedman, & Alexander, 1999). It was designed to gather information from parents and teachers regarding child symptoms of inattention, hyperactivity-impulsivity and other clinical disorders. Parents and teachers were asked to complete the first twenty items, as they addressed only the core symptoms that related to the ADHD criteria outlined in the *DSM-IV-TR* (2000): inattention (items #1-9) and hyperactivity-impulsivity (items #11-19). When completing the scale, parents and teachers were asked to provide demographic information of the child they were rating and to indicate the frequency they observed of each ADHD symptom during the past six months. Frequency is described on a Likert scale rating from 0-3 points: “not at all,” “just a little,” “quite a bit,” or “very much.”

Based on the first twenty items, the instrument produces three subscale scores: *ADHD-Inattention*, *ADHD-Hyperactivity-Impulsivity*, and *ADHD-Combined*. These scores were calculated by summing the points of the items in the subscale and dividing by the number of items in the subset. The scores for each subscale were expressed as the Average Rating-Per-Item. Average rating indices were constructed for each subscale, in which scores above the 95th percentile were labeled clinically significant. Data analyses were conducted using only the inattention subscale (first ten items) from the *SNAP-IV*, as it was the primary variable in the study.

Bussing and colleagues (2008) recently investigated the psychometric properties of the *SNAP-IV*. Overall, their findings revealed the scale's reliability was acceptable. Internal consistency for overall parent ratings was .94. Specifically, for the inattention domain, the coefficient alpha was .90. Internal consistency for overall teacher ratings was .97. For the inattention domain, the coefficient alpha was of .96. Inter-rater reliability between parent and teacher ratings was .49 for inattention. Even though the scale does not use age-specific normative cutoff points, analyses of *SNAP-IV* scores by age in the psychometric study did not support the notion of developmental amelioration of ADHD-related behaviors during the elementary school years (Bussing et al., 2008). Estimates revealed a small effect size for parent inattention ratings (.33) and teacher inattention ratings (< .2) comparing 8- to 10-year-olds to 11-year-olds. This finding is consistent with other studies reporting negligible to small age effects (Conners, 1997).

Estimated Full Scale IQ. The children also completed a brief standardized measure of verbal and non-verbal cognitive ability. A two-subtest combination of the *Wechsler Intellectual Scale for Children – Fourth Edition (WISC-IV)* short form (Sattler,

2008) was administered to each child participant. The administration of a short form is a reasonable strategy in research studies and in clinical situations where intellectual functioning is not the primary purpose of the assessment (Sattler & Dumont, 2004). The two selected subtests include *Vocabulary*, a verbal task which required the child to define different words, and *Matrix Reasoning*, a visual task which required the child to select a design that completes a pattern or sequence. This particular dyad of subtests is reported to have high internal consistency (Vocabulary subtest = .86; Matrix Reasoning = .85). The scaled scores from these two subtests were summed to yield a composite score, which was then calculated into an estimated Full Scale IQ score. The reliability and validity coefficients of the short form are .93 and .87, respectively.

Working Memory. The Digit Span subtest of the *WISC-IV* was administered to each child in order to assess auditory sequential working memory. It is composed of two parts: Digit Span Forward and Digit Span Backward. Digit Span Forward requires the child to repeat numbers in the same order read aloud by the examiner. Digit Span Backwards requires the child to repeat the numbers in the reverse order. A scaled score from this subtest is recorded. The internal consistency for the subtest is .87.

Demographic variables. Child and parent demographic data included the child's age, gender, parent SES, and ethnicity. Data were collected using a brief demographic form, given to the child's parents to complete. Parents were asked whether the child was receiving special education services. In addition, parents were asked their current occupation and their highest level of education completed. Data from both caregivers were collected if applicable.

Information on parental education and occupation were used to calculate parent SES using the Hollingshead Four-Factor Index of Socio-Economic Status (1975), one of the most frequently used measures of SES. The Index score was calculated from seven educational categories (from grades K-6 to graduate school) and nine occupational categories (from unskilled workers to professional). The scores on the index can range from 8 to 66. Lower scores reflected less education and lower level occupation, while higher scores reflected more education and higher-ranked occupations. If information from two caregivers was reported, individual scores were first calculated and subsequently averaged.

Supplemental reading achievement. Additional reading data from the *Michigan Educational Assessment Program (MEAP)* were also collected. The MEAP is a statewide annual standardized test assessing students from grades 3 to 9 in various subject areas (e.g., reading, mathematics, writing) based on the guidelines outlined in the Michigan Curriculum Frameworks. The reading area assessed the child's use of vocabulary and comprehension of narrative and informative text. Participants completed this assessment during the fall of 2008 prior to the study. Individual scores from the reading portion of the test were converted to z-scores, using mean scores and standard deviations for each grade level reported by the state.

Prior reading achievement data included literacy measures which assessed the participants' letter identification and sight word recognition. This assessment was part of the *Michigan Literacy Progress Profile (MLPP)*, given annually to every child to monitor early literacy skills. The Letter Identification measure, administered by the end of the participants' Kindergarten year, consists of letters of the alphabet written in uppercase

and lowercase print, which children were asked to identify quickly. The maximum raw score is 54. In addition, participants were also assessed on sight word recognition by the end of first grade. The Dolch word list was used for word recognition and consists of 220 high-frequency words in which the child was asked to identify quickly. The maximum raw score is 220.

Procedures

Prior to receiving approval from the Institutional Review Board (IRB), school administrators from one school district in Michigan were contacted about the purpose and procedures of the study. Written consent from the school superintendent was obtained to recruit children, parents, and teachers at the school sites. Out of the six elementary schools in the district, three principals from their respective schools agreed to participate in the study. Each principal aided the primary researcher in recruiting the third- and fourth-grade teachers at the school.

Following teacher consent, each teacher distributed envelopes containing packets for parents, which included (1) a parent recruitment letter introducing the research study, (2) a parent consent form, (3) a parent demographic form, and (4) the *SNAP-IV Teacher and Parent Rating Scale*, to each eligible student in the classroom. The children were instructed to bring the packets home to their parents. Parents signed the consent forms, completed the additional forms in the packet, and returned the forms to the teacher if they agreed to have their child participate in the study. Additionally, on the consent form, parents were given the option of allowing the primary researcher to review their child's school records in order to obtain prior standardized reading assessments. Out of the 295 packets distributed in the fifteen classrooms, 118 consent forms were returned. Out of

the 118 consent forms returned, 108 provided parental consent. Of those who provided parental consent, two were excluded from the study since the children did not meet criteria to participate in the study. An additional two were excluded due to missing data and incomplete responses on both the demographic form and the SNAP-IV rating scale. The parents could not be reached to complete the forms. Thus, data from 104 participants were collected and analyzed.

After parental consent has been obtained, each child was tested either at home or at school based on the decision made by the parent on the consent form. Every child participant was given a written assent form to read and sign before being tested by the primary investigator or a trained graduate assistant. The battery of tests was administered in a fixed order: (1) Digit Span, (2) Rapid Digit Naming, (3) Rapid Letter Naming, (4) Vocabulary and Matrix Reasoning of the WISC-IV, (5) Rapid Color Naming, (6) Rapid Object Naming, and (7) GORT-4. Each individual testing took approximately 30-45 minutes to complete. After completion of the testing, each child received a sticker or pencil as an incentive for participating. A second trained graduate assistant scored a portion of the completed tests. The primary researcher observed and reviewed the testing and scoring completed by both graduate assistants to ensure competency and proficiency in standardized test administration and scoring procedures.

After the testing, teachers were given the *SNAP-IV Parent and Teacher Rating Scale* of each child who participated in the study. Teachers were asked to complete the forms and return them to the primary researcher before the end of the school year.

Data Analyses

Hierarchical regression analyses were conducted on SPSS to examine relations between ratings of inattentive symptoms, RAN performance, and reading skills, while controlling for their background characteristics (i.e., gender, parent SES, ethnicity, supplemental reading achievement, working memory and IQ). Findings from multiple regression analyses allowed examination of the relation between children's inattention, RAN performance, reading fluency and comprehension measures after accounting for the effects of their background characteristics.

The first two research questions examined the association between reading fluency and comprehension (dependent variables) with RAN performance (independent variable) for each of the four different stimuli. The basic procedure consisted of two steps. In the first step, the six background variables were entered. The second step consisted of entering the standard scores of RAN performance, as the predictor variable of interest. The results reported standardized regression coefficients and the amount of variance explained at each step for reading fluency and reading comprehension.

Using regression analyses, the third research question determined whether symptoms of inattention (independent variables) contribute to RAN performance (dependent variable) after controlling for the covariates. Results included standardized regression coefficients and the amount of variance explained for each RAN task performed.

Regression and mediation analyses were used to answer the fourth research question if inattention does not significantly relate to reading skills after controlling for RAN performance. The presence of mediation effects were tested using hierarchical

regression according to guidelines recommended by Baron and Kenny (1986): (a) the predictor should be significantly associated with the outcome, (b) the predictor should be significantly associated with the mediator, (c) the mediator should be associated with the outcome variable, and lastly (d) the addition of the mediator to the model should significantly reduce the relationship between the predictor and outcome variable.

Standardized coefficients were calculated to examine changes in coefficients with the addition of the mediator to the model. Sobel's *z* statistic (Sobel, 1988) was calculated to assess the significance of changes in the coefficients.

CHAPTER 4 RESULTS

Outliers and Score Distributions

To examine the extent to which each variable was normally distributed, basic descriptive statistics and graphic representations of the score distributions for each variable were generated and reviewed. Tables 6 and 7 provide the mean, standard deviation, obtained range, skewness, and kurtosis for each variable. Table 8 provides a listing of all the outliers. Deleting outliers due to their extreme values was considered. According to Tabachnick and Fidell (2007), if outliers are part of the expected distribution for a variable, caution should be used in deleting them. Thus, no outliers were removed with the rationale that it was not unusual for typical children to score on the low or high end of the continuum in reading and inattention. Also, the primary interest of the study was to explore the influence of inattentive symptoms on RAN performance and reading skills. Including extreme data points suggestive of the presence of inattentive symptoms was thus viewed as important to the study.

The raw scores from both the parent and teacher ratings of inattention on the SNAP-IV markedly deviated from the normal distribution. The variables are considered approximately normal if the skewness and kurtosis values approach zero; however in the sample, the skewness and kurtosis values were greater than one (Table 7). Both distributions were very positively skewed, with a large number of raw scores falling in the range of 0 to 1, indicating that many children displayed few or no inattentive behaviors at home or school. This result was not surprising, given that the SNAP-IV rating scale outlines symptoms of a disorder that occurs in less than 10% of the

Table 6. Descriptive statistics of experimental measures of reading skills and RAN.

Variable/Measure	Mean	SD	Range	Skewness	Kurtosis
Age (years)	9.13	.73	8.00-11.00	-.06	-.73
Parent SES (Hollingshead Index)	42.80	11.63	14.00- 66.00	-.38	-.40
Estimated Full Scale IQ ^a	100.19	11.88	79.70- 140.60	.39	.45
Digit Span ^b	9.63	2.23	4.00-16.00	.36	.55
GORT-4 Reading Fluency ^b	10.98	2.47	5.00-18.00	.58	-.25
GORT-4 Reading Comprehension ^b	11.80	2.19	6.00-16.00	-.02	-.34
GORT-4 Oral Reading Quotient ^a	108.25	12.42	73.00- 142.00	.20	.25
CTOPP Digit RAN ^b	10.49	2.03	6.00-15.00	.04	-.27
CTOPP Letter RAN ^b	10.30	2.15	5.00-20.00	.92	.30
CTOPP Color RAN ^b	8.88	2.44	2.00-14.00	-.51	-.09
CTOPP Object RAN ^b	8.94	2.54	3.00-15.00	-.16	.21
CTOPP Rapid Naming Composite ^a	102.37	11.73	76.00- 145.00	.51	.03
CTOPP Alternate Rapid Naming Composite ^a	93.62	14.01	58.00- 127.00	-.37	.26
MEAP Reading ^c	.45	.95	-2.71-3.42	-.24	.87

^a Scores from these measures are based on a standard score, mean = 100, SD $\pm$ 15

^b Scores from these measures are based on a scaled score, mean = 10, SD $\pm$ 3

^c Scores from this measure are based on a z-score, mean = 0, SD $\pm$ 1

population. Scores from both parent and teacher ratings of inattention were summed to form a variable of overall inattention: Combined Parent and Teacher Rating of Inattention, which was still found to be positively skewed (Table 7).

Table 7. Descriptive statistics of inattention from SNAP-IV.

	Mean	SD	Range	Skewness	Kurtosis
SNAP-IV Parent Rating Inattention	.71	.61	0-3.00	1.16	1.43
Male Child*	.86*	.67	0-3.00	1.05	1.10
Female Child*	.59*	.53	0-2.10	1.11	1.13
SNAP-IV Teacher Rating Inattention	.64	.85	0-3.00	1.37	.79
Male Child**	.98**	.97	0-3.00	.63	-.88
Female Child**	.35**	.59	0-3.00	2.67	1.71
Combined Parent & Teacher Rating of Inattention	1.36	1.26	0-5.33	1.24	.89
Combined Parent & Teacher Rating Inattention (transformed)	.32	.21	0-.80	.42	-.69

Note. Individual parent and teacher ratings used to describe inattention ranged from 0 (Not at all) to 3 (Very Much)

Note. * $p < .05$ and ** $p < .001$

A logarithmic transformation of the Combined Parent and Teacher Rating of Inattention variable was conducted in an effort to make the scores more closely approximate to the normal distribution (Tabachnick & Fidell, 2007). Because the distribution of the raw scores contains zeroes, a constant of one was added to each raw score in order to avoid taking the log of zero. The variable transformation successfully

Table 8. List of variables with outliers.

Variable/Measure	Number of Outliers
Estimated Full Scale IQ	1
Digit Span (Working Memory)	2
GORT-4 Reading Fluency	0
GORT-4 Reading Comprehension	3
GORT-4 Oral Reading Quotient	1
CTOPP Digit RAN	0
CTOPP Letter RAN	4
CTOPP Color RAN	0
CTOPP Object RAN	3
CTOPP Rapid Naming Composite	3
CTOPP Alternate Rapid Naming Composite	0
SNAP-IV Parent Rating Inattention	3
SNAP-IV Teacher Rating Inattention	4
Combined Parent & Teacher Rating of Inattention	1
MEAP Reading	2

eliminated the positive skewness (Table 7). When relevant regression analyses were run with both the transformed variable and with the original non-transformed variable, no differences in significant results were found between the two variables. Therefore, the non-transformed Combined Parent and Teacher Rating of Inattention variable was used in all subsequent analyses. The primary benefit in using the original non-transformed

variable in the analyses is the relative ease in interpreting data compared to using a transformed variable.

There was extensive missing data regarding children's prior reading achievement from Kindergarten (Letter Identification) and first grade (Dolch words). Data were not available for 41 out of 104 children (39%). Many of these students might have come from different school districts outside of Michigan, and thus prior reading assessments in the earlier grades might not have conformed to the state's early literacy assessment protocols or were not recorded. Data imputation using regression methods was considered to estimate the missing data points; however, due to the large percentage of students whose prior reading achievement data were not available, the variable was eventually eliminated as it was not significantly pertinent to the study. Only supplemental reading achievement data from the Michigan Education Assessment Program (MEAP) were available for all the children in the sample and included in subsequent analyses.

Reading Skills.

The mean standard scores from the *GORT-4* reading measure are shown on Table 6. Generally, children performed average on both reading fluency and comprehension measures, as expected with a typically developing readers. However, there was still wide variability of performance on the reading measures with scaled scores ranging 5 to 18 on reading fluency and 6 to 16 on reading comprehension.

RAN Tasks

Mean time, errors, and self-corrections were also tabulated for each RAN task (Table 9). On average, children took more time naming colors and objects than letters and

numbers, a common finding seen in older children. For each RAN task with 64 items, the average number of errors committed was markedly less than one. Comparisons between errors and self-corrections were conducted to determine if differences in performance were significant for each RAN task. Because the data were not normally distributed, the nonparametric Wilcoxon signed-ranks test was used. On every RAN task, children made significantly more self-corrections than errors, which might have influenced their speed (Table 10). Children made an average of at least one self-correction on the letter and color RAN tasks.

Table 9. Mean completion time, errors, and self-corrections on RAN tasks.

	Time (seconds)	SD	Errors	SD	Self- Corrections	SD
CTOPP Digit RAN	33.79	6.60	.14	.35	.40	.77
CTOPP Letter RAN	37.65	7.21	.42	.79	1.03	1.11
CTOPP Color RAN	65.25	15.64	.31	.64	1.46	1.70
CTOPP Object RAN	68.76	14.76	.17	.40	.98	1.20

A Friedman non-parametric test was additionally conducted to assess differences among the four RAN tasks regarding self-corrections made, $\chi^2(3, N = 104) = 39.08, p < .001$. This finding indicates that there were significant differences among the four RAN tasks. Follow-up pairwise comparisons were conducted using Wilcoxon tests with the Bonferroni correction (*comparison-wise alpha* = .0083). Of the six pairwise comparisons, the most significant difference was between the color and digit RAN tasks. In other words, children exhibited the most self-corrections on the color RAN task, and

the fewest self-corrections on the digit RAN task. There were also significant differences among the RAN tasks regarding errors committed, $\chi^2(3, N = 104) = 12.12, p = .007$.

Children committed the most errors on the letter RAN task, but fewest errors on the digit RAN task.

Table 10. Comparisons between RAN performance errors and self-corrections.

	<i>Z</i>	<i>p</i>
CTOPP Digit RAN	-3.12	.002
CTOPP Letter RAN	-4.31	< .001
CTOPP Color RAN	-6.06	< .001
CTOPP Object RAN	-6.28	< .001

Inattention Measure

Mean scores from parent and teacher ratings of inattention were tabulated along with their summed score as an overall variable of inattention: Combined Parent and Teacher Ratings of Inattention (Table 7). A one-way ANOVA was conducted to determine whether there were significant differences of inattentive behaviors between boys and girls as rated by both parents and teachers. Parents rated boys significantly higher on inattention than girls, $F(1, 102) = 5.13, p < .05$. Teachers also rated boys higher on inattention than girls; however, this difference was more significant than the parent ratings, $F(1, 102) = 16.67, p < .001$.

Correlational Analyses

A correlation matrix of the primary variables of interest was constructed (Table 11). Inspection of these inter-correlations revealed that all reading tasks were positively

correlated with estimated IQ and RAN performance, and were negatively correlated with parent and teacher ratings of inattention. Beyond this, the strongest correlate of reading fluency was the letter RAN task ($r = .60, p < .01$), while the strongest correlate of parent and teacher ratings of inattention was the color RAN task ($r = -.42$ and $-.35$ respectively, $p < .01$). Reading comprehension was correlated with letter RAN ($r = .33, p < .01$) and both ratings of inattention ($r = -.32, p < .01$), albeit letter RAN had a relatively weaker correlation with reading comprehension than with fluency. On the other hand, the correlation between parent and teacher ratings of inattention was significantly correlated ($r = .47, p < .01$). Though this correlation is moderate at best, it is consistent with

Table 11. Inter-correlations between reading skills and experimental measures.

	2	3	4	5	6	7	8	9
1. Estimated IQ	.57**	.63**	.08	.18	.25*	.16	-.22*	-.27**
2. Reading Fluency		.55**	.52**	.60**	.48**	.47**	-.37**	-.31**
3. Reading Comprehension			.28**	.33**	.27**	.20*	-.32**	-.32**
4. Digit RAN				.75**	.52**	.58**	-.22*	-.14
5. Letter RAN					.52**	.57**	-.29**	-.25*
6. Color RAN						.80**	-.42**	-.35**
7. Object RAN							-.31**	-.27**
8. Parent Rating Inattention								.47**
9. Teacher Rating Inattention								

Note. * $p < .05$ and ** $p < .01$.

previous psychometric studies analyzing inter-rater reliability between parent and teacher ratings of ADHD symptoms (e.g., Bussing et al., 2008).

Relation between RAN & Reading Skills

Research Question 1: Is RAN performance related to reading fluency and comprehension in typically developing children?

Based on the literature review, two hypotheses were posed to address this question. After controlling for relevant background characteristics, it was predicted that RAN performance would be related with reading fluency. The second hypothesis predicted that RAN performance would also be related with reading comprehension. To test these hypotheses, two-step multiple regression models were developed. In each analysis, the control variables (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ) were regressed as a block in the first step of the analysis. In the second step, the variable of interest, RAN performance, was entered. Since there were two different RAN composites, the Rapid Naming Composite (i.e., letter and digit RAN) and the Alternate Rapid Naming Composite (i.e., color and object RAN), each composite was entered in a different regression model. Reading fluency and comprehension were entered as dependent variables alternatively. If the variable of interest resulted in a significant increment in variance and the sign of the standardized beta weight indicated that the relationship was in the predicted direction, the hypothesis was confirmed.

Both hypotheses were supported based on separate regression analyses. The Rapid Naming Composite significantly added to the models in both reading fluency ($\Delta R^2 = .24$, $F(7, 96) = 64.58$, $p < .001$) (Table 12) and reading comprehension ($\Delta R^2 = .04$, $F(7, 96) = 7.50$, $p < .01$) (Table 13). However, the additional variance contributed

Table 12. Regression analyses of Rapid Naming Composite predicting reading fluency.

	<i>b</i>	<i>SEb</i>	β	<i>Model R</i> ²	ΔR^2
Control Variables:					
Gender	.18	.31	.04		
Ethnicity	.07	.11	.04		
Parental SES	.03	.02	.12		
Supplemental Reading Achievement	.39*	.19	.15		
Working Memory	-.05	.08	-.05		
Estimated IQ	.08**	.02	.39		
				.37**	
Experimental Variable:	.11**	.01	.51		
Rapid Naming Composite				.61**	.24

Note. * $p < .05$ and ** $p < .01$

Table 13. Regression of Rapid Naming Composite predicting reading comprehension.

	<i>b</i>	<i>SEb</i>	β	<i>Model R</i> ²	ΔR^2
Control Variables					
Gender	.18*	.33	.18		
Ethnicity	.05	.12	.03		
Parental SES	.01	.02	.05		
Supplemental Reading Achievement	.20*	.20	.88		
Working Memory	.05	.09	.05		
Estimated IQ	.09**	.02	.51		
				.42**	
Experimental Variable:	.04**	.01	.21		
Rapid Naming Composite				.46**	.04

Note. * $p < .05$ and ** $p < .01$

was higher in fluency (24%) than in comprehension (4%). The model indicates that in this sample, reading fluency scores increased by .11 for each one standard score increase in the Rapid Naming Composite when background variables were controlled. Reading comprehension scores increased by .04 for each one standard score increase in the Rapid Naming Composite when background variables were controlled.

The Alternate Rapid Naming Composite also significantly added to the model for reading fluency ($\Delta R^2 = .09$, $F(7, 96) = 17.75$, $p < .001$) (Table 14), accounting for an additional 9% of the variance, but did not contribute any sizeable variance in reading comprehension ($\Delta R^2 = .00$, $F(7, 96) = .39$, $p = .53$) (Table 15). Reading fluency scores increased by .06 for each one standard score increase in the Alternate Rapid Naming Composite when background variables were controlled.

Estimated IQ and supplemental reading achievement predicted reading fluency and reading comprehension. However, parental SES and working memory surprisingly did not provide any significant variance in any of the reading skills. Interestingly, there was a small gender effect with girls attaining higher scores than boys only on reading comprehension. In regards to multicollinearity, tolerance values ranged from .66 to .99, and variation inflation factors (VIF) ranged from 1.0 to 1.5, suggesting relatively low multicollinearity.

Table 14. Regression analyses of Alternate Rapid Naming Composite predicting reading fluency.

	<i>b</i>	<i>SEb</i>	β	<i>Model R</i> ²	ΔR^2
Control Variables:					
Gender	.02	.37	.01		
Ethnicity	.05	.13	.03		
Parental SES	.02	.02	.10		
Supplemental Reading Achievement	.39*	.23	.15		
Working Memory	-.01	.09	-.01		
Estimated IQ	.08**	.02	.38		
				.37**	
Experimental Variable:	.06**	.01	.34		
Alternate Rapid Naming Composite				.46**	.09

Note. * $p < .05$ and ** $p < .01$

Table 15. Regression analyses of Alternate Rapid Naming Composite predicting reading comprehension.

	<i>b</i>	<i>SEb</i>	β	<i>Model R</i> ²	ΔR^2
Control Variables:					
Gender	.15*	.34	.17		
Ethnicity	.05	.12	.03		
Parental SES	.01	.02	.06		
Supplemental Reading Achievement	.24*	.21	.11		
Working Memory	.05	.09	.05		
Estimated IQ	.09**	.02	.51		
				.42**	
Experimental Variable:	.01	.01	.05		
Alternate Rapid Naming Composite				.42	.00

Note. * $p < .05$ and ** $p < .01$

Research Question 2: Which RAN stimulus is most related to reading fluency and reading comprehension?

Two hypotheses were posed to address this question. After controlling for relevant background characteristics, letter RAN would be most related with reading fluency. The second hypothesis also predicted that letter RAN would be most related with reading comprehension. To test these hypotheses, two-step multiple regression models were developed similarly to the previous research question; however, separate analyses were conducted for each of the four RAN tasks (i.e., letter, digit, color, and object) instead of their composites. Reading fluency and comprehension were entered as dependent variables alternatively.

As hypothesized, of the four RAN tasks, letter RAN significantly contributed the most to the model accounting for an additional 24% of the variance in reading fluency ($\Delta R^2 = .24$, $F(6, 97) = 58.40$, $p < .001$) (Table 16). Reading fluency scores increased by .58 for each one standard score increase in the letter RAN task when background variables were controlled. When reading comprehension was the dependent variable, letter RAN also contributed most significantly to the model, but provided only an additional 5% of the variance in reading comprehension ($\Delta R^2 = .05$, $F(6, 97) = 7.78$, $p < .01$). Reading comprehension scores increased by .22 for each one standard score increase in the letter RAN task when background variables were controlled.

As for the other RAN tasks, digit RAN was a significant predictor of reading fluency accounting for an additional 21% of variance in the model ($\Delta R^2 = .21$, $F(6, 97) = 46.52$, $p < .001$). However, digit RAN contributed less variance in reading comprehension, providing an additional 4% of the variance in the model ($\Delta R^2 = .04$, F

(6, 97) = 6.51, $p < .05$). Color RAN was also a significant predictor of reading fluency, contributing an additional 9% the variance ($\Delta R^2 = .09$, $F(6, 97) = 15.94$, $p < .001$), but did not contribute any sizeable variance in reading comprehension. Similarly, object RAN was also a significant predictor of reading fluency, contributing an additional 11% the variance in reading fluency ($\Delta R^2 = .11$, $F(6, 97) = 20.10$, $p < .001$), but was not a significant predictor of reading comprehension.

Table 16. Regression analyses of RAN tasks separately predicting reading fluency.

	<i>b</i>	<i>SEb</i>	β	Model R^2	ΔR^2
CTOPP Digit RAN	.57**	.08	.47	.55	.21
CTOPP Letter RAN	.58**	.08	.50	.58	.24
CTOPP Color RAN	.33**	.08	.32	.42	.09
CTOPP Object RAN	.35**	.08	.36	.45	.11

Note. Hierarchical regressions controlled for children's background characteristics (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ). * $p < .05$ and ** $p < .01$

Table 17. Regression analyses of RAN tasks separately predicting reading comprehension.

	<i>b</i>	<i>SEb</i>	β	Model R^2	ΔR^2
CTOPP Digit RAN	.21*	.08	.19	.45	.04
CTOPP Letter RAN	.22**	.08	.21	.46	.05
CTOPP Color RAN	.06	.07	.06	.42	.00
CTOPP Object RAN	.05	.07	.06	.42	.00

Note. Hierarchical regressions controlled for children's background characteristics (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ). * $p < .05$ and ** $p < .01$

Relation between Inattention and RAN

Research Question 3: Is there an influence of parent and teacher ratings of inattention on RAN performance?

The first hypothesis predicted parent ratings of inattention would influence RAN performance. The second hypothesis also predicted teacher ratings of inattention would also influence RAN performance. To test these hypotheses, two-step multiple regression models were developed similarly to the second research question; however, because RAN performance was separated into the Rapid Naming Composite and Alternate Rapid Naming Composite, each composite was included in separate regression analyses as dependent variables. The non-transformed Combined Parent and Teacher Rating of Inattention variable was initially entered as an overall variable of inattention, after including the background characteristics in the first step. If the model is significant, then the parent and teacher ratings of inattention would be included in separate regression models.

Hypotheses 3a and 3b were supported based on the analyses. When the Combined Parent and Teacher Rating of Inattention variable was entered in the regression analyses, it was negatively related to the Rapid Naming Composite ($\Delta R^2 = .04$, $F(7, 96) = 1.90$, $p < .05$) (Table 18). In other words, for each one unit score *increase* in inattention, Rapid Naming Composite scores *decreased* by 2.14 when background variables were controlled. Combined ratings of inattention also was negatively related to Alternate Rapid Naming Composite ($\Delta R^2 = .06$, $F(7, 96) = 4.17$, $p < .01$) (Table 19), that is for each one unit score increase in inattention, the Alternate Rapid Naming Composite scores *decreased* by 3.18 when background variables were controlled

However, when inattention was further explored by separating parent and teacher ratings, only the parent ratings remained consistently significant in explaining 4% of the variance in the Rapid Naming Composite ($\Delta R^2 = .04$, $F(7, 96) = 1.88$, $p < .05$), but not the teacher ratings of inattention. When the Alternate Rapid Naming Composite was the dependent variable, parent ratings of inattention contributed 5% of the variance ($\Delta R^2 = .05$, $F(7, 96) = 3.94$, $p < .01$), and teacher ratings of inattention contributed 4% of the variance ($\Delta R^2 = .04$, $F(7, 96) = 3.63$, $p < .05$) when all background characteristics were controlled.

Table 18. Regression analyses of inattention separately predicting RAN performance – Rapid Naming Composite: letter and digit RAN.

	<i>b</i>	<i>SEb</i>	β	Model R^2	ΔR^2
Combined Parent & Teacher Rating of Inattention	-2.14**	1.06	-.23	.06	.04
Parent Rating Inattention	-4.07*	2.08	-.21	.06	.04
Teacher Rating Inattention	-2.25	1.55	-.16	.04	.02

Note. Hierarchical regressions controlled for children's background characteristics (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ). * $p < .05$ and ** $p < .01$

Table 19. Regression analyses of inattention separately predicting RAN performance – Alternate Rapid Naming Composite: color and object RAN.

	<i>b</i>	<i>SEb</i>	β	Model R^2	ΔR^2
Combined Parent & Teacher Rating of Inattention	-3.18**	1.18	-.29	.18	.06
Parent Rating Inattention	-5.70*	2.33	-.25	.17	.05
Teacher Rating Inattention	-3.55*	1.73	-.22	.15	.04

Note. Hierarchical regressions controlled for children's background characteristics (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ). * $p < .05$ and ** $p < .01$

Relation between Inattention, RAN, and Reading

Research Question 4: Do parent and teacher ratings of inattention uniquely contribute to reading skills after controlling for RAN performance?

The first and second hypotheses predicted that parent ratings of inattention would influence reading fluency and comprehension after controlling for RAN performance.

The third and fourth hypotheses also predicted teacher ratings of inattention would influence reading fluency and comprehension after controlling for RAN performance.

Before testing these hypotheses, two-step regression models were developed to determine whether inattention predicted reading skills without controlling for RAN. Thereafter, three-step regression models were developed to test the proposed hypotheses with RAN included. Background characteristics were entered in the first step, while RAN performance was entered in the second step. The third step included parent and teacher ratings of inattention. The Combined Parent and Teacher Rating of Inattention variable was initially entered as an overall variable of inattention. If the model was significant, then parent and teacher ratings of inattention would be included in separate regression models.

Before controlling for RAN performance, results showed that Combined Parent and Teacher Ratings of Inattention significantly predicted reading fluency ($\Delta R^2 = .03$, $F(6, 97) = 10.99$, $p < .05$), accounting for approximately 3% additional variance, but not reading comprehension ($\Delta R^2 = .00$, $F(6, 97) = 11.98$, $p = .21$) (Table 20). The model indicates for each one unit increase in combined inattention scores, reading fluency scores decreased by .37 when background variables were controlled. When separating inattention scores by raters, the model indicates for each one unit increase in parent inattention scores, reading fluency scores decreased by .79. However, after controlling RAN performance (entered at step 2), the Combined Parent and Teacher Ratings of Inattention did not contribute significantly to reading fluency or reading comprehension (Table 21). Therefore, none of the hypotheses were supported for this research question. Given that ratings of inattention were a predictor of RAN performance, additional analyses were conducted to determine whether the effect of inattention on reading skills was mediated by the effect of RAN performance.

Sobel's z statistic was used (Sobel, 1988) for mediation analyses. Several components were obtained: the raw regression coefficient and the standard error for the association between ratings of inattention (predictor) and RAN (mediator), and the raw regression coefficient and the standard error for the association between RAN (mediator) and reading fluency (outcome) adjusting for inattention (Tables 22 and 23). Both Rapid Naming Composite and Alternate Rapid Naming Composite were separately included in the analyses. The appropriate unstandardized regression coefficients and standard errors were used in the calculation of the Sobel test through the use of an interactive calculation tool provided by Preacher & Leonardelli (2001).

Table 20. Regression analyses of inattention separately predicting reading skills.

	Reading Fluency				Reading Comprehension			
	<i>b</i>	<i>SEb</i>	β	Model R^2	<i>b</i>	<i>SEb</i>	β	Model R^2
Combined Parent & Teacher Rating of Inattention	-.37*	.18	-.19	.37	-.13	.18	-.09	.29
Parent Rating Inattention	-.79*	.35	-.20	.38	-.19	.34	-.07	.29
Teacher Rating Inattention	-.32	.27	-.11	.35	-.16	.26	-.07	.29

Note. Hierarchical regressions controlled for children's background characteristics (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ). * $p < .05$

Table 21. Regression analyses of inattention separately predicting reading skills after controlling for RAN performance.

	Reading Fluency				Reading Comprehension			
	<i>b</i>	<i>SEb</i>	β	Model R^2	<i>b</i>	<i>SEb</i>	β	Model R^2
Combined Parent & Teacher Rating of Inattention (controlling for Rapid Naming Composite)	-.13	.15	-.06	.61	-.14	.15	-.08	.46
Combined Parent & Teacher Rating of Inattention (controlling for Alternate Rapid Naming Composite)	-.17	.18	-.09	.46	-.20	.16	-.12	.43

Note. Hierarchical regressions also controlled for children's background characteristics (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ).

Table 22. Regression analyses used for mediation with Rapid Naming Composite.

Independent Variable	Dependent Variable	<i>b</i>	<i>SEb</i>	β	<i>t</i>	ΔR^2
Combined Parent & Teacher Rating of Inattention	Reading Fluency	-.37*	.18	-.19	-2.00	.03
Combined Parent & Teacher Rating of Inattention	Rapid Naming Composite	-2.14*	1.06	-.23	-2.01	.04
Rapid Naming Composite (controlling for inattention)	Reading Fluency	.11**	.01	.51	7.71	.21

Note. Hierarchical regressions also controlled for children's background characteristics (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ). * $p < .05$ and ** $p < .01$

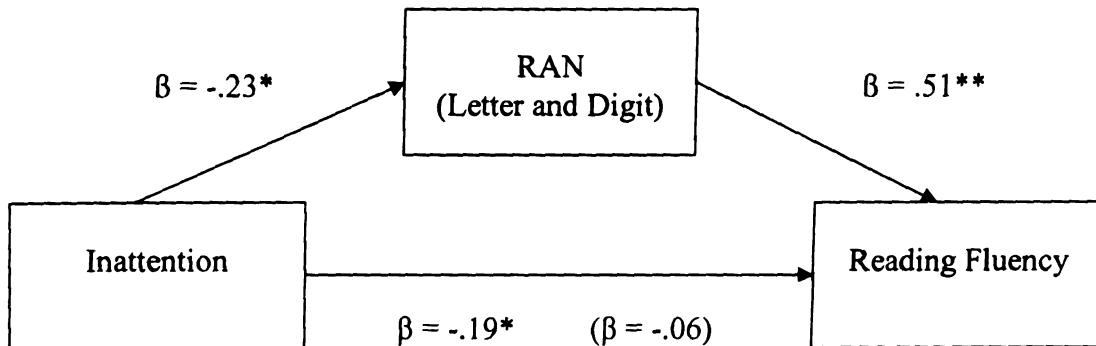
Table 23. Regression analyses used for mediation with Alternate Rapid Naming Composite.

Independent Variable	Dependent Variable	<i>b</i>	<i>SEb</i>	β	<i>t</i>	ΔR^2
Combined Parent & Teacher Rating of Inattention	Reading Fluency	-.37*	.18	-.19	-2.00	.03
Combined Parent & Teacher Rating of Inattention	Alternate Rapid Naming Composite	-3.18**	1.18	-.29	-2.70	.06
Alternate Rapid Naming Composite (controlling for inattention)	Reading Fluency	.06**	.02	.34	3.83	.08

Note. Hierarchical regressions also controlled for children's background characteristics (i.e., gender, ethnicity, parent SES, supplemental reading achievement, working memory, and estimated IQ). * $p < .05$ and ** $p < .01$

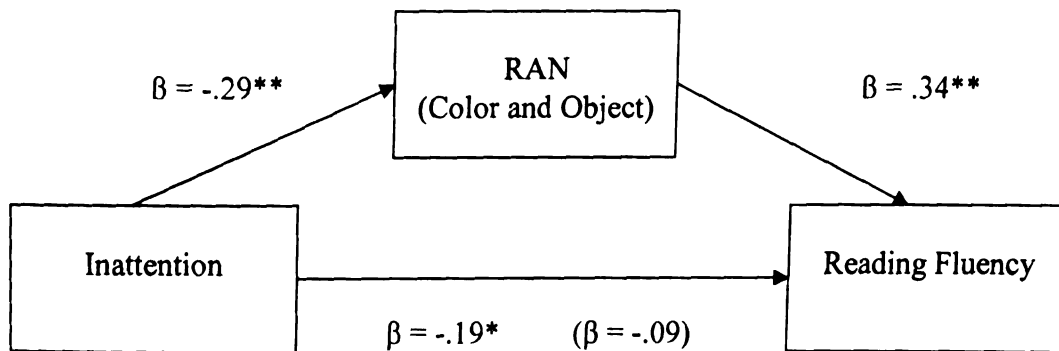
Indeed, both RAN composites mediated the relation between Combined Parent and Teacher Rating of Inattention and reading fluency. When the Rapid Naming Composite was incorporated into the mediational analyses, the result was significant (Sobel's $z = -1.99, p = .047$), along with the Alternate Rapid Naming Composite (Sobel's $z = -2.00, p = .045$). Figures 2 and 3 below demonstrate the decrease in the standardized regression coefficients for the possible effect of inattention and reading fluency with both RAN composites as mediators (Baron & Kenny, 1986). In figure 2, the standardized coefficients in the model were $-.19$ for inattention and $.51$ for RAN, with reading fluency as the outcome variable. Changing the inattention scores by one standard deviation significantly decreased reading fluency scores by $.19$ standard deviations. Changing RAN performance by one standard deviation significantly increased reading fluency scores by $.51$ standard deviations. When conducting the mediation analyses, the relation between inattention and reading fluency in the model becomes insignificant when the direct influence of RAN was included in the regression.

Figure 2. Rapid Naming Composite as a mediator between inattention and reading fluency.



Note. The figure shows standardized regression coefficients for the relation between inattention and reading fluency as mediated by the Rapid Naming Composite. The standardized regression coefficient between inattention and reading fluency controlling for RAN performance is in parentheses. $*p < .05$ and $**p < .01$

Figure 3. Alternate Rapid Naming Composite as a mediator between inattention and reading fluency.



Note. The figure shows standardized regression coefficients for the relation between inattention and reading fluency as mediated by the Alternate Rapid Naming Composite. The standardized regression coefficient between inattention and reading fluency controlling for RAN performance is in parentheses. $*p < .05$ and $**p < .01$

CHAPTER 5 DISCUSSION

Although research has been conducted to understand the comorbidity between ADHD and reading disabilities, relatively few studies have explored the influence of specific behaviors of inattention on reading skills, especially among the normal population. For many children, sustained attention is needed to read fluently and comprehend text. It is evident also that RAN tasks contribute to the variance in children's attention and reading skills, even among typically developing readers. However, estimates on how much variance each RAN stimulus contributes to fluency and comprehension varies across studies. By conducting a closer examination of how individual differences in inattention are associated with these reading components, researchers are able to develop a more precise model of how the domains of inattention, RAN, reading fluency and comprehension are interrelated and why.

Developmental models of reading take into account cognitive and phonological processes, instructional foci, and outcomes (Figure 1). However, the role of attention needs to be incorporated into the model as it provides an important contribution to achieving proficiency in reading fluency and comprehension. Considering the relatively high comorbidity of children with both reading difficulties and attention deficits, neurodevelopmental evidence suggests attention is a critical component in improving the cognitive processes involved in reading, particularly rapid naming. Beginning readers who exhibit higher levels of inattention during any aspect of reading acquisition may fall behind peers who are fluent readers. Therefore, assessing attention among typically developing readers can provide important information about those who are at risk for reading difficulties.

RAN and Reading Skills

Even though the children who participated in the study are average readers with no history of learning disabilities, ADHD, neurological, or psychological problems, they performed variably across reading and RAN measures. Consistent with the literature, RAN performance is significantly related to reading fluency (e.g., Savage & Frederickson, 2005; Wolf & Bowers, 2000), and thus, the results supported Hypothesis 1a. However, when RAN was separated into two groups of stimuli, the Rapid Naming Composite (letter and digit RAN) significantly related to reading comprehension, but not the Alternate Rapid Naming Composite (color and object RAN); thus partially supporting Hypothesis 1b. Because the alphanumeric stimuli from the Rapid Naming Composite tap into orthographic and phonological processing and word recognition better than non-alphanumeric stimuli, the Rapid Naming Composite may allow for quicker lexical access in order to understand text (Wolf & Bowers, 1999). Another reason for this finding may be the notion that color and object RAN tasks have traditionally been used to assess basic literacy skills as early as preschool, usually before children have been exposed to letters, and thus, would not necessarily be predictive of future reading, particularly for such a higher-level skill as reading comprehension.

Specifically, both hypotheses (2a and 2b) regarding the relation between letter RAN and reading skills were also supported. Letter RAN contributed most of the variance in reading fluency and comprehension than the other stimuli. However, the amount of variance contributed to comprehension is less than fluency. Letter RAN may be more indicative of connected-text reading due to its heightened timed demands and

also its involvement with orthographical representations and lexical retrieval processes (Bowers, 1995; Savage et al., 2007).

Previous studies suggest that RAN performance is more predictive of reading performance in struggling and disabled readers than average readers (e.g., Compton et al., 2001; Johnson & Kirby, 2006). If children with reading disabilities were to have participated in the study, the variance RAN contributes to both reading fluency and comprehension might have been greater. Considering the wide variability of reading performance among the sample, the results from this study further provides evidence that RAN is significantly related to reading development for both good and struggling readers. These relations were also significant even after controlling for IQ and supplemental reading achievement (i.e. MEAP), which historically have contributed sizeable variance in future reading skills.

Inattention and RAN

The correlational relations obtained suggest that letter and digit RAN is more highly correlated with reading fluency and comprehension than attentional difficulties. However, regression analyses indicate that combined ratings of inattention had a negative influence on Rapid Naming Composite and Alternative Naming Composite scores. This finding suggests that higher levels of attention are needed to perform well on all four RAN stimuli. This finding contradicts some studies that have found that only color and object RAN tap into more attentional resources than letter and digit RAN. A fairly common notion among neuropsychological studies suggests that color and object tasks are significantly related to inattention and executive functioning difficulties (e.g., Stringer, Toplak, & Stanovich, 2004). However, young children typically learn colors

and objects before they learn numbers and letters, so it seemed illogical that it would take substantially more attention and processing to name colors and objects when they get older.

One explanation proposed in the literature is that color and object naming is associated with developmental delays in effortful attentional and semantic processing for children with attention deficits (Tannock, Banaschewski, & Gold, 2006). Older children may have more than one appropriate name for a given color or object as their vocabulary increases, and thus requires more attention to select the most appropriate word for that color or object. The process to identify a color is likely more complex and takes longer than the processing to identify letters and digits which have simpler and clearer boundaries. In addition, letters and digits are over-learned and emphasized more so than colors and objects as children move through first, second, and third grades due to the increased exposure of reading and mathematics in the classroom. Thus, for typically developing readers, their performance on letter and digit RAN tasks may become more automatic and require less attention to complete than color and object RAN tasks. Nevertheless, considering that the sample did not include children with diagnoses of a reading disorder or ADHD, the children in the study who displayed low levels of inattention likely performed better on the color and object RAN tasks than those who exhibit high levels of inattention

Completion time, errors and self-corrections. It takes significantly longer time to name colors and objects than letters and numbers, which is a common finding among assessments of RAN (Wagner, Torgesen, & Rashotte, 1999) and research studies (Semrud-Clikeman et al., 2000). Errors were relatively infrequent and thus were not

predictive of reading performance or attention difficulties (Semrud-Clikeman et al., 2000). In addition, error rates are not necessarily reflected in their performance score, which is mainly determined by speed and not accuracy.

Considering many studies that explore RAN also take into account number of errors committed during naming, this is the first study that explores the number of self-corrections committed when children complete RAN tasks. Self-corrections were observed because they negatively influence the speed in performance, since children have to be aware of the errors committed and to quickly produce a different verbal output, which often results in a longer completion time. Children exhibited the least number of self-corrections on digit RAN tasks, which may indicate more automatic processing for these stimuli. However, children exhibited more self-corrections on letter and color RAN tasks than digit or object tasks. This finding suggests that letter and color RAN tasks may be sensitive to issues relating to individual differences in attention and/or reading skills.

Parent vs. Teacher Ratings of Inattention

Individual differences in inattention can be assessed with a variety of tools. In particular, behavior rating scales are commonly used by practitioners and researchers to assess levels of inattention in children. The SNAP-IV measure aligns with criteria for children who are diagnosed with ADHD. Symptoms related to ADHD primarily occur across settings, and thus behavior rating scales can provide these data via multiple informants. However, parent-teacher agreement for behavior ratings in general has been found to be low to moderate across a range of ages and types of behaviors. The relatively low agreement between raters in clinical samples is often due to effects of restricted-

range, non-normally distributed data, and the fact that the ratings provides are ordinal rather than continuous.

In addition, it is important to recognize some of the differences between settings in which parents and teachers observe children. In contrast to the home environment, where a child may have no or few siblings and the expectations and structure may vary, schools typically require children to interact with peers, may place greater or at least different demands for attention upon children, and expose them to various activities that generally follow a consistent schedule. Parents may lack knowledge of what is developmentally appropriate, while teachers can determine which behaviors are considered typical. Teachers can compare a child who is inattentive to another child who is listening and following directions at school. On the other hand, parents may have a greater sample of behavior upon which to rate their child, not just across time historically but also at different times of day than when teachers are making observations. Thus, there are many setting differences that may contribute to low agreement rates.

Though combined parent and teacher ratings of inattention was used as an overall measure of attention, there were significant differences between how parents and teachers rated male and female children. Both parents and teachers rated boys significantly higher on inattention than girls. One study also found similar gender differences among ADHD girls and boys, but only in regards to teacher ratings (Gershon & Gershon, 2002). These data could suggest that parents and teachers may over-recognize inattentive behaviors in males and correctly identify their female counterparts. Alternatively, gender differences in ratings may indicate a "halo effect," whereby raters attend more to behaviors exhibited by boys than girls.

Overall analyses from both parent and teacher ratings indicate 4-6% of the variance in RAN performance is attributed to inattention. In addition, regression analyses indicate a relatively weaker relationship with teacher ratings of inattention and RAN performance than parent ratings. Even though Hypotheses 3a and 3b were generally supported, teacher ratings of inattention did not contribute sizeable variance in predicting letter and digit RAN performance. Because the participants in this study did not have any notably severe academic or behavioral issues in school, teachers might not rate the children's classroom behaviors as problematic as their parents would rate their own children at home. Nevertheless, further studies should explore these rating differences between informants among typically developing children, since it is difficult to determine whether these disparities are due to rater biases or that children's behaviors may actually be dissimilar across both settings.

Inattention, RAN, and Reading Skills

As with reading scores, children exhibit individual differences in inattention. There were several children who were rated relatively high, though they had no prior history of ADHD. In regards to the fourth research question, none of the hypotheses were supported. Before RAN performance was entered into the regression model, only combined ratings of inattention predicted reading fluency. When separating the raters, only parent ratings significantly predicted reading fluency, and not the teacher ratings. However, after controlling for RAN performance, the parent and teacher ratings of inattention did not contribute significantly towards reading fluency, suggesting the notion that RAN performance mediated this relation.

Two sets of mediation analyses were performed to separate the two different RAN composites. Regression analyses indicated that higher levels of inattention were significantly related to both RAN performance and reading fluency, while both alphanumeric and non-alphanumeric RAN were mediator variables that assisted in explaining the relation between ratings of inattention and reading fluency. Thus, it is likely that children with higher levels of inattention would have difficulty with RAN tasks, which adversely affects their performance on reading fluency measures.

Because RAN takes into account several different processes that relate to both reading and attention, it is possible that RAN can be seen as the intersection of several processes, one domain being the phonological or orthographic components of the task, a second domain reflecting executive functioning or attention (Stringer, Toplak, & Stanovich, 2004), and a third domain addressing processing speed. However, the model is unfortunately not as simplistic, because these domains (which together still do not specify all of the variance in RAN performance) require the integration of both visual processes (interpretation of the stimulus) and verbal processes (articulation of the label). Berninger and colleagues (2008) emphasize the importance of bringing all these processes into synchrony. However, if slow processing occurs in one or more of these elements, integration would not occur efficiently and would lead to lower scores on RAN tasks.

Thus, individuals may be slow on RAN tasks for various reasons. Children who struggle with letter and digit RAN may have more difficulties with phonological and orthographic processes, while color and object RAN are not considered phonological or orthographic in nature. This would explain why alphanumeric RAN is significantly

related to reading fluency and comprehension. Color RAN may be more influenced by attention and processing speed, which explains its relatively small contribution to reading fluency scores. In addition, Davis et al. (2001) reported heritabilities of alphanumeric RAN with orthography, approximately twice the size of those with phonological decoding, which would appear to offer additional support for the notion of a primary influence of RAN deficits on the development of orthographic representations for words in older children (Manis & Freedman, 2001; Wolf & Bowers, 1999).

Implications for Practitioners

There are several implications from this study for parents, teachers, and practitioners. Children who are typically developing readers still need to accrue attentional resources to engage and succeed in reading. In addition, research exploring the role inattention and RAN play in reading skills provides a theoretical foundation and rationale for developing reading interventions that address not only phonological awareness, but processing speed and attention (Wolf & Bowers, 1999). Until recently, reading interventions were largely directed to improve only phonemic awareness or phonologically-related decoding skills. Children with dyslexia or other reading difficulties who either have RAN performance deficits or a combined deficit (i.e., phonemic and RAN deficits) would not be positively aided by interventions that only address improving phonological awareness skills. This dilemma explains why some struggling readers do not respond to phonologically-based reading interventions, especially for older children in elementary school, when reading instruction is focused on higher level reading skills.

There are currently few comprehensive reading interventions that specifically address naming speed deficits to improve reading fluency. Repeated readings and listening previewing are widely used inventions for children who have difficulties with fluency (Rathvon, 2008). These interventions emphasize repetition in order to improve word recognition accuracy, automaticity, and fluency rate. Attention is also essential for these interventions, as struggling readers must attend and listen to a fluent reader before reading the passages on their own. Another available reading intervention, the *RAVE-O* (Wolf, Miller, & Donnelly, 2000), focuses on the phonological processes involved in reading, which include [lexical] retrieval, automaticity, vocabulary, elaboration, and orthography.

Limitations

There were several limitations in this study that are worth mentioning. A convenience sample was used due to geographic restrictions of the researchers. Parents who agreed to participate in the study might have children who have suspected reading difficulties, and thus were more likely to participate than those who did not have these difficulties. However, only one parent requested results of her child's individual testing, while the rest of the participants did not, even though they had that option available to them. The sample size was also a limitation; with a larger sample, power would have increased, and it is possible that additional relationships would have been significant given the large number of variables included in the study.

Children in the sample performed relatively higher on reading comprehension than reading fluency on the GORT-IV. Reading comprehension was assessed via multiple choice questions, after reading a brief passage aloud. However, a majority of

the comprehension questions asked were deemed as *passage-independent*, where readers may already know the answers to the questions, without needing to read the text (e.g., What color is the sky?). Questions that are *passage-dependent* would have assessed comprehension more carefully as readers needed to rely on the passage to answer the question (e.g., What did John do after work?). Thus, the multiple choice questions may not have assessed reading comprehension accurately. On the hand, one may argue that prior knowledge is an important factor in reading comprehension (Rand Reading Study Group, 2007). Nevertheless, this would still make it difficult to ascertain whether comprehension difficulties are due to lack of prior knowledge or a specific reading problem. All participants also were not allowed to revisit the passage, and therefore were not able to use specific comprehension strategies such as contextual clues, if they were not able to read fluently. Children who misread words orally are provided with the correct word as indicated by the standardized administration procedures. A child who does not read well can still obtain a high comprehension score on the passage even if their fluency score is low. Thus, what was assessed during the comprehension task may be listening comprehension and not actual reading comprehension.

Auditory and sequential working memory was not found to be a significant predictor of reading comprehension, even though the comprehension measure supposedly relies on recall and recognition to answer the questions correctly. Alternative methods of assessing oral reading comprehension, such as providing open-response answers to questions, retelling the passage, or reading longer passages may provide a more accurate depiction of children's reading comprehension.

Because attention was one of the primary variables in the study, additional measures of sustained attention or executive functioning (e.g., continuous performance tests) used in clinical and research settings would be useful to explore the cognitive aspects of attention, rather than solely using behavior rating scales. This data would be gathered based on individual student performance rather than solely from observation conducted by parents or teachers. Visual and auditory continuous performance tests (CPT) can be used to assess whether there are differences between sustained visual and auditory attention, since RAN and reading tasks requires the integration of both domains.

Even though prior reading achievement from Kindergarten was considered in the study, it was not included because many children who participated in the study did not have that data available in their school records. Some children might have recently moved to the district, so the specific assessments were not conducted then. This data would have determined whether phonological awareness and letter recognition scores had an impact on future RAN performance and reading ability.

A fixed order of tests might have confounded the results. Participants performed slightly lower on color and object RAN tasks, after completing the letter and digit RAN tasks. Even though these results are not unusual, counterbalancing the measures would have resolved this issue regarding the lower RAN performance scores. The letter and digit RAN tasks could have been administered to half of the participants, while the color and object RAN tasks could have been given to the other half. In addition, examiner bias might have influenced the results, as the primary investigator administered the battery tests to 100 out of the 104 participants. The remaining four participants were tested by research assistants.

Future Directions

This study provides new information on how RAN draws on different processes including phonological awareness, attention, and speed, all of which are needed for successful reading. It is important to emphasize that these relations exist in children along the normal continuum of RAN, attention, and reading ability. Thus, it was not necessary to look at children diagnosed with reading disorders or ADHD in order to find these effects. These findings also underscore the importance of observing all of the constructs, both cognitive and behavioral, across a continuum of performance. This method of examining the problems of reading, attention, behavior, and the various forms of RAN, can also provide a productive structure to frame future research questions.

This study provided information on how typically developing children perform on RAN and reading ability measures. In order to address cross-cultural considerations in literacy and linguistics, researchers can look at the relation between RAN and reading ability across languages, particularly those that use both pictographic and orthographic representations (e.g., Japanese kanji vs. romaji). Assessment of RAN performance has been most useful during elementary school years to predict reading skills. Future research can also address whether rapid serial naming (RSN), is more related to attention and reading ability given its increased cognitive demands in switching between stimuli (e.g., letter-color-letter).

Because children in this study displayed varying levels of RAN, attention and reading performance, research endeavors should continue to explore how specific aspects of attention are needed to succeed in various aspects of reading development. If children have any difficulties in attending to the auditory, visual, or speeded processing demands

of reading, early assessment is needed to address these specific deficits. Incorporating attention measures is necessary to provide a better understanding of reading development in a holistic manner. These results can further assist researchers on developing a more complex model of reading while also creating more evidence-based interventions which address attention and reading skills.

APPENDICES

SCHOOL/TEACHER RECRUITMENT LETTER

Date: 3/15/2009

Dear Faculty at Holt Public Schools:

We are writing to invite your student to participate in a research study conducted as part of the investigator's dissertation. This study is about reading, and several of the processes that may contribute to reading fluency. We have partnered with the Holt Public Schools, and all of the third- and fourth-grade students in Holt who are in general education are being invited to participate in this study.

We hope to learn how students' level of attention at home and in school relates to naming speed (the ability to rapidly name letters, numbers, objects and colors) and reading outcomes. This may allow teachers and parents to better predict reading or attention problems based on performance on different naming speed tasks.

The dissertation research study will involve your student completing three brief intellectual and reading tests which will take a total of 30-40 minutes to administer after parental consent has been received. The assessment will be completed during non-academic time or at the student's home, and students will receive a small prize or snack as a thank you. In addition, each teacher will complete a brief rating scale assessing the student's classroom behaviors, which should take approximately 10 minutes. The testing data will be completed for research purposes only, and the results will be kept confidential. However, results of the testing will only be provided to the parent at their request.

If you have any questions, please feel welcome to contact the researchers, Andy V. Pham, by phone: 781-541-0212 or email: phamandy@msu.edu, or Jodene G. Fine, by phone: 517-884-0443 or email: finej@msu.edu.

Thank you,

Andy V. Pham, M.A.
Doctoral Candidate in School Psychology

Jodene G. Fine, Ph.D.
Assistant Professor of School Psychology

SUPERINTENDENT APPROVAL LETTER

Andy V. Pham, M.A.
Doctoral Candidate in School Psychology
Michigan State University

RE: Request to Conduct Dissertation Research at Holt Public Schools

Dear Mr. Pham,

Your research proposal, **“The Relationship between Rapid Automatized Naming (RAN), Symptoms of ADHD, and Specific Reading Outcomes ,”** has been approved by Holt Public Schools on December 5, 2008.

I understand that a recruitment letter and consent form will be sent home to parents in order for the parent and child to participate in the dissertation study. Their participation in the study is voluntary.

I support this effort and will provide any assistance necessary for the successful implementation of this study. If you have any questions, please do not hesitate to call. I can be reached at (517) 694-5715.

Sincerely,

Johnny A. Scott, Ph.D.
Superintendent
Holt Public Schools
5780 W. Holt Road
Holt, MI 48842
(517) 694-5715
jscott@hpsk12.net

TEACHER CONSENT FORM

Some of your students are being asked to participate in a dissertation research study. Researchers are required to provide a consent form to inform you about the study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions may have.

Study Title: **The Relationship between Rapid Automatized Naming (RAN), Symptoms of ADHD, and Specific Reading Outcomes**

Researchers and Titles: **Andy V. Pham, M.A.**, Doctoral Candidate in School Psychology
 Jodene G. Fine, Ph.D., Assistant Professor of School Psychology

Department and Institution: **Department of Counseling, Educational Psychology, and Special Education, Michigan State University**

Purpose of Research: Some of the students in your classroom are eligible to participate in a research study as part of the investigator's dissertation exploring how students' naming speed is related to attention problems and reading skills. The third- and fourth-grade students in your school district are invited to participate in this study. Each student's participation in this study will take about a total of 30-40 minutes. From this study, the researchers hope to learn how students' naming speed can determine whether children are at risk of developing reading and/or attention problems. Only students in general education are eligible to participate in the study.

What You and Your Student Will Do: If you and the student are willing to participate in this research study, information will be collected from you (as the teacher), the student(s), and their parents/caregivers. You will be given a brief rating scale assessing the student's classroom behaviors, which should take 10 minutes to complete. Students will complete three standardized reading and intellectual tests, which will take a total of 30-40 minutes, outside of the student's classroom. The student's parents can decide whether the assessment should be conducted at the student's school or at home. Parents will complete a brief questionnaire about their educational history and a brief rating form. Results of the individual testing are for research purposes and are only available to the parent of the student if requested.

With parent permission, the researchers will collect additional standardized test data from the student's school records. This information will be used to better understand the student's academic skills.

Your Rights to Participate, Say No, or Withdraw: Your participation in this research study would be greatly appreciated. However, your participation in this study is entirely voluntary. You and the students have the right to say no. You may change your minds at any time and withdraw from the study. You may refuse to answer or skip any question listed on the rating scale. Whether or not you or the students may choose to participate will have no effect on their academic grades at school. An assent form, written in language understandable to the student, will be read to the student and signed.

Privacy and Confidentiality: The data from this research study will be kept confidential. Information about you will also be kept confidential to the maximum extent allowable by law. All test protocols will be stored in a locked file cabinet and will only be marked with an assigned subject number. Data from the students' assessment and school records will be entered into a database by their subject number and will not be personally identifiable. At no point will the students' names or testing performance be disclosed to teachers or others. The information will be recorded in a database by the researcher on a personal laptop that will be protected by a password. In the event that results of this research project are presented at a professional conference or published journal article, the students' identities will be disguised with pseudonyms and will not be disclosed. Only the researcher and the research supervisor will have access to the data. It will be kept for 5 years and then will be destroyed.

This consent form was approved by the Social Science/Behavioral/Education Institutional Review Board (SIRB) at Michigan State University. Approved 02/26/09 – valid through 01/14/10. This version supersedes all previous versions. IRB# 08-1139.

Potential Benefits: The students will not directly benefit from your participation in this study, with the possible exception that participating in one-on-one testing could be a positive experience for some. Other potential benefits of participating in this study include a better understanding of how naming speed is related with reading skills and attention problems.

Potential Risks: There is minimal risk in participating in the study. Students may become stressed by the academic testing procedures if there is a history of learning problems. However, the researchers will address any student concerns or questions before, during, or after the testing. Students are allowed to take breaks if needed, and are provided with encouragement and feedback when appropriate. Students are also allowed to discuss this research study with their parents before participating. Testing will be discontinued if students express desire to stop.

Costs and Compensation for Being in the Study: It does not cost anything to participate in this study. Students will receive a small prize/snack following the completion of the individual testing.

Contact Information for Questions or Concerns: If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researchers:

Researcher

Andy V. Pham, M.A.
Doctoral Candidate in School Psychology
401C Erickson Hall
Michigan State University
East Lansing, MI 48824
(781) 541-0212
phamandy@msu.edu

Faculty Research Supervisor

Jodene G. Fine, Ph.D.
Assistant Professor of School Psychology
440 Erickson Hall
Michigan State University
East Lansing, MI 48824
(517) 884-0443
finej@msu.edu

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact the following, anonymously if you wish:

Michigan State University's Human Research Protection Program
202 Olds Hall, MSU
East Lansing, MI 48824
Phone: 517-355-2180
Fax 517-432-4503
E-mail: irb@msu.edu

You may keep the above information for your records.

DOCUMENTATION OF INFORMED TEACHER CONSENT

Please select a box and sign below. Submit this form to the researchers.

☐ YES, I _____ will participate in this research study.

☐ NO, I _____ will not participate in this research study.

Teacher's Signature: _____ Date: _____

School: _____ Grade: _____

This consent form was approved by the Social Science/Behavioral/Education Institutional Review Board (SIRB) at Michigan State University. Approved 02/26/09 – valid through 01/14/10. This version supersedes all previous versions. IRB# 08-1139.

PARENT RECRUITMENT LETTER

Date: 3/15/09

Dear Parent/Guardian:

We are writing to invite your child to participate in a research study conducted as part of the investigator's dissertation. This study is about reading, and several of the processes that may contribute to reading fluency. We have partnered with the Holt Public Schools, and all of the third- and fourth-grade students in Holt who are in general education are being invited to participate in this study.

We hope to learn how students' level of attention at home and in school relates to naming speed and reading outcomes. This may allow teachers and parents to better predict reading or attention problems based on performance on different naming speed tasks.

The dissertation research study will involve your child completing three brief intellectual and reading tests which will take a total of 30-40 minutes to administer. The assessment can be completed during non-academic time at school or at the child's home. After completion of the assessment, your child will receive a small prize or snack as a thank you. You will complete a brief demographic form and a rating scale. Both forms are attached to this letter and should take approximately 10 minutes to complete. The testing data will be completed for research purposes only, and the results will be kept confidential. If desired, your child's scores will be provided to you only and no one else.

We have enclosed a consent form and additional forms for you to fill out in order for your child to participate in this research study. If you decide to participate, please complete the **Parent Consent Form, SNAP-IV Rating Scale, and Demographic Form**, and return them to your child's classroom teacher by _____, 2009.

If you have any questions, please feel welcome to contact Andy V. Pham, by phone: 781-541-0212 or email: phamandy@msu.edu, or Jodene G. Fine, by phone: 517-884-0443 or email: finej@msu.edu.

Thank you,

Andy V. Pham, M.A.
Doctoral Candidate in School Psychology

Jodene G. Fine, Ph.D.
Assistant Professor of School Psychology

PARENT CONSENT FORM

Your child is being asked to participate in a dissertation research study. Researchers are required to provide a consent form to inform you about the study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

Study Title: The Relationship between Rapid Automatized Naming (RAN), Symptoms of ADHD, and Specific Reading Outcomes

Researchers and Titles: Andy V. Pham, M.A., Doctoral Candidate in School Psychology
Jodene G. Fine, Ph.D., Assistant Professor of School Psychology

Department and Institution: Department of Counseling, Educational Psychology, and Special Education, Michigan State University

Purpose of Research: Your child is being asked to participate in a research study as part of the investigator's dissertation exploring how students' naming speed is related to attention problems and reading skills. All of the third- and fourth-grade students at your child's school are being invited to participate in this study. Your child's participation in this study will take about a total of 30-40 minutes. From this study, the researchers hope to learn how students' naming speed can determine whether children are at risk of developing reading and/or attention problems. Only students in general education are eligible to participate in this study.

What You and Your Child Will Do: If you and your child are willing to participate in this research study, information will be collected from you (as the caregiver) and your child. You will be given a brief questionnaire and a child behavior rating form which will take 10 minutes to complete. Your child will complete three standardized reading and intellectual tests, which will take a total of 30-40 minutes. The testing can be conducted at the child's school or at home. In addition, your child's teacher will also complete a brief rating form assessing the child's classroom behaviors. Results of the individual testing are for research purposes only but can be provided to you at your request.

With your permission, researchers will review additional standardized test data (e.g., MEAP) from your child's school records. This information is used to better understand your child's past academic skill performance.

Your Rights to Participate, Say No, or Withdraw: Your participation in this research study would be greatly appreciated. However, your participation in this study is entirely voluntary. You and your child have the right to say no. You or your child may change your minds at any time and withdraw from the study. You may refuse to answer or skip any question listed on the brief questionnaire. Whether or not you or your child chooses to participate will have no effect on your child's grade at school. An assent form, written in language understandable to the child, will be read to your child and signed.

Privacy and Confidentiality: The data from this research study will be kept confidential. Information about you will also be kept confidential to the maximum extent allowable by law. All test protocols will be stored in a locked file cabinet and will only be marked with an assigned subject number. Data from the child's assessment and school records will be entered into a database by his/her subject number and will not be personally identifiable. At no point will the child's name or testing performance be disclosed to teachers or others. The information will be recorded in a database by the researcher on a personal laptop that will be protected by a password. In the event that results of this research project is presented at a professional conference or published journal article, the child's identity will be disguised with a pseudonym and other personally identifiable information will not be disclosed. Only the researcher and the research supervisor will have access to the data. It will be kept for 5 years and then will be destroyed.

This consent form was approved by the Social Science/Behavioral/Education Institutional Review Board (SIRB) at Michigan State University. Approved 02/26/09 – valid through 01/14/10. This version supersedes all previous versions. IRB# 08-1139.

Potential Benefits: Your child will not directly benefit from your participation in this study, with the possible exception that participating in one-on-one testing could be a positive experience for your child. Other potential benefits of participating in this study include a better understanding of how naming speed is related with reading skills and attention problems.

Potential Risks: There is minimal risk in participating in the study. Your child may become stressed by the academic testing procedures if there is a history of learning problems. However, the researchers will address any of your child's concerns or questions before, during, or after the testing. Your child is allowed to take breaks if needed, and is provided with encouragement and feedback when appropriate. The child is also allowed to discuss this research study with you before participating. Testing will be discontinued if the child expresses a desire to stop.

Costs and Compensation for Being in the Study: It does not cost anything to participate in this study. Your child will receive a small prize/snack following the completion of the individual testing.

Contact Information for Questions or Concerns: If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researchers:

Researcher

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If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact the following, anonymously if you wish:

Michigan State University's Human Research Protection Program
202 Olds Hall, MSU
East Lansing, MI 48824
Phone: 517-355-2180
Fax 517-432-4503
E-mail: irb@msu.edu

You may keep the above information for your records.

DOCUMENTATION OF INFORMED PARENT CONSENT

Please select the appropriate box(es), and sign below. Submit the forms to your child's teacher.

- ☐ YES, my child _____ may participate in this research study.
- ☐ If YES, I also give permission for the researchers to have access to my child's school records. Only information regarding standardized testing (e.g., MEAP) will be reviewed from the file.
- Check Location where you would like to have your child complete the assessment:**
- ☐ School ☐ Home (Phone number to contact: _____)
- ☐ NO, my child _____ may not participate in this research study.

Parent's Signature: _____ Date: _____

This consent form was approved by the Social Science/Behavioral/Education Institutional Review Board (SIRB) at Michigan State University. Approved 02/26/09 – valid through 01/14/10. This version supersedes all previous versions. IRB# 08-1139.

PARENT DEMOGRAPHIC FORM

➤ *Child Name:* _____ *Child's Date of birth:* _____

Sex of Child: ☐ Male
☐ Female

Child's Age: _____
Child's Grade: _____

Child's ethnicity/race:

☐ Caucasian/White
☐ Asian-American/Pacific Islander
☐ African-American/Black

☐ Latino/Hispanic
☐ American Indian
☐ Other (describe) _____

➤ Is your child currently receiving **special educational services**?

☐ Yes ☐ No

➤ **Caregiver Information**

Caregiver #1

Relation to child (e.g., mother, father, etc): _____

Current Occupation: _____

Highest level of education completed:

☐ Grades K-6
☐ Grades 7-9
☐ Grades 10-11
☐ High School Graduate or GED

☐ Some college (1 year or more)
☐ College graduate
☐ Post-college

Caregiver #2 (if applicable)

Relation to child (e.g., mother, father, etc): _____

Current Occupation: _____

Highest level of education completed:

☐ Grades K-6
☐ Grades 7-9
☐ Grades 10-11
☐ High School Graduate or GED

☐ Some college (1 year or more)
☐ College graduate
☐ Post-college

Child Assent Form

My name is _____, and I am from Michigan State University.

I am doing a research study to learn how children read. I am asking for your help because I want to know more about how naming different things quickly can help children read better.

If you agree to be in the study, I am going to ask you to do some different things, including tell me about things you know, solving puzzles, and reading short paragraphs. We will work together for 30 to 40 minutes.

You can ask questions about what I am doing at any time. If you decide at any time not to finish, you can ask me to stop.

If you don't want to be in the study or if you don't understand it, don't sign this paper. Being in the study is up to you, and your school grades will not be affected. No one will be upset if you don't sign this paper or if you change your mind later.

If you don't want to be in the study, do not sign this paper. If you sign this paper, it means that you agree to be in the research study.

Your Name: _____

Your Birthday: _____

Your Signature: _____ Date _____

Name of Investigator: _____

Signature of Investigator: _____ Date _____

This consent form was approved by the Social Science/Behavioral/Education Institutional Review Board (SIRB) at Michigan State University. Approved 01/15/09 – valid through 01/14/10. This version supersedes all previous versions. IRB# 08-1139

The SNAP-IV Teacher and Parent Rating Scale
James M. Swanson, Ph.D., University of California, Irvine, CA 92715

Name: _____ Gender: _____ Age: _____ Grade: _____

Ethnicity (circle one which best applies): African-American Asian
Caucasian Hispanic
Other _____

Completed by: _____ Type of Class: _____ Class size: _____

For each item, check the column which best describes this child:

	Not At All	Just A Little	Quite A Bit	Very Much
1. Often fails to give close attention to details or makes careless mistakes in schoolwork or tasks	_____	_____	_____	_____
2. Often has difficulty sustaining attention in tasks or play activities	_____	_____	_____	_____
3. Often does not seem to listen when spoken to directly	_____	_____	_____	_____
4. Often does not follow through on instructions and fails to finish schoolwork, chores, or duties	_____	_____	_____	_____
5. Often has difficulty organizing tasks and activities	_____	_____	_____	_____
6. Often avoids, dislikes, or reluctantly engages in tasks requiring sustained mental effort	_____	_____	_____	_____
7. Often loses things necessary for activities (e.g., toys, school assignments, pencils, or books)	_____	_____	_____	_____
8. Often is distracted by extraneous stimuli	_____	_____	_____	_____
9. Often is forgetful in daily activities	_____	_____	_____	_____
10. Often has difficulty maintaining alertness, orienting to requests, or executing directions	_____	_____	_____	_____

Hollingshead Scale

HOLLINGSHEAD CODES FOR OCCUPATIONAL QUESTIONS

This scale was devised from the Hollingshead Occupational Scale (1975) and is a simplified version. The jobs listed under each heading are representative examples of each category.

Code the occupation according to the scale regardless of if the work is in the home or out.

Score 9

Executives

Chairpersons

Presidents

Vice-Presidents

Other major officers of large business organizations

Commissioned officers in the military

Upper ranks: Lieutenant commanders, majors and above

Major government officials (Federal, State, Local)

City Managers

State Officials

State Legislature

U.S. Congress

Professionals (Group A)

Lawyers

Bank Officers

College/University Teachers

Doctors (optometrists, physicians)

Engineers

Scientists (geologists, social, political, chemists, etc.)

Psychologists

Score 8

Owners of large business or farms

Administrative Officers in large concerns

Executive Assistant

Managers (district, personnel, production)

Commissioned military officers

Captains

Lieutenants

Professionals (Group B)

School Administrators (college, secondary, elementary)

Public Administrative Officials

Clergy

Secondary School teachers

Accountants

Registered Nurses

Pilots

Pharmacists

Computer specialists
Industrial engineers
Musicians/composers

Score 7

Owners of medium sized business or farms
Managers

Administrative
Residential buildings
Office
Sales (not retail)

Professionals (Group C)

Health practitioners
Real estate brokers and agents
Teachers (not college or secondary)
Buyers (wholesale, retail)
Computer programmers
Social workers
Reporters
Sales representative (manufacturing)
Vocational/educational counselors
Entertainers and artists
Actors
Painters
Designers
Writers

Score 6

Technicians

Computer operators
Dental technicians

Semi-professionals

Sales managers (retail)
Sales representatives (wholesale)
Legal and medical secretaries, and all other secretaries
Sheriffs
Teachers' aides
Therapists
Military personnel (master sgt, chief petty officer)
Athletes
Dental hygienists
Department heads (retail)
Managers
Research workers
Graduate students

Score 5

Owners of small business or farms
Clerical workers

- Clerks (statistical)
- Bank tellers
- Billing clerks
- Bookkeepers
- Typists
- Telephone operators
- Sales workers
 - Cashiers
- Miscellaneous
 - Dental Assistants
 - Recreation workers
 - Health trainers
 - Bill collectors
- Score 4**
- Skilled manual workers
 - Electricians
 - Law enforcement
 - Counter clerks
 - Mechanics
 - Fireman
 - Plumbers
 - Practical nurses
 - Bakers
 - Housekeeper (not private household)
 - Repairmen
 - Shipping/receiving clerks
 - Receptionists
 - Stock clerks
 - Storekeepers
 - Telephone lineman
 - Welders
 - Carpenters
- Craftsmen
 - Decorators
 - Jewelers
- Noncommissioned officers in the military
 - Below master sgt. or c.p.o.

Score 3

- Machine operators and semi-skilled workers
 - Barbers
 - Bus drivers
 - Childcare workers (non private household)
 - Cosmetologists
 - File clerks
 - Guards
 - Nursing aides

Private housekeepers
 Seamstresses
 Service workers
 Taxi drivers
 Truck drivers
 Enlisted military members (noncommissioned officers)

Score 2

Unskilled workers
 Bartenders
 Busboys
 Childcare workers (private)
 Cooks
 Food service workers
 Garage/gas station workers
 Garbage collectors
 Gardeners/ground keepers
 Laborers
 Laundry/dry cleaning operators
 School monitors
 Waiters
 Warehousemen

Score 1

Farm laborers, service workers
 Attendants
 Bellhops
 Maids
 Dishwashers
 Janitors
 Ushers

Score 0

Housewives
 Those on welfare
 Laid-off workers
 Unemployed

Education Scale

Convert education level in completed years to Hollingshead levels:

Grades K-6	= 1
Grades 7-9	= 2
Grades 10-11	= 3
High School or GED	= 4
Some college (1+ year)	= 5
College Graduate	= 6
Post-College	= 7

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