CONTRASTING COGNITIVE ABILITIES IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER AND READING DISABILITY

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
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CONTRASTING COGNITIVE ABILITIES IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER AND READING DISABILITY

Doctor of Philosophy, 1999

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Abstract

Attention Deficit Hyperactivity Disorder (ADHD) and Reading Disabilities (RD) are common developmental disorders that frequently co-occur. In children who meet criteria for both disorders, it is not known if one disorder is primary, the other secondary or if both true disorders are present. The overall objective of this investigation was to test for the distinctiveness or independence of the two single disorders (ADHD-only, RD-only) and the independence of the two cognitive domains, executive function (EF) and phonological processing (PP), which are proposed as central to ADHD and RD respectively, using a classic double dissociation design. A 2 (ADHD vs. no ADHD) X 2 (RD vs. no RD) model was used to examine the cognitive profile of 4 groups of 17 children each, aged 7-11 years: ADHD, RD, ADHD+RD and controls. The EF tasks involved two measures of inhibitory control, while the phonological measures consisted of 3 tasks varying in level of phonemic processing required. A third measure, locus of control, was employed to investigate the role of attributions in the performance of children on these tasks. The two RD groups (RD, ADHD+RD) were significantly impaired relative to the two non-RD groups (controls, ADHD) on all phonological processing measures. The two ADHD groups were significantly impaired in terms of simple go-task responding relative to the non-ADHD groups and
in terms of inhibitory control on both EF measures. Contrary to predictions, an RD effect on inhibitory control was found on one EF measure which involved rapid sequential processing. This finding, together with the ADHD impairment on non-EF aspects of the EF tasks, question the role of inhibitory control as a unique cognitive marker for ADHD. The comorbid group (ADHD+RD) generally exhibited the deficits of both single groups in an additive fashion, suggesting true comorbidity. An external locus of control was found to be associated with ADHD, not RD.
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I Introduction

1.1 Rationale and Overview

Attention Deficit Hyperactivity Disorder (ADHD) is the most common psychiatric disorder of childhood, affecting approximately 3 - 10% of the population (McGee, Partridge, Williams & Silva, 1991; Szatmari, Offord, Boyle, 1989). Until recently, the three primary symptoms were considered to be poor sustained attention, impulsiveness, and hyperactivity (American Psychiatric Association, [APA], 1987). The current clinical view of ADHD as offered in the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; APA, 1994) has reduced the three major impairments to two: hyperactivity/impulsivity and poor attention, resulting in three subtypes; predominantly inattentive, predominantly hyperactive-impulsive, and combined types.

In addition to symptoms of inattention and/or hyperactivity/impulsivity, the diagnosis of ADHD is associated with a host of other difficulties. For example, children with ADHD are at greater risk for low academic achievement, poor school performance, anxiety, depression, aggression, and conduct problems (Biederman, Newcorn & Sprich, 1991; Epstein, Shaywitz, Shaywitz & Woolston, 1991; see Jensen, Martin & Cantwell, 1997 for a recent review). These high rates of comorbidity (co-occurring diagnoses within the same individual) have been found in both clinical and epidemiological samples of ADHD children (Anderson, Williams, McGee & Silva, 1987; Biederman et al., 1991; Bird, Canino, & Rubio-Stipec et al., 1988; Cohen, Cohen, Kasen et al., 1993; Offord, Boyle, Szatmari et al., 1987; Rutter, 1989). In recent years, there has been increasing interest in the significance and patterns of comorbid disorders in childhood psychopathology in general and in ADHD in particular because it is a heterogeneous disorder of unknown etiology (Biederman et al., 1991; Jensen et al., 1997).
Comorbidity raises fundamental questions concerning the boundaries and conceptual underpinnings of psychiatric disorders (Achenbach, 1990/1991). It influences diagnosis, prognosis and treatment in both research and clinical practice. In recent years there has been increasing recognition of the need to identify subgroups of individuals with ADHD and comorbid disorders who have potentially different etiologic and modifying risk factors as well as different outcomes (Biederman et al., 1991). This is particularly important for the conceptual underpinnings of ADHD since there is a continued search for a specific and unique set of risk factors and cognitive impairments which can be associated with this behaviorally diagnosed disorder (Barkley, 1997; Jensen et al., 1997).

Studies have consistently shown that children with ADHD perform more poorly in school than controls as evidenced by more grade repetitions, poorer grades, more placement in special classes and more tutoring (Edelbrock, Costello & Kessler, 1984; Frick, Kamphaus, Lahey, Loeber, Christ, Hart & Tannenbaum, 1991; Weiss, Hechtman, Perlman, Hopkins & Wener, 1979). It is unknown whether this is related to the psychiatric picture of inattention and impulsivity interfering with classroom learning, or to associated learning disabilities. Disentangling the difficulties that can be attributed to specific disorders can lead to more appropriate treatment strategies. The research presented here will focus on the relationship between ADHD and a specific type of academic failure, the failure to acquire reading skills. As will be reviewed in later sections, reading disability (RD) frequently co-occurs with ADHD at a rate greater than would be expected by chance; thus it is a fairly prevalent comorbid condition. The nature of the association of ADHD and RD is unknown; however the question frequently arises in both clinical practice and
research as to whether one disorder is primary or the other secondary in children in whom the disorders co-occur.

The overall objective of the research was to test the distinctiveness or independence of the two single disorders (ADHD-only and RD-only) and the independence of the two cognitive domains which are proposed as central to each disorder. (For the remainder of this paper, the ADHD group without RD will be referred to as the ADHD-only group, and the RD group without ADHD as the RD-only group. It is recognized that other difficulties may be present but this format was chosen for brevity). The nature of the association between the disorders was examined by comparing the performance of ADHD-only and RD-only children to those with both disorders. The two contrasting cognitive domains include: executive function and phonological processing, each of which is proposed as central to ADHD and RD respectively. Executive functions are higher order cognitive processes that are involved in the planning and regulation of thought and action (Logan, 1985; Luria, 1966). Phonological processing refers to one’s sensitivity to, or explicit awareness of, the phonological structure (basic units of sound) of the words in one’s language (Stanovich, 1992).

Previous research using a similar double dissociation design had found that children diagnosed with both ADHD and RD manifested only the cognitive deficits associated with the RD-only group, not the ADHD-only group (Pennington, Groisser & Welsch, 1993). This suggests that the presence of a reading disability leads to secondary ADHD symptomatology but not the core cognitive deficits associated with that disorder. The research reported here tests that finding using a clinically referred ADHD sample which may represent a more impaired sample than those
in Pennington et al.’s (1993) study who were obtained from a university-based clinic for learning disabilities (Shaywitz, Fletcher, Shaywitz, 1994). 

Lastly, performance deficits on neuropsychological tasks may not always reflect a primary impairment of the cognitive process thought to be measured by that task. Effort, drive or motivation have been implicated in the performance of ADHD children (Barkley, 1997) and motivational or attitudinal difficulties which result as a secondary consequence of the experience of failure, have been implicated in the poor performance of children with learning disability (LD) (e.g. Stanovich, 1986; Torgesen, 1994). Therefore when searching for primary, disorder-specific deficits, alternate explanations should be explored. For this reason, a personality variable reflecting beliefs about the value of effort, was included in the assessment in order to examine its relationship to performance on neuropsychological tasks.

1.2 Prevalence and Comorbidity Rates of ADHD and RD

Attention Deficit Hyperactivity Disorder and reading disability are two common developmental disorders of childhood, each of which are estimated to affect approximately 6-9% of school age children (ADHD: Anderson et al., 1987; Szatmari et al., 1989, RD: Shaywitz, Shaywitz, Fletcher, & Escobar, 1990). Estimates of the rates of overlap between the two disorders vary depending upon the initial sample selected. Of the children initially diagnosed with ADHD, estimates of the presence of reading disability range from 15-45% (Dykman & Ackerman, 1991; Faraone, Biederman, Lehman, Spencer, Norman, Seidman, Kraus, Perrin, Chen & Tsuang, 1993; Semrud-Clikeman, Biederman, Sprich-Buckminster, Lehman, Faraone & Norman., 1992; Shaywitz et al., 1994). Conversely, approximately one-third of children diagnosed with RD meet criteria for a diagnosis of ADHD (Biederman et al., 1991; Hinshaw, 1992; Levine, Busch &
The high rates of comorbidity are found in both clinic and epidemiological samples and is greater than would be expected by chance, indicating that comorbidity is not simply an artifact. However, estimates of prevalence and comorbidity are dependent upon the criteria used to define the disorders and concerns have been raised about potential weaknesses in the nosological systems (Achenbach, 1990/1991; Caron & Rutter, 1991). For example, the very definition of ADHD as evidenced by the frequent changes in criteria in the revisions of the DSM (APA, 1968, 1980, 1987, 1994) has led to changes in prevalence rates (e.g. Lahey, Applegate, McBurnett, et al., 1994; Wolraich, Hannah, Pinnock, Baumgaertel, & Brown, 1996; see Shaywitz et al., 1994 for a review of issues). Therefore, the development of a conceptual model for understanding the high rate of comorbidity of learning disabilities in ADHD is complicated by the conceptual and methodological variation among studies. However, in spite of this variation, studies have consistently found a high rate of overlap between the two disorders. The next section will review competing hypotheses and methods that attempt to understand the nature of the comorbidity.

1.3 Hypotheses of Comorbidity: Models and a Method for their Evaluation

With the high rates of comorbidity consistently found in both clinic and epidemiological samples, the hypothesis that ADHD and RD co-occur as an artifact of sampling or observation procedures is ruled out. The question remains whether the comorbid pattern of ADHD and RD conveys unique information concerning etiology, clinical correlates, prognosis, treatment and outcomes and whether it may be advantageous to group ADHD subjects into more homogeneous subgroups (Jensen et al., 1997). Several hypotheses arise regarding the nature of the association of ADHD and RD. For instance, in children comorbid for ADHD and RD, it is possible that one
disorder is a risk factor for the development of the other disorder. This possibility is subdivided into three possibilities: (a) one disorder produces a complete copy of the second; (b) one disorder produces only symptoms of the second disorder (phenocopy), not the full cognitive syndrome; or (c) that the presence of comorbidity is greater than the sum of the two individual disorders. It is also possible that the disorders have a common etiology in all cases, or that the comorbidity is caused by one factor in an etiologic subtype, but the two disorders are otherwise etiologically independent. Various methodologies have been used to address comorbidity in psychiatric disorder (see Cantwell, 1995 for a review).

Longitudinal and behavior genetic methodologies can provide some information regarding the nature of the association of ADHD and RD. Unfortunately there is a paucity of longitudinal research beginning with preschool ADHD children to determine if early hyperactivity predicts later reading difficulties. One such study by McGee and colleagues (McGee et al., 1991), found that children identified as hyperactive at age three years tended to show poorer reading ability in primary school. However, these children also had poorer early language skills which are strongly associated with later reading difficulties (see Mann, 1991 for a review). In fact the hyperactives did not differ from a developmental control group with similar language delays on later reading measures. The authors concluded that preschool hyperactivity per se does not predict learning difficulties during the early years. However, by age 15, there was some indication that the hyperactive children had higher levels of reading disability compared with a developmental control group. In general, results from other cross-sectional and longitudinal studies suggest that ADHD has little impact on the development of specific reading skills such as word identification (e.g., Wood & Felton, 1994, Nussbaum, Grant, Roman, Poole & Bigler, 1990). However, ADHD does
have repercussions for long term educational outcome as measured in years of formal education (Wood & Felton, 1994) and on other areas of academic functioning such as math skills (Nussbaum et al., 1990).

In the reverse situation, McGee and colleagues examined problem behaviors from ages 5 to 13 years in children with persistent reading disability (McGee, Share, Anderson & Silva, 1986). They found a significant increase in both parent and teacher ratings of ADHD related behaviors over time for boys but not girls. However, another study which followed poor and normal readers through adolescence and adulthood found that increased levels of conduct problems among poor readers at the start of the study reflected the strong correlation between inattentiveness and antisocial behavior rather than a direct association with reading difficulties per se (Maughn, Pickles, Hagell, Rutter & Yule, 1996).

Overall, the research indicates that the presence of ADHD leads to an overall poorer educational outcome; however it does not provide a direct link between the presence of ADHD and later specific reading skill deficits associated with a reading disability. The presence of early reading difficulties does seem to be linked to later behavior and attentional difficulties; however it is unclear whether these behavioral problems represent a “true” attention disorder or whether they represent secondary symptoms of ADHD, without the full cognitive syndrome (i.e., a phenocopy). These studies clearly indicate that a directional or causal link from one disorder to the other cannot be made and support factor analytic studies which have identified separate LD and hyperactivity factors (Lahey, Pelham, Schaughency, & Atkins et al, 1987).

Recent behavior genetic studies examining the comorbidity of ADHD and RD have found clear evidence of genetic influence on each disorder considered separately, but not significant evidence.
of genetic overlap (Faraone, et al., 1993; Gilger, Pennington, & DeFries, 1992; Gillis, Gilger, Pennington & DeFries, 1992), although evidence was found for a small etiologic subtype of ADHD children with RD who have a common genetic etiology (Light, Pennington, Gilger, & DeFries, 1995). Faraone et al., 1993; however, noted in their study of familial transmission that there was non-random mating between spouses with ADHD and learning disabilities which may affect heritability estimates and concluded that the two disorders are likely to be etiologically independent.

In summary, the existing epidemiological, longitudinal and behavior genetic studies clearly reject the artifact and common etiology hypothesis for the basis of the comorbidity between ADHD and RD. Another method for disentangling the association between ADHD and RD is termed the multiple comparison approach, used in cognitive studies of the disorders. This type of study can address the remaining hypotheses concerning the nature of the association of the two disorders: the phenocopy and the etiologic subtype (additive effects or greater than additive effects of the two disorders), by testing for the cognitive separability of the two disorders in a classic double dissociation. Evidence that the cognitive profile of the comorbid group resembles that of one of the single groups, rather than exhibiting the deficits of both, would support the phenocopy hypothesis, with one disorder primary and the other secondary. If the comorbid group exhibited the deficits of both single disorders, in a purely additive fashion, an etiologic subtype hypothesis would be supported. If, however, the comorbid group resembled neither of the two single groups, a distinct etiologic subtype would be supported. To test for a double dissociation, there must be previous studies supporting different core cognitive deficits in each disorder. The following section will review empirical studies investigating deficits associated first with ADHD
and then with RD. It will be followed by a review of studies, contrasting groups of children with ADHD and learning/reading disorders.

I. 4 Fundamental Deficits Associated with the Disorders

I. 4. 1 ADHD and Executive Function

The current clinical classification of ADHD (DSM-IV; APA, 1994) is presented as purely descriptive of two behavioral deficits, inattention and hyperactivity/impulsivity. This is in part a result of the inability to delineate cognitive or neuropsychological markers which are associated uniquely and specifically to the disorder (Epstein et al., 1991). The history of the disorder which has been reviewed in depth elsewhere (see Barkley, 1990; Schachar, 1986) reveals the changing views on the cardinal manifestations of the syndrome as well as the different theories of etiology. Briefly, the disorder was initially conceived of as “morbid defects in moral control,” (Still, 1902). Etiology was not specified, however it was soon linked to brain damage (Strauss & Lehtinen, 1947; Werner & Strauss, 1941) and later to minimal brain dysfunction (Clements & Peters, 1962). Emphasis shifted from hyperkinetic behavior (Laufer & Denhof, 1957) to attentional deficits (Cantwell, 1983; Douglas & Peters, 1979). Other theories which have received attention have suggested that deficiencies arose from motivational deficits (Glow & Glow, 1979) or from low arousal levels (Zentall, 1985).

Current concepts of ADHD suggest that the behavioral manifestations of the disorder result from fundamental deficits in self-regulation or what is also referred to as executive functions (Barkley, 1997; Douglas, 1983; 1988; Pennington & Ozonoff, 1996; Tannock & Schachar, 1996). Douglas (1983; 1988) proposed that this poor self-regulation arises from deficiencies in: (a) investment, organization and maintenance of attention and effort; (b) inhibition of impulsive
responding; (c) modulation of arousal levels to meet situational demands; and (d) a strong inclination to seek immediate reinforcement. Of these four abilities, the ability to inhibit or delay a response has been proposed as the central deficit underlying self-regulation (Barkley, 1997; Frick et al., 1993; Milich, Hartung, Martin & Higler, 1994; Quay, 1988; 1997). In fact, much of the research upon which the DSM-IV (1994) was based, pointed to the primacy of behavioral impulsivity, rather than attention in the clinical diagnosis, degree of impairment, and negative outcomes of children with ADHD (Fischer, Barkley, Fletcher, & Smallish, 1993; Frick et al., 1993). Deficits in inhibition will be discussed in detail later in this section.

Executive functions generally refer to higher order, self-regulatory processes involved in the planning and regulation of thought and action (Logan, 1985; Luria, 1966; Goldman-Rakic, 1987). They are required for effortful planning, organizing, monitoring and evaluating behavior (Luria, 1966; Goldman-Rakic, 1987) and involve the utilization of knowledge to flexibly guide actions in the pursuit of goal directed behavior (Dennis, 1991). As is evident by this description, executive functions encompass a range of abilities such as: the ability to inhibit a prepotent response (impulse control), strategic planning, organizing and monitoring action sequences, set shifting or set maintenance, and more recently, working memory (Eslinger, 1996; Goldman-Rakic, 1987; Luria, 1966; Roberts & Pennington, 1996; Shallice & Burgess, 1991). The behaviors that are indicated by the term executive function, however, are still a subject of much debate. Eslinger (1996) reports the results of an informal survey of respondents at a 1994 conference on executive function and concluded that no universal definition of executive function exists. In addition, he notes the difficulties inherent in measuring, and defining the complex behaviors listed above.
There is a general consensus that executive function (EF) is mediated by the prefrontal regions of the cortex (frontal lobes) and their interconnecting pathways or structures (Fuster, 1985; Goldman-Rakic, 1987; Shallice, 1982; Stuss & Benson, 1986). Theories of executive control deficits in ADHD arose because of the similarity between behavioral manifestations of this disorder and descriptions of patients with frontal lobe lesions who also exhibit disinhibition, impulsivity, poor planning ability and perseveration (Fuster, 1989; Grattan & Eslinger, 1991; Luria, 1966; Mattes, 1980; Pennington & Ozonoff, 1996; Stuss & Benson, 1986). Frontal lobe patients manifest a dysregulation of goal-directed behavior that cannot be attributed to a more basic deficit in perception, memory or language comprehension such as those measured by tests of intelligence (Duncan, 1995). Preliminary evidence from neuroimaging and neurophysiological studies are also suggestive of frontal dysfunction in individuals with ADHD (e.g., Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990; Lou, Henriksen & Bruhn, 1984; Lou, Henriksen, Bruhn, Borner & Nielsen, 1989; Zamenkin, et al., 1990), although findings have not always been consistent (see Hechtman, 1994; Tannock, 1997 for reviews).

1.4.2 Summary of Neuropsychological Studies of Executive Function in ADHD

Based on the frontal analogy, neuropsychological studies have frequently employed tasks derived from the adult literature of patients with circumscribed frontal lobe lesions (see Barkley, Grodzinsky & DuPaul, 1992, and Pennington & Ozonoff, 1996 for reviews). For example, studies have included the Wisconsin Card Sort Task, Stroop, Rey-O Complex Figure, Porteus Mazes, Trail-Making and various go-no-go tasks to name just a few. These vary in demand characteristics, content domain and often measure the net outcome of a variety of cognitive processes all of which may not relate specifically to frontal lobe functioning (Denkla, 1996). For
example, the Stroop interference effect, in which words interfere with naming the color of the ink in which they are printed, is affected by simple reading proficiency (Pennington & Ozonoff, 1996). The Wisconsin Card Sort Task is another example of a task frequently used in studies with both adults and children. It can be affected by the child’s knowledge of concepts such as number, shape or color. Patients with damage to areas other than the frontal lobe exhibit deficits on this task (Heaton, Chelune, Talley, Kay & Curtiss, 1993) and it may suffer from a ceiling problem and poor reliability in school age populations (Pennington & Ozonoff, 1996). This latter point illustrates the importance of the age of the subjects which can complicate frontal interpretations of outcomes due to the developmental alterations in childhood prefrontal functions (Barkley et al., 1992; Stuss, 1992).

Despite the apparently heterogeneous nature of the tasks employed, commonalities do exist across such tasks (Goldman-Rakic, 1987; Luria, 1966). In general, these tasks require planning or programming future actions, holding those plans on-line until executed (working memory), and inhibiting irrelevant actions. A common structure to many of the tasks places subjects in a context in which a prepotent response tendency is directly opposed to the activity or activities that lead to correct responding (Roberts, Hager & Heron, 1994). In other words they set up a dynamic between a prepotent and alternative response in which the subject must keep in mind information that is required to make a correct response. Several authors have suggested that tasks that are high in both their working memory and inhibition demands are more likely to tax the prefrontal cortex (e.g., Goldman-Rakic, 1987; Pennington & Ozonoff, 1996).

Studies which have employed EF tasks have found that ADHD subjects exhibit significantly poorer performance than controls (e.g., Boucugnani & Jones, 1989; Chelune, Ferguson, Koon &
Dickey, 1986; Douglas, 1983; Gorenstein & Mammato, 1989; Grodzinsky & Diamond, 1992; Reader, Harris, Schuerholz & Denckla, 1994; see Barkley et al., 1992 and Pennington & Ozonoff, 1996 for reviews). Furthermore, these deficits have also been found in preschool children with ADHD, suggesting that EF deficits are inherently associated with the disorder from an early age (Mariani & Barkley, 1997). The deficits in ADHD appear to be relatively specific to EF, rather than to generalized cognitive impairment since consistent deficits have not been found in other areas such as verbal processing (Kemp & Kirk, 1993) or other non-EF tasks (Reader et al., 1994; Shue & Douglas, 1992; Weyandt & Willis, 1994). Furthermore EF deficits are found in ADHD children with above average IQ (Shue & Douglas, 1992) and when IQ is comparable to controls (Grodzinsky & Diamond, 1992).

As noted earlier, EF deficits have not always been found in ADHD children (e.g. Loge, Staton & Beatty, 1990). This is due in part to the complex conceptual nature of executive functions and the molar nature of the tasks which may tap multiple executive functions. Barkley and Grodzinsky (1994) recently evaluated nine commonly used neuropsychological tests for their accuracy in classifying ADHD and LD groups. These authors strongly recommended against the use of these measures for detecting ADHD in children. Therefore the search for deficits specific to ADHD requires a finer-grained measurement approach in order to differentiate it from other disorders which may demonstrate impairment on molar EF tasks. Pennington and Ozonoff (1996), in their review, note the measures across studies on which ADHD were shown to be most consistently impaired. These include, the Tower of Hanoi, Matching Familiar Figure errors, Stroop, Trails B and motor inhibition such as the Continuous Performance Test (CPT). As stated earlier, response inhibition or inhibitory control (i.e., the ability to inhibit a planned or prepotent
action) is emerging as a possible candidate for a primary specific EF deficit in ADHD (Barkley, 1997; Oosterlaan & Sergeant, 1996; Pennington & Ozonoff, 1996; Schachar & Logan, 1990; Schachar, Tannock, Marriott & Logan, 1995; Quay, 1997).

1.4.3 ADHD and Inhibitory Control

Inhibitory control refers to the ability to inhibit a prepotent response to an event or the stopping of an ongoing response. It is hypothesized to underlie the behavioral symptoms of impulsivity in children with ADHD and their proposed deficits in executive control. According to Barkley (1997), inhibition allows a delay between signal and response and thereby permits executive functions, which subserve self-control and goal-directed behavior, to occur. In real-life, many situations require individuals to stop and change planned or ongoing actions when these actions are suddenly rendered inappropriate by changes in the environment (Logan, 1994). Recent evidence suggests that inhibitory control is evident in toddlerhood and is a relatively stable, coherent quality (Kochanska, Murray & Coy, 1997).

Evidence for poor inhibition in ADHD comes from motor inhibition tasks such as in the go-no-go paradigms in which children are asked to respond to some signals and not others (Iaboni, Douglas, & Baker, 1995; Milich et al., 1994; Shue & Douglas, 1989; Trommer, Hoeppner, Lorber & Armstrong, 1988). Inhibitory control dysfunction is also found on continuous performance tests (e.g., Barkley, 1991; Grodzinsky & Diamond, 1992; Robins, 1992; see Corkum & , 1993 for a review). On both of these tasks, children with ADHD consistently make more errors of commission in that they do not withhold responses when appropriate. Evidence of poor inhibition has also been demonstrated in a very different manner than those described above. Ors
and colleagues (O'rs, Homer, Briefer, Valley & Radiant, 1994) demonstrated that children with ADHD were poorer than controls at inhibiting eye movements on a delayed response task.

According to Quay (1997), the best (i.e. the purest) test of disinhibition comes from the stop-signal task developed by Logan and colleagues (Logan, Cowman & Advise, 1984) and later revised (Logan, Schachar & Tannock, 1997). Unlike other tasks, the stop-signal paradigm makes it possible to quantify inhibition and disentangle different processes involved in inhibition. The stop-signal task provides a laboratory analogue of situations where one has to stop or change a current course of action. In it, subjects are engaged in a primary task for the majority of the time (prepotent response). On some trials a tone is presented signaling the subject to inhibit the response to the primary task if they can. The stop-signal is based on the race model. Information that tells a subject to discontinue an ongoing action or thought initiates an inhibitory process that races against the independent process underlying the ongoing behavior: response execution. If the inhibitory process runs to completion first, action or thought is inhibited and vice versa. One of the advantages of this model is that it allows for the separation of primary task “go” responses which are generally not considered executive, and inhibition which are attributed to EF. Another major advantage is provides an estimate of the latency of the inhibitory response.

Several studies have used the stop-signal task with ADHD children. In their original study, Schachar and Logan (1990) compared ADHD children with normal children, those with conduct disorder (CD), with ADHD and CD, with emotional disorders (anxiety) and with learning disorders. Compared with the other groups the inhibition mechanism of the ADHD group was triggered less frequently, was more variable, and slower. In particular, disinhibition appears to be most evident in children with pervasive ADHD (i.e. symptoms both at home and at school)
(Schachar et al., 1995). Oosterlaan and Sergeant (1996) studied four groups of children: ADHD, aggressive, anxious and normal controls. In this study, which had a different primary task, both the ADHD and the aggressive groups demonstrated poorer inhibitory control as evidenced by fewer inhibitions and longer stop-signal reaction times. Furthermore, they demonstrated a significant correlation between response inhibition and externalizing symptomatology but not with internalizing symptoms. Therefore response inhibition is most consistently associated with ADHD and it clearly differentiates externalizing from internalizing disorders.

To summarize, current theories have conceptualized ADHD as reflecting an impairment in higher-order executive or self-regulatory functions. Executive function as a general concept is not well defined and is difficult to observe and measure. Response inhibition, a more precisely defined concept, has been intimately associated with these higher order functions. It has been linked most clearly with ADHD and is posited as the central deficiency in the disorder. The following section will now review evidence for the primary deficit associated with reading disability.

I. 4. 4 Reading Disability and Phonological Processing

Reading disability generally refers to a reading level that is significantly below acceptable levels and can occur in the absence of sensory deficits, neurological impairment or inadequate educational opportunity. There has been considerable debate regarding the precise definition of reading disability (e.g., Dykman & Ackerman, 1992; Siegel, 1989; Stanovich, 1991); however, it is well established that impairment in reading is due primarily to problems in word decoding (Bruck, 1988; Conners & Olson, 1990; Gough & Tunmer, 1986; Perfetti, 1985; Rack, Snowling & Olson, 1992; Stanovich, 1988).
In contrast to ADHD, there now exists a clear consensus on the locus of the primary specific deficit which underlies the problem in word recognition. This deficit lies in phonological processing which refers to the use of phonological information (the sounds of a language) in processing written and oral language (Adams, 1990; Stanovich, 1992; Stanovich, Siegel & Gottardo, 1997; Wagner & Torgesen, 1987). In learning to read, the child must apply the alphabetic principle which maps graphemes (units of print) onto phonemes (units of sound). There exists considerable evidence indicating that lack of awareness of the phoneme as the basic unit of the spoken word is one of the most important stumbling blocks in learning this principle (Gough & Hillinger, 1980; Perfetti, 1985).

Phonological processing skills have been linked repeatedly in a variety of correlational, longitudinal and experimental studies to early reading success and stand out as the most potent predictors of the ease of reading acquisition (more than intelligence, vocabulary, listening comprehension and reading readiness tests) (Adams, 1990; Bradley & Bryant, 1983; Gough & Hillinger, 1980; Juel, 1988; Liberman, 1983; Maclean, Bryant & Bradley, 1987; Share, Jorm Maclean & Matthews, 1984; Stanovich, Cunningham & Cramer, 1984; Stanovich, Cunningham & Freeman, 1984; Stanovich et al., 1997; Tunmer & Nesdale, 1985; Wagner & Torgesen, 1987). The fact that phonological processing tasks account for variance independent of general cognitive ability (IQ) points further to their unique role in reading acquisition (Tunmer & Nesdale, 1985; Wagner & Torgesen, 1987; Wagner et al., 1993).

Further evidence that phonological processing deficits are primary in reading disability is provided by studies that suggest they are universally found in different clinically ascertained populations with reading disability and are the most persistent feature of the disorder, occurring in
adult poor readers (Bruck, 1992; Pennington, Van Orden, Smith, Green & Haith, 1990). In
addition, these deficits are found to be specific to reading disabled populations (Stanovich, 1982)
and are heritable (DeFries & Gillis Light, 1996; Olson, Wise, Conners, Rack, & Fulker, 1989;

I. 5 Review of Studies Contrasting ADHD and Reading/Learning Disorders

I. 5.1 Review of General Neuropsychological Studies

In general, studies of cognitive deficits associated with ADHD and RD have varied in terms of
the definitions and classifications of the disorders and in terms of the areas of cognition and tasks
used to measure proposed deficits. For example, some of the studies to be reviewed have referred
to learning disability, not specifically reading disability and others have failed to use a complete
design with four subgroups of children, controls (without ADHD or RD), ADHD (no RD), RD
(no ADHD) and ADHD+RD. As the studies are reviewed, these limitations will be discussed in
light of conclusions that can be made.

Numerous studies have shown separable cognitive deficits in association with ADHD and RD.
In general, the findings support a language based deficit for reading disability in children with and
without ADHD. Felton, Wood, Brown, Campbell and Harter (1987) compared children with
ADHD alone to children with only RD. They found that RD children exhibited difficulty with
tasks involving confrontation naming (word retrieval) and rapid automatized naming, whereas
children with ADHD experienced more difficulty with word list learning and recall. The authors
interpreted the ADHD findings as reflecting deficits in learning and memory for material that has
no inherent organizing structure (i.e., requires effort). The RD, language-based deficit was later
replicated in a larger, non-referred sample which found phonemic awareness, confrontation
naming and rapid automatized naming deficits in reading disability even among a sample of children as young as the first grade (Felton & Wood, 1989). The ADHD effects on memory were found to be more variable and complex.

Further evidence for RD specific language deficits were reported by Ackerman and colleagues (Ackerman, Dykman & Gardner, 1990; Ackerman & Dykman, 1993) who surveyed a large sample of school children with ADHD and RD and found that children with ADHD and RD were impaired relative to children with ADHD alone on an auditory test of phonological sensitivity to rhyme and alliteration. The later study found RD-only children impaired on simple auditory phonological sensitivity and continuous naming speed tasks. Shaywitz and colleagues (Shaywitz, Fletcher, Holahan, Schneider et al., 1995) again, in a large scale study, found that reading disability, not ADHD was characterized by phonological processing deficits. Children with both ADHD and RD exhibited the language deficits associated with RD and the behavioral characteristics associated with ADHD. The authors concluded that the two disorders are distinct and separable.

The finding that children with RD, regardless of ADHD status, exhibit relatively discrete deficits in the language system, (phonological processing) has been repeated many times (e.g., Hynd, Morgan, Edmonds, Black, Riccio, Lombardino (1995). Studies searching for deficits uniquely associated with ADHD are somewhat more variable although deficits on “executive” styled tasks have some support.

The finding of Felton et al. (1987) that ADHD children are impaired on effortful, self-organized tasks are supported by those of August (1987) who compared ADHD, RD and control children on free recall tasks. ADHD boys showed less category organization and recalled fewer
words than the other two groups in a free recall condition, but improved when semantic encoding of words was encouraged. The author concluded that ADHD boys had difficulty spontaneously generating an organization strategy and sustaining sufficient effort to task completion. Douglas and Benezra (1990) also assessed memory problems in ADHD, RD and control children and found that deficits in ADHD boys became most apparent on measures requiring organized, deliberate rehearsal strategies, sustained strategic effort and careful consideration of response alternatives. Children with RD showed more generalized deficits across the verbal measures. The ADHD results were interpreted in terms of impaired self-regulatory or "executive" processes. August and Garfinkel (1990) compared ADHD children with and without RD and controls on a variety of cognitive and attentional measures. They found the ADHD-only and the ADHD+RD groups impaired on measures of sequential memory and attentional tasks involving impulse control and planful organization. In contrast only the ADHD children with RD performed worse than controls on rapid word naming and vocabulary. Robins (1992), however, did not find short-term verbal memory and verbal learning over trials to discriminate ADHD and learning disabled children, although both groups were impaired relative to controls. Sample differences may in part explain the differences since Robins' learning disabled children consisted both of reading disabled and non-reading, learning disabled subjects.

Not all studies directly comparing groups have found differences between ADHD and RD children on tasks designed to tap difficulties associated with ADHD. Ackerman and colleagues (Ackerman, Anhalt, Dykman & Holcomb, 1986; Ackerman, Anhalt, Holcomb & Dykman, 1986) compared ADHD (with and without RD) and control boys on a variety of automatic and effortful processing tasks. No clear differences between groups emerged and no unique deficit associated
with ADHD was found. However, these studies illustrate problems often found in defining groups. In these studies, the RD group scored significantly higher than controls on teacher ratings of ADHD symptomatology and were similar to ADHD boys on other measures of ADHD. In addition, the ADHD groups scored significantly lower than controls on measures of reading.

McGee, Williams, Moffitt and Anderson (1989) also compared groups of 13-year olds with either RD or ADHD with controls and children with both RD and ADHD. Consistent with other studies reported above, both RD groups (RD and ADHD+RD) exhibited deficits in verbal skills and did not differ from each other. In contrast, no unique deficits on the neuropsychological tests of executive function (e.g., Wisconsin Card Sort, Grooved Pegboard) differentiated ADHD from controls. Again, sample selection and group definitions may account for the lack of findings. The study had a small sample size (12-13 children in each group) and subjects for this study were obtained from a general population sample which tend to contain children who are less clinically impaired. In addition, the criterion for selection of the reading disabled group was different from that used in other studies and selected less reading impaired children. It was not based on discrepancy or achievement levels, but rather children were diagnosed as RD if their reading performance was below the median score of the ADHD group. The finding that the ADHD+RD group did not differ from those with RD-only led the authors to suggest that deficits often attributable to ADHD may be a consequence of the association between ADHD and RD.

In a more recent study with a complete 2 x 2 design, Pennington and associates (Pennington, Groisser & Welsh, 1993) did find a dissociation of deficits between ADHD-only and RD-only groups on measures of executive function. However, they too concluded that in the case of children comorbid for ADHD and RD, the presence of primary RD leads to secondary ADHD
symptoms (i.e. a phenocopy), not the true disorder. More specifically, using a classic double dissociation design, these authors compared the two disorders on two contrasting cognitive domains (executive function and phonological processing) each of which was proposed as central to one disorder and not the other. They found that the ADHD-only group (no RD) showed a significant impairment in executive function but no impairment in phonological processing. The RD group exhibited the reverse profile. These results support the contention that ADHD and RD represent two distinct clinical syndromes. The finding of EF deficits in the ADHD-only group (and not RD) provides evidence that the deficits observed in ADHD are not simply an epiphenomenon of the presence of RD as suggested by McGee et al. (1989). However, the comorbid group’s profile was similar to that of the RD-only group (i.e., exhibited deficits in phonological processing but no impairment on EF tasks) supporting the phenocopy hypothesis, that ADHD symptoms develop as a secondary consequence of the stresses incurred by their learning problems. The authors cite methodological differences relating to sample source; their sample was drawn from a university-based clinic to which many children with RD are referred. Therefore their sample may have contained children with less severe symptomatology than children referred for ADHD, and as a consequence will be less likely to have overlapping cognitive deficits.

Sample source may not entirely explain the findings of Pennington et al. (1993). Partial support for the phenocopy hypothesis was found in a rigorously diagnosed clinic sample of children. Hall, Halperin, Schwartz and Newcorn (1997) examined motor decision/response organization aspects of executive function using the same four groups as reported above. Using a competing programs task, modeled after a paradigm used with frontal lobe patients, these authors
found both ADHD groups made fewer correct responses to the incompatible and compatible conditions. However, the ADHD-only group exhibited longer reaction times than the ADHD+RD in the incompatible condition, suggesting difficulties in motor decision/response organization (EF). The ADHD+RD group had longer reaction times in the compatible condition suggesting difficulties in a cognitive process, not EF. These differences were found despite similarities between the two groups on impulsiveness (on a vigilance CPT) and activity levels as measured by an actigraph. Therefore, although there were similar behavioral manifestations of ADHD symptoms in the two ADHD groups, only the ADHD-only children exhibited deficits in the EF measure of generating an incompatible response. Unlike Pennington et al. (1993), the comorbid group also differed from the RD group in that they were slower at generating a compatible response. These results suggest that the comorbid group could be at least in part, distinct from both single groups.

Several other studies; however, have not supported the phenocopy hypothesis. For example, Korkman and Pesonen (1994) compared controls to ADHD children with or without a spelling disability (SD) on a large battery of tests that tapped various aspects of attention, language, motor, sensory and spatial functions. They found a dissociation of deficits in ADHD and SD children. Generally, the ADHD group had a relatively good overall performance level, but exhibited a specific impairment in inhibition and control which involves motor decision processes. The SD children’s performance approached the normal mean on this test, but they were impaired on phonological and language measures. The combined ADHD+SD group exhibited the deficits of both single groups; however they also showed some unique impairments that were not seen in the other two groups. Specifically, they exhibited more pervasive attention deficits than the
ADHD-only and SD-only groups. Therefore, in this sample of children, the impairments of the comorbid group was greater than the sum of the impairments of the two single disorders.

Reader and colleagues (1994) examined the relationship between executive function and ADHD-only versus ADHD+RD children in a follow-up of the Pennington et al (1993) findings. This study also failed to support the phenocopy hypothesis since no significant differences were found between ADHD with or without RD on any of the EF measures, with both groups exhibiting impairments in this area. However, in this study, RD children were defined simply by a discrepancy between IQ and reading achievement. This method can classify children as RD who are reading in the normal range (Siegel, 1992). Indeed, in this study, only 4 children of 14 were below 1 standard deviation on the reading test, indicating that most children classified as RD were average readers.

Narhi and Ahonen (1995), comparing RD, ADHD+RD, ADHD and controls, also did not support the phenocopy hypothesis since both ADHD groups exhibited deficits on two executive function tasks (WCST, Trailmaking). However, they also found the RD-only group were equally impaired on these EF tasks which suggests that in this sample, EF deficits were not specific to ADHD, but rather were a function of all clinical groups relative to controls. Similarly, Weyandt and Willis (1994) found both ADHD groups and children with a developmental language disorder to be equally impaired on all but 1 EF task. The EF measures used in these two studies were those based on the adult frontal lobe literature (e.g. WCST) and in general suggest that these measures may not best discriminate ADHD from other control groups.

Taken together, neuropsychological studies clearly link impairments in phonological processing to the presence of RD, regardless of ADHD status. However, neuropsychological
tests of purported executive functions, (particularly those associated with the adult frontal lobe literature), have not always differentiated children with ADHD from normals or RD. As discussed earlier, this may reflect the molar nature of many EF tasks. The examination of more basic components of executive functions, such as inhibitory control, may serve as more precise and reliable markers in the search for disorder-specific deficits. In fact the literature does suggests that tasks such as the continuous performance tests (CPT), response inhibition, or go-no-go paradigms produce the most consistent deficits in ADHD children (Barkley & Grodzinsky, 1994; Barkley et al., 1992).

I. 5.2 ADHD and RD and Inhibition, Sustained Attention Tasks

There is some evidence that studies specifically investigating impulsivity and inhibitory control have shown dissociable deficits in ADHD and learning disabled children. As cited previously, Schachar and Logan (1990), using the stop-signal paradigm demonstrated that deficient inhibitory control most clearly distinguishes children with ADHD from normally developing children. Children with learning, emotional and conduct disorders may have shown some deficit but they were not distinguishable from normal children. This study did not contain a group comorbid for both ADHD and LD which would permit a test of the phenocopy hypothesis.

Continuous performance tests (CPT) are generally viewed as vigilance tasks in which subjects respond to a series of target stimuli (usually letters or digits) and refrain from responding to nontarget stimuli. The number of targets missed (omission errors) is generally thought to reflect inattention, whereas false alarms to non-targets (commission errors) reflect impulsivity although alternate interpretations can be made (Conners, 1995). In a review of this area, Corkum and Siegel (1993) concluded that ADHD subjects exhibit poor attention and impulse control
difficulties relative to normal controls. These is still some debate as to whether they exhibit sustained attention problems (i.e., a decrement in performance over time) (Corkum, Schachar & Siegel, 1996).

Studies comparing ADHD and RD groups on CPT type measures generally have been inconsistent. For example, August and Garfinkel (1989) found only the comorbid ADHD+RD group, not the ADHD to perform poorly. Aylward, Verhulst and Bell (1990) found main effects for ADHD, not LD and no interactions suggesting poor performance is influenced by the presence of ADHD. Others have found generalized deficits in both ADHD, LD and ADHD+LD groups (e.g., Robins, 1992). Corkum and Siegel (1993) have suggested that tasks with a short display time, short inter-stimulus intervals and a higher percentage of targets, place heavy demands on attentional resources and maximize the likelihood of producing deficits in ADHD children. This also suggests that differentiating ADHD from other childhood disorders will require more precise task definitions.

Kupietz (1990), using more precise measures, investigated different performance aspects on an A-X version of the CPT and found differences between ADHD and RD children. In this version of the CPT, children are instructed to respond to a two-color/letter sequence. Generally both clinical groups (RD and ADHD+RD) were impaired on this task relative to controls, although the RD group improved with age whereas the ADHD+RD did not. However, an analysis of types of commission errors revealed that the ADHD+RD group tended to make more commission errors that were related to impulsiveness or poor inhibitory control. More specifically, ADHD+RD and young RD children made more A-O commission errors (i.e., responded based on the first stimulus in the sequence) and these errors persisted at older ages only for the comorbid group. In contrast,
O-X commission errors predominated in the younger RD children and diminished with age. These errors were interpreted, not as errors of impulse control, but rather as reflecting difficulties in processing sequential information or short-term memory. Therefore this study demonstrated dissociable deficits in these clinical groups when more precise analysis of error type was undertaken.

I. 6 Personality and Executive Function

In the ADHD literature, behaviors such as self-monitoring, planning and self-regulation are referred to as executive function. In the field of learning disabilities, many of these executive function behaviors are also subsumed under the term "metacognition" (Flavell, Miller & Miller, 1993). Research with LD populations (undifferentiated with respect to ADHD) have found deficits in the use of self-regulatory strategies such as checking, planning, monitoring and revising in learning situations (Wong, 1991). In a discussion of research on metacognitive functioning, Meltzer (1993) identified areas in which LD children frequently experience problems. For example, these children have limited awareness of the usefulness of strategies and show poor cognitive flexibility in shifting strategies.

A major issue with respect to executive function is whether these deficits are primary or whether they are secondary consequences of the experience of failure. Motivational or attitudinal problems can strongly influence the efficiency, flexibility and application of effortful strategies (Licht, 1993; Meltzer, 1994; Torgesen, 1994). Early school failure can result in more generalized and cumulative effects (Stanovich, 1986), including low self-esteem, the tendency to avoid active learning strategies (Wong, 1991), and cognitive attributions such as learned helplessness (Licht, 1993; Pearl, Donahue & Bryan, 1982). In recognition of this fact, researchers have suggested
that measures of attributional style should be included in the assessment of executive functioning in children with LD (Pressley, Borkowski, Forrest-Pressley, Gaskins & Wile, 1993; Torgesen, 1994).

Attributional style, such as locus of control has also been implicated in ADHD. Children with ADHD have been found to have an external locus of control (i.e., feel that they have little control over events that happen to them) (Linn & Hodge, 1982; Lufi, & Parish-Plass, 1995), although in these studies the presence of possible learning disabilities was not reported. However, attributional training has been shown to improve strategy use, increase beliefs about personal causality and reduce impulsivity in children with ADHD (Reid & Borkowski, 1987). Only one study was found which examined locus of control in ADHD children with and without LD. Tarnowski and Nay (1989) compared 7-9 year-old children with ADHD, ADHD+LD, LD and controls on a general locus of control measure, and found that children with LD (LD and ADHD+LD) had a more external locus of control than controls. No main effect of ADHD or interaction was found, implicating academic failure, not ADHD in external beliefs about personal control. This study will include an assessment of the children’s locus of control to investigate attitudinal or motivational relationships to executive functioning.

I. 7 Methodological Issues

I. 7.1 Assessment of ADHD

All studies of children with ADHD incorporate issues of classification and definition which are then explicitly or implicitly embedded in the research design. These different methodologies influence nearly all outcomes such as prevalence rates, and characteristics and correlates of the disorder. For example, the source of subjects can influence severity and rates of comorbidity.
The current study chose children who were referred to a clinic rather than a population sample since they present with more severe psychopathology, increasing the likelihood of obtaining deficits (Caron & Rutter, 1991; Shaywitz et al., 1994).

In diagnosing ADHD, the parent interview is the core of the assessment process, although reports of behavior in school are essential. The current study chose subjects who had been rigorously diagnosed in a clinic setting according to DSM-III-R criteria (APA, 1987). Both parent and teacher reports were obtained in order to obtain a sample of children who would be considered pervasively ADHD, which is now a DSM requirement (DSM IV; APA, 1994). Current symptoms were confirmed using parent and teacher rating scales which have been shown to be comparable to structured interviews in identifying the presence of disorders (Boyle, Offord, Racine, Szatmari, Sanford, Flemming, 1997). In addition to parent ratings, teacher ratings in the clinical range were deemed necessary for diagnosis since teacher ratings at school have been found to be more closely associated with neurocognitive impairments than parent ratings (Szatmari, Offord, Siegel, Finlayson, Tuff, 1990). Therefore in summary, using rigorous diagnostic procedures, the current study was designed to incorporate more severely impaired children with ADHD.

I. 7. 2 Assessment of Reading Disability

Unlike ADHD; which is established primarily on the basis of a history of behavior, reading disability is assessed through performance on tests of achievement and/or ability. Several definitions of reading disability exist which vary along several dimensions including: the emphasis placed on underlying etiology, the importance of specific skill deficits, and the definition of underachievement (see Beitchman & Young, 1997, for a review). As stated earlier, the primary
deficit is now recognized as problems in word identification. In the current study, low achievement on two tests of word recognition were required for defining impairment. Although a controversy exists concerning the requirement for a discrepancy between ability (often measured by IQ tests) and achievement, much of the research has indicated that there are no qualitative differences in reading related variables between reading disabled children defined by either a discrepancy or by low achievement (Shaywitz, Fletcher, Holahan & Shaywitz, 1992; Siegel, 1992; Stanovich, 1991).

I. 7.3 Assessment of Executive Function

As concluded from the literature review, neuropsychological tests from the frontal lobe literature have produced mixed results in studies of ADHD children. The tests measure a variety of interacting executive and non-executive processes and therefore performance on them can be disrupted for a variety of reasons. Inhibition, on the other hand, is a specific executive process that lends itself well to operationalization and isolation from other processes, using an information processing approach (Barkley, 1997) and was therefore chosen as the executive measure.

Two tasks, each with different methodologies and variables were selected to assess inhibition. The use of two complementary measures provides for a more general test of the inhibitory deficit hypothesis. The first task chosen was a variant of the stop-signal paradigm, originally developed by Logan, Cowan and Davis (1984), and later revised (Logan et al., 1997). The theoretical assumptions and predictions of the model have been validated empirically in numerous studies of adults (e.g., De Jong, Coles, Logan, Gratton, 1990; Logan et al., 1984, 1997; Osman, Kornblum & Meyer, 1990). As reported earlier, impairment on this task has been most closely associated with ADHD, differentiates it from other childhood psychiatric disorders, and is related to other
measures of impulsivity (Logan et al., 1997). In addition, using a race model, this task makes it possible to quantify inhibition and disentangle the different processes that operate in response inhibition.

The second task chosen was the Conners' Continuous Performance Test (CPT) which, unlike the stop-signal task, is a norm-referenced, clinic based measure of inhibition (Conners, 1995). CPTs have been used frequently in the assessment of attentional and behavioral difficulties. This particular CPT was chosen because it is an "inhibition" version of the task in which a prepotent response is established and an intermittent stop-signal is presented. Traditional CPTs are such that only rare targets get responses, thus failing to set up a prepotent active response. In addition the Conners' version generates a large sample of responses and has variable interstimulus intervals which maximizes the likelihood of producing deficits in children with ADHD (Corkum & Siegel, 1993). Together, both tasks provide an assessment and quantification of related variables using different methodologies. In addition, these tasks were chosen because they involve simple rules for correct responding, reducing the higher level working memory load which has been found to interact with inhibition (Barkley, 1997; Roberts et al., 1994), and thus isolating and emphasizing the inhibitory process in response generation.

As reviewed earlier, in assessing executive functions, the issue of primary versus secondary deficits should be addressed. In other words deficits on executive function measures may not always reflect a primary neuropsychological deficit but rather may reflect a secondary consequence of the experience of psychopathology. The inclusion of personality measures such as attributional style allows for the examination of alternative hypotheses for any observed deficits on executive function tasks.
I. 7. 4 Assessment of Phonological Processing

Three phonological processing tasks were chosen based on complexity or level of phonemic processing required. Although previous research has found that phonological tasks tend to be positively and significantly correlated (Stanovich, Cunningham & Cramer, 1984), factor analysis has differentiated simple from more complex phonological processing tasks (Yopp, 1991). Firstly, a norm-referenced word attack test in which subjects were required to read nonwords was chosen as it is a direct measure of a child's ability to apply knowledge of phoneme-grapheme relationships. Oral reading of nonwords has consistently been found to be the task which differentiates good and poor readers (Jorm & Share, 1983; Olson et al., 1989; Stanovich & Siegel, 1994).

Secondly, an oral task was employed which involved awareness of, and the ability to segment and blend sounds in words (Rosner & Simon, 1971). Thus it involves both awareness of, and the ability to manipulate sounds, but it does not involve applying this knowledge to written symbols. Similar tasks have consistently differentiated good and poor readers (e.g. Bruck, 1992; Cornwall, 1992). Lastly, a phoneme segmentation task was chosen because it is a less complex task of "pure" phonemic awareness requiring simple sound identification from speech. It was developed for this study based upon a similar task employed with LD children (McBridge-Chang, 1995).

I. 8 Current Study: Outline and Hypotheses

The purpose of the present study was to test the distinctiveness or independence of the two single disorders ADHD and RD, and the independence of the two cognitive domains which are proposed as central to each disorder, in a sample of children aged 7 to 12 years. Based on the review provided above, the two aspects of cognitive function that were assessed include executive
function and phonological processing, each of which is proposed as central to ADHD and RD respectively. The issue of the nature of the comorbidity was addressed by examining the deficits of the comorbid (ADHD+RD) group relative to the two single groups. We tested for a double dissociation using a 2 (ADHD vs. no ADHD) x 2 (RD vs. no RD) model to examine the cognitive profiles of four groups of children: ADHD, RD, ADHD+RD, and controls. In addition, an alternative personality measure was included in order to test an alternative personality hypothesis for any observed executive function deficits.

The tasks chosen, based on the literature reviewed above were chosen to measure and isolate specific cognitive processes and avoid the problems of non-specificity inherent in many neuropsychological tests. The executive function measures were chosen to reflect inhibitory control (stop-signal task and an inhibition version of the continuous performance test). Three phonological processing tasks, which vary in level of phonological analysis required were employed: pseudoword reading, phoneme deletion and blending, and phoneme segmentation. In addition, we included an attributional measure of locus of control, since it was deemed possible that a deficit on executive function tasks could reflect secondary personality variables rather than a primary underlying neuropsychological deficit.

Since the ADHD children were clinic referred, and therefore more likely to represent a globally more severely impaired group of children with more severe symptomatology (Shaywitz et al., 1994), we hypothesized that children with ADHD, regardless of RD status would exhibit inhibitory control problems on both the stop-signal task and the CPT; RD-only children and controls would not. Consistent with the literature, children with RD, regardless of ADHD status, were expected to exhibit the strongest phonological processing deficits. The control group was
not expected to exhibit deficits on these tasks, however, due to the demand for working memory on some of the phonological tasks, it was hypothesized that the ADHD-only children may have some difficulty. In contrast to the phenocopy hypothesis, we predicted that the comorbid group would exhibit the impairments of both single disorders, although there may be some differences between groups on the CPT since the literature is inconsistent with respect to these types of tasks. This again was hypothesized due to the use of a clinic sample which generally contain children who are more likely to have comorbid diagnoses (Epstein et al., 1991). Lastly, based on the one previous study of locus of control which differentiated LD from ADHD children, (that reported that RD, not ADHD was associated with higher attributions of helplessness), children with RD (RD and ADHD+RD) were expected to exhibit greater externality on the locus of control measure than children without RD.
II Method

II. 1 Subjects.

II. 1. 1 General description and Source.

A total of 68 children, aged 7 to 11 years participated in the study. Of these 17 had a confirmed diagnosis of ADHD, 17 met the criteria for ADHD and reading disability (ADHD + RD), 17 had a diagnosis of reading disability alone (RD) and 17 children did not meet criteria for ADHD or RD (controls). The majority of ADHD children (85%) were recruited from children who participated in research studies conducted at a children’s hospital in a large metropolitan urban area and were assigned a diagnosis of ADHD. Five of the 34 ADHD children were identified through the intake procedure for reading disabled children. Children with ADHD who were receiving psychostimulant medication discontinued this treatment 24 hours before the day of testing. The controls and reading disabled children were volunteers from the community who responded to an advertisement in a city paper for children with and without reading problems. Current symptoms for the two ADHD groups and the absence of symptoms for the controls and RD-only children were confirmed for the current study using parent and teacher behavior rating scales (discussed below).

II. 1. 2 Diagnostic Criteria.

The control and RD-only children had no history of behavioral or attentional problems, nor any current medical, behavioral or attentional problems. Any child whose estimated full scale IQ (based on Vocabulary and Block Design of the Wechsler Intelligence Scale for Children - 3rd Edition [WISC-III]) was less than 80 or who showed evidence of a neurological disorder, poor physical health, uncorrected sensory impairments, or a history of psychosis or was excluded. In
addition all children participating in the study were native English speakers. The short form of the WISC-III is highly correlated with the full scale IQ (r = .91) and was chosen in order to reduce testing time.

The diagnosis of ADHD was based on information obtained from semi-structured interviews conducted with the child’s parents (Parent Interview for Child Symptoms - Revised, PICS: Schachar & Ickowicz, 1994) and teacher (Teacher Telephone Interview, TTI; Schachar, Corkum, & Tannock, 1994). The PICS is a semistructured interview that covered DSM-III-R criteria for ADHD, ODD, CD, Overanxious, Separation Anxiety and Depressive Disorders, and provides functional inquiry for phobias, tic disorders, and other problems of childhood (e.g., enuresis, encopresis). It was administered by an experienced clinician who used clinical skills and judgment to ascertain the absence, presence, and severity of symptoms based on examples of the child’s behavior provided by the parents in response to probes. The TTI uses a parallel format, but for issues of feasibility, it focuses on symptoms of ADHD, ODD, CD, with functional enquiry for anxiety, depression, phobias, and tic disorders. The inter-rater reliability of these instruments is acceptable: agreement for diagnoses on the PICS was found to be 100%. Some disagreement occurred on ratings of individual symptoms, but this did not affect diagnostic agreement.

Substantial inter-rater agreement has also been obtained for diagnoses based on the TTI: ADHD (k = .76), ODD (k = .76), and CD (k = .83) (Schachar & Logan, 1990; Schachar et al., 1995).

Current symptoms were confirmed with the use of parent and teacher questionnaires including Parent and Teacher versions of the Ontario Child Health Study Scales (OCHS:Boyle et al., 1993), Rutter A for parents and Rutter B for teachers (Rutter, 1967), and the SNAP questionnaire for both parent and teacher (Pelham, Atkins, & Murphy, 1981). The five ADHD children who were
identified from the children referred for RD were diagnosed based upon these parent and teacher questionnaires. The diagnosis of ADHD was given only when criteria were reported in both situations (home and school). Specifically, the scales used were the subscales of ADHD on the SDI, the subscale of Hyperactivity on the Rutter, the Inattentive subscale of the SNAP and lastly, both the Impulsivity and Hyperactivity scale of the SNAP. The child was required to meet criteria on 2 of these 4 variables on either the parent or teacher variables plus at least 1 from the other situation (home or school).

In addition to ADHD, ratings were obtained for symptoms of Oppositional Defiant Disorder (ODD), Conduct Disorder (CD), Overanxious/Generalized Anxiety Disorder (OANX) and Separation Anxiety Disorder (SAD) based on the parent and teacher questionnaires. Self-reported anxiety was also assessed using the Revised Children’s Manifest Anxiety Scales (RCMAS; Reynolds & Richmond, 1985). Diagnostic criteria for ADHD and comorbid disorders are presented in Appendix A.

The classification of reading disability was based on achievement levels in individual word reading. A discrepancy between IQ and achievement was not required since the literature has generally found that there are no qualitative differences in component reading skills between discrepancy-based and low-achievement based RD children in reading subskills (Siegel, 1989; Shaywitz et al., 1992; Stanovich, 1988). Reading disability was defined as a score of at least 1.5 standard deviations below the mean for age on either the Reading subtest of the Wide Range Achievement Test - 3rd Edition (WRAT-3, [Jastak & Wilkinson, 1993]) or the Reading Recognition subtest of the Peabody Individual Achievement Test (PIAT, [Dunn & Markwardt, 1970]) or 1 standard deviation below the mean for age on both.
II. 2 Dependent Measures.

Five cognitive tasks, in the two contrasting cognitive domains of executive functions and phonological processing were selected based upon prior research with ADHD and RD populations.

II. 2. 1 Executive Function Tasks:

1. Stop Task.

The Stop task is a new variation of the stop-signal paradigm (Lappin & Eriksen, 1966; Logan & Cowan, 1984; Logan, Cowan & Davis, 1984; Osman, Kornblum & Meyer, 1986, 1990) used to measure the degree of voluntary inhibitory control that subjects can exert over response processes. The paradigm involves two concurrent tasks, a ‘go’ task and a ‘stop’ task. The go task is a choice reaction time task that requires subjects to discriminate an X from an O by pressing the associated buttons on a separate response box. The stop task, which occurs on 25% of go-task trials, involves presentation of a tone (a stop signal) that tells subjects to inhibit their response to the go task on that trial. The paradigm is designed so that the go task becomes the prepotent response. The stop signal is a control signal that makes the prepotent response inappropriate. Thus, inhibiting when given a stop signal is evidence of good impulse control and failing to inhibit when given a stop signal is evidence of poor impulse control (Logan et al., 1997).

Whether or not subjects are able to inhibit depends on a race between the stop task and the go task. If they finish the stop task before the go task, they inhibit their responses to the go task. However, if they finish the go task before the stop task, they fail to inhibit their response to the go task, responding much as they would if no stop signal had been presented. Thus, inhibitory control depends on the latency of the response to the go signal (go signal reaction time) and the
latency of the response to the stop signal (stop-signal reaction time). The race model has been developed formally and shown to be able to account quantitatively for all of the data in stop-signal experiments (Logan & Cowan, 1984; Osman et al., 1986; for a review, see Logan, 1994).

According to the race model, poor inhibitory control could result from responding too quickly to the go signal or responding too slowly to the stop signal. Fast responses to the go signal would be executed before the person could respond to the stop signal, and slow responses to the stop signal would allow normally speeded responses to the go signal to escape inhibition. Studies of ADHD children (Schachar & Logan, 1990; Schachar et al., 1995) and undergraduate students (Logan et al., 1997) suggest that slow stop-signal reaction time is responsible for poor impulse control.

The speed and variability of the go task processes can be measured directly from performance on trials in which no stop-signal is presented. However the stop-signal reaction time cannot be measured directly. Subjects either inhibit or fail to inhibit when a stop signal is presented. The race model of the stop-signal paradigm provides a method for estimating stop signal reaction time. This method uses a tracking procedure, in which stop signal delay changes after every stop-signal trial, increasing by 50 ms if subjects inhibit and decreasing by 50 ms if they respond. This tracking procedure, introduced by Osman et al. (1990), converges on a stop-signal delay at which subjects inhibit 50% of the time. That delay is important because it represents the amount of handicapping necessary to "tie" the race. At that delay, the stop process and the go process finish at the same time, on average, and the one that happens to win on a particular trial depends on random variation. Thus, we know, on average, the point in time at which the stop process finishes, and we can use that knowledge to estimate the stop-signal reaction time. Since we know the go
reaction time and the stop-signal delay, and because subjects inhibit 50% of the time at the critical delay, we know that stop-signal reaction time plus stop-signal delay must equal mean go reaction time. Stop signal reaction time can be calculated simply by subtracting stop-signal delay from mean go reaction time.

The stimuli were presented on an IBM-compatible computer. The stimuli for the go task were the letters X and O presented in the center of the screen for 1,000 ms. The subjects pressed buttons on a separate response box, labeled X and O. The X or O was preceded by a 500-ms fixation point, also presented in the center of the screen, and followed by a blank screen that was exposed for 1,000 ms. The stop signal was a 100-ms, 1000-Hz tone played through the internal speaker of the computer at a comfortable listening level. Stop-signal delay was set at 250 ms initially and then adjusted dynamically depending on the subject’s behavior. The delay increased by 50 ms if the subject inhibited successfully (making it harder to inhibit on the next stop-signal trial) and decreased by 50 ms if the subject failed to inhibit (making it easier to inhibit on the next stop-signal trial).

Subjects were given one practice set consisting of 24 trials before they began the test. The experimental task involved a total of 256 trials administered in eight blocks of 32 trials (192 non-signal trials, 64 signal trials). There were an equal number of Xs and Os in each block. Stop signals were presented on 25% of the trials in each block (i.e. on 8 trials), half of the time with an X and half of the time with an O. The order in which trials were presented was randomized separately for each subject. Once started, the program ran continuously, presenting one trial every 2.5 s. It paused after each block (32 trials) and presented the speed of the go-signal reaction time.
The instructions described the go task first, telling subjects their task was to respond to the letter as quickly as possible without making mistakes. Then the stop task was described. Subjects were told that occasionally they would hear a beep that told them not to press the button on that trial. They were told to inhibit their response if they could, but not to worry if they were not able to inhibit because sometimes it would be easy and sometimes it would be hard. They were also told specifically not to wait for the beep.

2. **Conners Continuous Performance Test (CPT)**

The Conners CPT is a 14-minute, computerized, norm-referenced, clinic-based assessment measure of inhibition in which the child is required to press the space bar each and every time a letter, other than the letter X, appears on the screen. For 90% of the time, the child actively responds to letters on the screen. For a mere 10% of the time a letter X appears and the child must inhibit his or her response and refrain from responding. Therefore the prepotent response is to press the space bar and the signal to inhibit this response is the letter X. This task differs from the traditional CPT task in which only rare targets get responses. In the inhibition version of this task, the child is responding for the majority of the time which then allows for useful reaction time measures such as response variability as a measure of attention. The letters in this task are presented in either 1, 2, or 4 second inter-stimulus intervals (ISI’s). This variable “foreperiod” creates temporal uncertainty and greatly influences speed and reaction time variability particularly in subjects with relatively poor anticipatory or preparatory sets (Sergeant & Scholten, 1985; Zahn, Kruesi, & Rapoport, 1991). Inattention on this task is indicated by high omission errors, accompanied by slow reaction times, highly variable reaction times, changes in response speed over time as well as a slowing and variability in reaction time as interstimulus intervals increase.
Indices of impulsivity include high commission error rates (responses to non-target X) as well as unusually fast reaction times.

In the standard mode, a total of 360, 1 inch letters were presented with a display time of 250 milliseconds. Of these, 324 were target letters, 36 were non-target Xs. There were 6 blocks with 3 sub-blocks each of 20 trials. For each block, the sub-blocks had different ISIs: 1, 2 or 4 seconds. The order of the ISIs varied between blocks. The program ran continuously for approximately 14 minutes. The subjects were told that they would see letters on the screen, one at a time. They were instructed to quickly press, then release the space bar for any letter except the letter X.

II. 2. 2 Phonological Processing Tasks:

1. Word Attack Subtest of the Woodcock Johnson Reading Mastery Tests - Revised
(Woodcock, 1987)

This is a norm-referenced test which requires reading a list of phonologically legal pseudowords. It provides a standard score with a mean of 100 and a standard deviation of 15. The ability to name pseudowords is one of the tasks that most clearly differentiates good from poor readers (Juel, 1988; Juel, Griffith & Gough, 1986; Rack et al., 1992; Stanovich et al., 1984; Stanovich et al., 1997; Tunmer & Nesdale, 1985). As pseudowords have never been seen by the children before, naming them requires transforming a letter string into a phonological form. This process requires knowledge of the correspondence of graphemes and phonemes. This knowledge of grapheme-phoneme correspondences is intimately linked to the acquisition of basic reading skills (Jorm et al., 1984; Juel, 1988; Juel et al., 1986; Tunmer & Nesdale, 1985).
2. **Test of Auditory Analysis** (Rosner & Simon, 1971)

   This is a norm referenced phoneme deletion and blending task (e.g., say "pray". Now say it again without the "p" sound). It is a measure of phonological processing which is the ability of the individual to make use of the phonological structure of words in processing written and oral language. Phonological skills are important because they are a necessary (but not sufficient) condition for the development of decoding skills which in turn, are linked to reading comprehension (Tunmer & Nesdale, 1985). This particular task requires a relatively deep processing of the phonemic structure of words since it involves segmenting words into sounds, deleting a phoneme or syllable, and blending the remaining phonemes. Items for this task are presented in Appendix B.

   The test consisted of 2 practice words and 40 items arranged in approximate order of difficulty. The items are arranged in terms of 7 levels, although levels 1 and 2 consisted of one word each which all children were successfully able to complete. The subsequent levels required the child to delete syllables, single phonemes from final, and initial positions in words, single phonemes from blends and medial syllables.

   The child was told that, "We are going to play a word game. I am going to say a word and I want you to say it the same way I do. Then I am going to tell you to take a part out of the word and tell me what’s left.”

3. **Phoneme Segmentation Task**

   This test was developed for this study based on the work of McBride-Chang (1995). It is a 32-item measure of phonological processing which requires the child to identify, isolate and articulate individual sounds within pseudowords presented as wholes. The items were grouped
into four categories based on the number of sounds in the words and the presence of consonant clusters. If the subject was not able to correctly identify the first word in each category, the item was demonstrated. The first eight words consisted of three sounds with no consonant blends. Items 9 to 16 were words with 4 sounds, each containing one consonant cluster. Items 17-24 were words of five sounds with no consonant cluster. By necessity, these were two syllable words. Finally items 25-32 were words with five sounds and two consonant clusters. Thus the task manipulated length (number of sounds) and difficulty level. Difficulty level was manipulated by the presence of consonant clusters which have been found to be more difficult to identify than non-clustered sounds (McBride-Chang, 1995). Items for this task are presented in Appendix C.

Each word was presented orally and the children were asked to repeat it. They were then instructed to tell the examiner each and every sound they heard in the words. In addition they were told to hold up a finger for each separate sound they said so that the examiner could be certain of how the children separated the sounds. They were given two practice items before beginning the test.

II. 2. 3 Personality Measure: Locus of Control

Nowicki-Strickland Internal-External Locus of Control Scale for Children (Nowicki & Strickland, 1973)

The Nowicki-Strickland instrument was designed as a measure of generalized expectancies for internal versus external control of reinforcement among children. It is a 40-item, paper and pencil test having a yes-no format, with half the items worded internally and half worded externally. The test is administered orally. Estimates of internal consistency for the ages of children in this study range from .63 to .68, and test-retest reliability over a 9-month interval of .63 (Nowicki & Duke,
Scores on this measure appear to be unrelated to IQ scores derived from the WISC (Nowicki & Duke, 1983). Factor analyses of the scale support a unidimensional interpretation with high scores representing a “general feeling of helplessness.” Questions for this task are presented in Appendix D.

II. 3 Testing Procedure

Children were tested individually in one session (lasting approximately 2 to 2.5 hours) in a small quiet room in the clinical research department at the hospital. The Nowicki-Strickland locus of control scale was always administered first so that responses were not affected by performance on any of the tasks. The independent measures were then administered, including in order, the Vocabulary and Block Design subtests of the WISC-III, the Reading and Arithmetic subtests of the WRAT-3, Reading Recognition of the PIAT and the RCMAS. The two computer tasks and the two phonological tasks were administered in alternating positions in order to counterbalance any possible order effects. Order 1 consisted of the Stop, Rosner, CPT, Phoneme Segmentation and the Word Attack subtest of the WRMT-R. Order 2 consisted of the CPT, Phoneme Segmentation, Stop task, Rosner, and Word Attack.

II. 4 Statistical Analyses

Results were analyzed using the Statistical Package for the Social Sciences - windows version 6.0. Unique variables were each analyzed in separate 2 (ADHD) x 2 (RD) ANCOVA’s with IQ as a covariate. Significant interactions were examined using post hoc Tukey tests. The Multivariate Analysis procedure was used to analyze level effects in the Rosner and Phoneme Segmentation tasks, and for the effects of time (block) in both the CPT and Stop tasks.
II. Results

II.1 Sample Description.

Table 1 displays the descriptive characteristics and academic criterion variables including gender distribution, age, IQ and reading and arithmetic levels. No age differences were found between groups; however $\chi^2$ analyses of the proportion of males to females within each group was significant. Follow-up proportion testing revealed the ADHD groups (ADHD, ADHD+RD) to consist of more males than females, relative to the non-ADHD groups (controls, RD). In terms of IQ, all groups were functioning well within the normal range; however a main effect of RD indicated that the two groups of children with RD had lower estimated IQs than children without RD. Achievement levels in arithmetic were affected by the presence of both ADHD and RD as revealed by the two main effect findings. Thus, children with ADHD scored lower than children without ADHD and children with RD scored lower than children without RD.

As a result of the differences in estimated IQs between RD and non-RD children, estimated IQs were included as a covariate in the analyses of the phonological processing and executive function measures. Without covarying for IQ, any differences between RD and non-RD children in the dependent measures may have been difficult to interpret.

II.1.1 RD Criterion Variables.

Reading disability was defined on the basis of the two reading measures listed in Table 1; therefore main effects of RD on these measures were expected. Indeed, this was found for WRAT-III reading and PIAT Reading Recognition, although for the PIAT, an ADHD by RD interaction was found. Post hoc Tukey tests, however, did not reach significance, but examination of the means suggests that the ADHD-only group scored somewhat below the
<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n=17)</th>
<th>RD (n=17)</th>
<th>ADHD (n=17)</th>
<th>ADHD+RD (n=17)</th>
<th>F-values and significance (df = 3, 64)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Gender (M/F)°</td>
<td>11 / 6</td>
<td>8 / 9</td>
<td>16 / 1</td>
<td>14 / 3</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>9.5 (1.3)</td>
<td>9.5 (1.1)</td>
<td>9.1 (1.1)</td>
<td>9.2 (1.7)</td>
<td></td>
</tr>
<tr>
<td><strong>WISC-III</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated IQ</td>
<td>107.3 (9.4)</td>
<td>101.7 (10.4)</td>
<td>110.7 (11.8)</td>
<td>97.6 (11.4)</td>
<td>12.7°</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>10.1 (2.1)</td>
<td>8.6 (2.0)</td>
<td>9.9 (3.6)</td>
<td>8.4 (2.0)</td>
<td>5.9°</td>
</tr>
<tr>
<td>Block Design</td>
<td>12.3 (2.2)</td>
<td>12.0 (2.8)</td>
<td>13.1 (3.5)</td>
<td>10.4 (3.1)</td>
<td>4.4°</td>
</tr>
<tr>
<td>PIAT Reading Rec</td>
<td>102.2 (9.9)</td>
<td>69.1 (7.5)</td>
<td>95.4 (12.9)</td>
<td>72.6 (10.7)</td>
<td>119.8**</td>
</tr>
<tr>
<td><strong>WRAT-III</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td>105.9 (9.3)</td>
<td>77.1 (5.6)</td>
<td>101.5 (10.9)</td>
<td>77.7 (7.9)</td>
<td>157.3**</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>103.0 (8.7)</td>
<td>89.9 (10.8)</td>
<td>95.8 (11.9)</td>
<td>82.5 (12.1)</td>
<td>7.4°</td>
</tr>
</tbody>
</table>

Note: ° Chi-square analyses (Pearson = 10.7, df = 3, p < .05). *p < .05. **p < .001.
controls. The fact that the RD-only group did not differ from the ADHD+RD group in terms of reading levels indicates that comorbidity was not confounded with severity in reading.

III.1.2 ADHD Criterion Variables.

The mean number of symptoms rated by parents and teachers on the SDI, and Rutter, Conners and SNAP questionnaires are presented in Tables 2 and 3 respectively. As expected analyses of parent ratings produced main effects of ADHD, and no interactions, on the various subscales of ADHD (SDI, ADHD; Rutter, hyperactivity; SNAP scales) indicating that both groups of children with ADHD were rated similarly in severity and differed from the non-ADHD groups (who also did not differ from each other). Teacher ratings also generally produced ADHD main effects for ADHD symptoms; however findings were not as straightforward as with parents. In general, the RD-only children were reported by teachers as exhibiting mild symptoms of ADHD. On the SDI, an ADHD by RD interaction was found for teacher rated ADHD symptoms; however post hoc tests did not reach significance either between the two non-ADHD groups, or between the two groups with ADHD. Examination of the means suggests that the interaction resulted from the RD-only group having slightly higher ratings than controls. Main effects of RD were found for symptoms of impulsivity and inattentiveness on the SNAP questionnaire, suggesting that teachers view children with RD as displaying more of these behaviors than children without RD. Overall, it should be noted that the two ADHD groups did not differ from each other in terms of severity on either parent or teacher ratings of ADHD symptomatology, suggesting that severity in terms of ADHD behaviors was not confounded with comorbidity.

Although the ADHD subjects were diagnosed according to DSM-III-R criteria, the current version of the DSM (DSM-IV; APA, 1994) defines three ADHD subtypes: predominantly
Table 2. Mean Scores and Standard Deviations for Child Symptoms, Derived from Parent and Teacher Ontario Child Health Study Scales

<table>
<thead>
<tr>
<th>DSM-III-R Diagnostic Variables and Cutoff Scores&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Controls</th>
<th>RD</th>
<th>ADHD</th>
<th>ADHD+RD</th>
<th>F-values and significance (df = 3, 64)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Parent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADHD (15, 12)</td>
<td>5.9 (5.5)</td>
<td>7.8 (3.3)</td>
<td>18.4 (4.8)</td>
<td>16.9 (3.6)</td>
<td>100.9**</td>
</tr>
<tr>
<td>oppositional/defiant (8.5, 6)</td>
<td>3.4 (3.3)</td>
<td>3.9 (2.9)</td>
<td>9.0 (3.5)</td>
<td>7.1 (4.4)</td>
<td>25.3**</td>
</tr>
<tr>
<td>conduct disorder (3, 2)</td>
<td>0.8 (1.2)</td>
<td>0.9 (1.3)</td>
<td>2.9 (2.4)</td>
<td>1.9 (1.9)</td>
<td>13.0*</td>
</tr>
<tr>
<td>depression (6, 6)</td>
<td>2.5 (1.9)</td>
<td>3.7 (2.2)</td>
<td>6.4 (2.3)</td>
<td>6.1 (3.1)</td>
<td>26.9**</td>
</tr>
<tr>
<td>overanxious (6, 6)</td>
<td>2.5 (1.9)</td>
<td>4.1 (2.5)</td>
<td>3.5 (2.5)</td>
<td>4.1 (3.1)</td>
<td>3.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>separation anxiety (6, 6)</td>
<td>2.2 (2.5)</td>
<td>3.1 (2.8)</td>
<td>2.4 (3.1)</td>
<td>3.9 (3.7)</td>
<td></td>
</tr>
<tr>
<td>Teacher</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADHD (16, 12)</td>
<td>1.8 (2.6)</td>
<td>6.0 (3.8)</td>
<td>20.2 (4.1)</td>
<td>18.9 (4.9)</td>
<td>234.7**</td>
</tr>
<tr>
<td>oppositional/defiant (7.2, 4)</td>
<td>0.6 (1.5)</td>
<td>2.0 (4.2)</td>
<td>6.5 (5.5)</td>
<td>4.9 (3.4)</td>
<td>19.9**</td>
</tr>
<tr>
<td>conduct disorder (3, 3)</td>
<td>0.2 (0.6)</td>
<td>0.4 (1.3)</td>
<td>2.7 (2.8)</td>
<td>1.6 (1.6)</td>
<td>17.2**</td>
</tr>
<tr>
<td>depression (5, 5)</td>
<td>0.7 (1.0)</td>
<td>3.6 (2.7)</td>
<td>5.3 (2.5)</td>
<td>5.6 (2.7)</td>
<td>29.9**</td>
</tr>
<tr>
<td>overanxious (5, 5)</td>
<td>1.2 (1.6)</td>
<td>3.2 (2.2)</td>
<td>3.2 (2.6)</td>
<td>3.2 (3.2)</td>
<td></td>
</tr>
</tbody>
</table>

Note: <sup>a</sup>Cutoff scores refer to those for males and females.

<sup>b</sup>Trend, p = .053

<sup>c</sup>Teacher SDI's unavailable for 7 subjects, 1 in each of control, RD, ADHD+RD, 4 from ADHD.

* p < .05, ** p < 001.
Table 3. Mean Scores and Standard Deviations for Child Symptoms, Derived from Parent and Teacher Rutter and Snap Questionnaires and RCMAS

<table>
<thead>
<tr>
<th>DSM-III-R Diagnostic Variables and Cutoff Scores*</th>
<th>Controls</th>
<th>RD</th>
<th>ADHD</th>
<th>ADHD+RD</th>
<th>F-values and significance (df = 3, 62)</th>
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<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td><strong>Parent, Rutter A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (13)</td>
<td>5.4</td>
<td>(5.4)</td>
<td>9.2</td>
<td>(7.5)</td>
<td>18.7</td>
</tr>
<tr>
<td>hyperactivity (4)</td>
<td>0.5</td>
<td>(1.2)</td>
<td>1.0</td>
<td>(1.2)</td>
<td>4.2</td>
</tr>
<tr>
<td>emotional (4)</td>
<td>0.9</td>
<td>(1.1)</td>
<td>2.0</td>
<td>(1.4)</td>
<td>2.4</td>
</tr>
<tr>
<td>conduct disorder (4)</td>
<td>0.7</td>
<td>(1.3)</td>
<td>0.8</td>
<td>(1.5)</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Parent SNAP</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>impulsivity (3)</td>
<td>0.5</td>
<td>(0.8)</td>
<td>0.7</td>
<td>(0.7)</td>
<td>3.8</td>
</tr>
<tr>
<td>inattentiveness (3)</td>
<td>0.2</td>
<td>(0.7)</td>
<td>1.1</td>
<td>(1.3)</td>
<td>3.4</td>
</tr>
<tr>
<td>hyperactivity (2)</td>
<td>0.2</td>
<td>(0.6)</td>
<td>0.2</td>
<td>(0.6)</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Teacher Rutter B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (9)</td>
<td>1.3</td>
<td>(1.9)</td>
<td>6.2</td>
<td>(6.0)</td>
<td>14.7</td>
</tr>
<tr>
<td>hyperactivity (4)</td>
<td>0.2</td>
<td>(0.5)</td>
<td>1.2</td>
<td>(1.4)</td>
<td>4.5</td>
</tr>
<tr>
<td>emotional (4)</td>
<td>0.3</td>
<td>(0.8)</td>
<td>2.1</td>
<td>(2.2)</td>
<td>1.8</td>
</tr>
<tr>
<td>conduct disorder (4)</td>
<td>0.4</td>
<td>(1.3)</td>
<td>0.8</td>
<td>(2.2)</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Teacher SNAP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>impulsivity (3)</td>
<td>0.1</td>
<td>(0.2)</td>
<td>0.9</td>
<td>(1.3)</td>
<td>3.4</td>
</tr>
<tr>
<td>inattentiveness (3)</td>
<td>0.1</td>
<td>(0.3)</td>
<td>1.5</td>
<td>(1.8)</td>
<td>3.3</td>
</tr>
<tr>
<td>hyperactivity (2)</td>
<td>0.0</td>
<td>(0.0)</td>
<td>0.1</td>
<td>(0.4)</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>RCMAS</strong></td>
<td>49.5</td>
<td>(9.8)</td>
<td>53.1</td>
<td>(11.2)</td>
<td>51.0</td>
</tr>
</tbody>
</table>

Note: *p<.05. **p<.001. *a trend, p=.062
inattentive, predominantly hyperactive-impulsive, and combined types. In order to determine how this sample of children might compare to those diagnosed with the current version of the DSM, ratings on the SNAP questionnaire were examined. This questionnaire differentiates between inattentive and hyperactive-impulsive symptoms and allows for an approximation of the DSM-IV subtypes. According to the SNAP, all of the children with ADHD (ADHD-only and ADHD+RD) fell into the combined-type category. However, three of the children in the RD-only group fell into the inattentive-only category.

III.1.3 Comorbid Symptomatology.

As shown in Tables 2 and 3, analyses of symptom counts revealed only main effects of ADHD (no main effects of RD or interactions) for symptoms of conduct and oppositional/defiant disorders. This was true for both parents and teachers and for both the SDI and Rutter questionnaires. In terms of emotional functioning, an RD factor emerged. On the parent SDI, an RD trend was found for symptoms of overanxious disorder. An interaction was also found for this variable, with post hoc tests indicating that within the non-ADHD grouping, controls exhibited fewer emotional symptoms than RD-only children. Similarly, on the teacher Rutter, children with RD were rated as having more symptoms of an emotional disorder than were children without RD. However, on the parent version of the Rutter, more symptoms of emotional disorder were reported for children with ADHD. No differences between groups emerged for either separation anxiety on the SDI or for child’s self-reported anxiety levels (Table 3). In contrast to ratings of anxiety symptoms, analysis of ratings of depression generally produced main effects of ADHD. This finding is not surprising given that on the SDI, many of the items for depression are similar to those of ADHD. An interaction occurred between ADHD and RD for
teacher ratings of depression. Post hoc analysis revealed the interaction occurred within the non-ADHD group, with controls rated as exhibiting fewer symptoms than children with RD-only. In terms of overall disturbances in functioning, revealed by the Rutter total score, both parent and teacher ratings indicated higher levels of disturbance for children with ADHD. Teachers also found children with RD to display more overall disturbance than children without RD. An interaction between ADHD and RD factors was found for parent ratings; however, post hoc analyses did not reach significance in the comparisons between controls and RD or between ADHD and ADHD+RD. The number of children in each group who met criteria for comorbid disorders is presented in Table 4. As can be seen these numbers mirror those of the symptom counts.

III.2 Cognitive Dependent Measures.

III.2.1 Intercorrelations Between the Stop Task, CPT and Phonological Tasks.

Table 5 presents the intercorrelations between the phonological processing tasks and variables of the Stop and CPT. The pattern of correlations gives an indication of the discriminant validity of the two domains. Firstly, scores on the phonological tasks were found to be highly correlated with each other, ranging from $r(68) = .58$ to $r(68) = .73$, whereas, in general, correlations between the phonological tasks and EF measures were low and non-significant. However, examinations of the correlations between the phonological tasks and those of the Stop and CPT, differentiates the Rosner from Phoneme Segmentation and the Word Attack. Generally, performance on the Rosner was found to be significantly correlated with all but one of the ten variables (number of commission errors) of the inhibitory control tasks, whereas analysis of the other two phonological measures resulted in only a few significant correlations with go task.
Table 4. Number of Children Meeting Criteria for Comorbid Disorders

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Controls</th>
<th>RD</th>
<th>ADHD</th>
<th>ADHD+RD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oppositional/Defiant</td>
<td>0</td>
<td>3</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Conduct</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Overanxious</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Separation Anxiety</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Child-Identified Anxiety</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Table 5. Correlations between Stop Task, CPT, and Phonological Measures

<table>
<thead>
<tr>
<th>Task and Variable</th>
<th>Response Execution</th>
<th>Variables</th>
<th>Inhibition</th>
<th>Phonological</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1      2    3</td>
<td>4  5  6  7</td>
<td>8  9  10</td>
<td>11  12 13</td>
</tr>
<tr>
<td><strong>Response Execution</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Reaction time</td>
<td>-.59**</td>
<td>.01  -.17</td>
<td>.57**  .44**  .37*</td>
<td>.48**  -.11</td>
</tr>
<tr>
<td>2. Standard deviation</td>
<td>-.60**</td>
<td>-.48**  .54**  .63**  .55**</td>
<td>.65**  .07</td>
<td>.47**  -.42**  -.23</td>
</tr>
<tr>
<td>3. # Correct</td>
<td>-.79**</td>
<td>-.18  -.54**  -.47**  -.39*  -.31*  -.12</td>
<td>.39*  .15  .26*</td>
<td></td>
</tr>
<tr>
<td>4. # Valid Trials</td>
<td>-.20</td>
<td>-.42**  -.42**  -.18  -.17  -.08</td>
<td>.31*  .19  .22</td>
<td></td>
</tr>
<tr>
<td><strong>CPT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Reaction Time</td>
<td>-.47**</td>
<td>.44**  .48**  .41*  .54**</td>
<td>-.39*  -.18</td>
<td>-.14</td>
</tr>
<tr>
<td>6. Standard Error</td>
<td>.76**</td>
<td>.49**  .22  .55**</td>
<td>-.47**  -.22  -.27*</td>
<td></td>
</tr>
<tr>
<td>7. # Omission Errors</td>
<td>.36*</td>
<td>.18  .46**</td>
<td>-.44**  -.18  -.32*</td>
<td></td>
</tr>
<tr>
<td><strong>Response Inhibition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. SSRT</td>
<td>-.10</td>
<td>.44**  -.27*  -.16  -.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CPT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. # Commission Errors</td>
<td>-.06</td>
<td>.02  .02  .03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Commission Error RT</td>
<td>-.44**</td>
<td>-.24  -.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phonological Tasks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Rosner</td>
<td></td>
<td></td>
<td></td>
<td>-.73**  .71**</td>
</tr>
<tr>
<td>12. Phoneme Seg.</td>
<td></td>
<td></td>
<td></td>
<td>-.58**</td>
</tr>
<tr>
<td>13. WRMT Word Attack</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

Note: * p < .05, ** p < .001, two tailed
variables. As stated earlier, the Rosner involves working memory to a greater extent than Phoneme Segmentation or Word Attack and therefore may be more closely associated with tasks tapping executive functions.

Examination of the intercorrelations between the Stop task and the CPT indicates that performance on these tasks are moderately related and appear to be more closely associated with each other than with either Phoneme Segmentation and Word Attack. Analysis of commission errors did not result in many significant correlations.

III.2.2 Phonological Variables.

Group means and standard deviations for the standard scores of the Word Attack subtest of the WRMT-R, were found to be: controls, 104.2 (10.4), RD, 70.0 (11.6), ADHD, 97.5 (11.2), and ADHD+RD, 70.8 (13.3). Statistical analysis of these means, revealed an RD main effect (F[1,63] = 84.9, p < .001). Thus, the two groups, RD and ADHD+RD, exhibited a similar degree of impairment and were less able to apply phonological knowledge to read new words than children without a reading disability. No other main effects or interactions were present.

The mean proportion correct at each level of the Rosner are illustrated in Figure 1. This figure illustrates that the controls appeared to be most successful, closely followed by the ADHD-only group. The two RD groups appeared to perform similarly and much below the two non-RD groups. Statistical analysis revealed a small main effect of ADHD (F [1,63] = 4.4, p < .05) and a large effect of RD (F [1,63] = 43.8, p < .001). A main effect of level was also found (F [4, 256] = 79.7, p < .001). Post hoc Tukey comparisons among the means at each level revealed the levels in order of difficulty to be: levels 1 and 2 (deleting final and initial phoneme), levels 3 and 4, (deleting first and second phoneme in a consonant blend) and level 5 (deleting the medial
Figure 1. Rosner Proportion Scores by Level and Diagnosis

- Control
- RD
- ADHD
- ADHD+RD

Proportion vs. Level
However, a two-way interaction between RD and level occurred ($F_{4, 256} = 6.5, p < .001$). Post hoc analyses comparing differences between levels for RD versus non-RD children indicated that non-RD children performed better at level 4 than level 5 whereas RD children performed similarly at levels 4 and 5. This result is illustrated in Figure 1 which shows the non-RD children performing well up to level 4 and dropping down at level 5. On the other hand, children with RD performed poorly at both levels 4 and 5.

Mean raw scores at each level for the Phoneme Segmentation task are illustrated in Figure 2. Similar to the Rosner results, this figure shows that the controls appeared to be the most successful at all levels, followed by the ADHD-only group, and then the two RD groups who appeared to perform similarly to each other. Statistical analysis of these results revealed a main effect of RD ($F_{1, 63} = 19.3, p < .001$), indicating that children with RD-only and children with both ADHD and RD were less able to segment nonsense words at all levels of difficulty than were children without RD. However, a main effect of ADHD ($F_{1, 63} = 5.7, p < .05$) as well as an interaction between ADHD and RD were found ($F_{1, 63} = 4.3, p < .05$). Post hoc tests revealed that the ADHD-only group performed less well than control children on this task, although they still performed better than both groups of children with RD. Children with RD and children with ADHD+RD did not differ from each other. A main effect of level was found ($F_{3, 192} = 45.5, p < .001$). Post-hoc Tukey comparisons among the means at each level revealed that children in general were more successful at segmenting words at level 1 than levels 2, 3 and 4, and were more successful at level 2 than at levels 3 and 4. Levels 3 and 4 were equated in difficulty level. In other words, in terms of difficulty level, all children found segmenting 3 phoneme words easiest, followed by 4 phoneme words and then 5 phoneme words. At the 5 phoneme word level
Figure 2. Phoneme Segmentation Raw Scores by Level
levels 3 and 4) no difference was found between 1 and 2 syllable words. No significant interactions between RD or ADHD factors and levels were found.

**III.2.3 Executive Function Variables.**

For the sake of conceptual clarity, results of the Stop task and CPT will first be presented according to the categories of response execution (results associated with the go task) and response inhibition (results associated with the stop task). Results from similar variables belonging to both tasks will be presented first, followed by variables unique to each task. Means and standard deviations for the four groups for overall task performance are presented in Table 6.

**III.2.3.1 Response Execution.**

The variables to be discussed in this section involve those associated with the go task, and all involve maintenance of a mental set and vigilance to an ongoing task. Means, standard deviations and significance values are presented in Table 6. Analyses of overall go reaction times on both the Stop and CPT revealed a main effect of ADHD for only the Stop task. No other interactions or main effects were found. Therefore, children with ADHD were slower overall on the Stop than children without ADHD. The CPT task, however, presented data at varying speeds (1, 2 and 4 second ISI's). When reaction times on the CPT were analyzed with regard to ISI, an interaction between ADHD and ISI was found (F [2, 128] = 5.0, p < .05) (see Figure 3 for raw means, unadjusted for IQ). Post hoc tukey tests comparing ADHD to non-ADHD children at each ISI revealed that children with ADHD were similar to children without ADHD at 1 second intervals, but were slower than children without ADHD at 2 and 4 second interstimulus intervals. The interstimulus interval for the Stop task was 2.5 seconds. Overall, therefore, children with ADHD appear to be slower than non-ADHD children at longer interstimulus intervals.
In terms of variability, simple main effects of ADHD were found for both tasks, with no other main effects or interactions. When CPT standard error was analyzed according to ISI, findings similar to those for reaction time were found (i.e. an ADHD by ISI interaction (F [2, 128] =8.9, p < .001), see Figure 4 for unadjusted means). Post hoc analyses revealed that children with ADHD (ADHD and ADHD+RD) were more variable than those without ADHD at ISIs of 2 and 4 seconds but not at 1 second. No other main effects or interactions were found.

The Stop task involves a choice response and provides two measures of the ability to perform the task according to instructions. The first is the number of correct choices (X or O) and the second is the number of valid trials (i.e., invalid refers to holding down a button or pressing too early). No effects were found for percent correct; however an ADHD main effect was found for number of valid trials. Thus, children with ADHD had more difficulty performing the task correctly. No other main effects or interactions were found. In terms of go task performance on the CPT, omission errors (i.e., failing to press for a non-X) are available. Analyses of these errors revealed a two-way interaction between ADHD and RD. Post hoc analyses located the source of this interaction within the ADHD groups. Examination of the means indicates that children comorbid for ADHD and RD performed worse than children with ADHD-only (as well as controls and RD). Analysis of omission errors by ISI did not reveal any interactions between diagnostic groups and ISI.

Both the Stop task and the CPT are divided into blocks and therefore provide a measure of the effect of time on children’s performance. Analysis of the Stop task variables by block found no interactions between block and diagnosis on any of the measures reported above (i.e., go task reaction time, variability, number of valid trials, or number of correct trials). Similarly, on the
CPT, no interactions between diagnostic group and time were found for go task reaction time, number of omission errors or variability. Thus all children performed both tasks consistently from the beginning to the end.

To summarize these results, processes involved in response execution appear to be associated with the presence of ADHD, not RD. Children with ADHD were slower, more variable in performance and more affected by lengthy interstimulus intervals. Except for omission errors, these results were not differentially affected by comorbidity with RD. With variance due to IQ partialled out, reading disability itself did not appear to be a factor in responding to the go task. The absence of interactions between diagnostic factors and block (time) effects indicates that none of the groups exhibited a decrement in performance over time on both tasks.

III.2.3.2 Response Inhibition

Group means for the three overall response inhibition measures (Stop task: mean stop-signal reaction time [SSRT], CPT: number of commission errors and commission error reaction time) are also presented in Table 6. Examination of the two inhibition measures for the CPT reveals only main effects of ADHD with no interactions. Thus, on the CPT, children with ADHD made more commission errors (i.e., pressed the button when given the signal not to press) and were slower to press when they should not have, than children without ADHD. This slower commission error latency suggests that the failure to inhibit is not a result of "going too fast."

Comorbidity with RD was not a factor in the performance of ADHD children as indicated by the absence of ADHD by RD interactions. When these CPT results were analyzed according to ISI, no main effects or interactions involving ADHD or RD and ISI were found. As with the go task
performance, no interactions between diagnostic group and time were found for either of the variables reported above, suggesting that all children performed consistently throughout the task.

In contrast to the results of the CPT, inhibition on the Stop task is associated with RD as indicated by the main effect of RD on SSRT, although the trend for ADHD indicates that this disorder is also associated with longer SSRTs. Thus, children with RD take longer to respond to a stop-signal than children without RD. In terms of milliseconds, the mean raw difference between RD groups and non-RD groups was found to be 336 ms versus 287 ms, or approximately a 49 ms difference. The mean raw difference between ADHD and non-ADHD children was found to be 55 ms (339 versus 284) which is longer; however analyses removed the variance in SSRT due to IQ, resulting in a stronger RD effect. As with the results reported above, no interactions between block and diagnostic groups were found for SSRT. In order to examine the specificity of longer stop-signal reaction times to diagnostic groups, results were compared with those of normal children obtained in a developmental study of performance on the Stop task (Williams, Pomesse, Schachar, Logan & Tannock, 1999). The number of children in each group with SSRTs longer than 1 standard deviation for their age was counted. The numbers were as follows: controls, 4 (23.5%), RD, 8 (47.0 %), ADHD, 7 (41.2%), ADHD+RD, 8 (47.0%). Therefore the clinical groups were roughly equal in the number of children with longer SSRTs relative to their age.
### Table 6. Mean Scores and Standard Deviations Stop Task and CPT

<table>
<thead>
<tr>
<th>Task and Variable</th>
<th>Controls M</th>
<th>Controls SD</th>
<th>RD M</th>
<th>RD SD</th>
<th>ADHD M</th>
<th>ADHD SD</th>
<th>ADHD+RD M</th>
<th>ADHD+RD SD</th>
<th>F-values and significance (df = (1, 63))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Execution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>main main 2-way effect effect effect 2-way</td>
</tr>
<tr>
<td>Stop Task</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ADHD RD ADHDxRD ADHD RD ADHDxRD</td>
</tr>
<tr>
<td>Reaction time</td>
<td>533.9 (89.0)</td>
<td>565.1 (125.7)</td>
<td>658.1 (105.3)</td>
<td>638.0 (155.2)</td>
<td>11.1*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>154.5 (44.6)</td>
<td>180.1 (55.6)</td>
<td>234.7 (88.9)</td>
<td>270.0 (110.0)</td>
<td>19.3**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Correct</td>
<td>94.9 (4.7)</td>
<td>92.2 (6.7)</td>
<td>92.9 (4.9)</td>
<td>88.3 (10.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Valid Trials</td>
<td>188.4 (5.7)</td>
<td>187.5 (8.1)</td>
<td>185.9 (6.9)</td>
<td>177.7 (12.8)</td>
<td>8.3*</td>
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<td></td>
<td></td>
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<tr>
<td>CPT</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Reaction Time</td>
<td>386.8 (79.1)</td>
<td>414.6 (74.1)</td>
<td>399.1 (99.9)</td>
<td>447.8 (114.1)</td>
<td></td>
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<tr>
<td>Standard Error</td>
<td>8.9 (2.9)</td>
<td>12.3 (5.2)</td>
<td>14.5 (5.6)</td>
<td>18.6 (8.6)</td>
<td>17.2**</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td># Omission Errors</td>
<td>10.4 (6.9)</td>
<td>13.0 (9.6)</td>
<td>12.82 (5.9)</td>
<td>30.8 (18.3)</td>
<td>13.4**</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>10.0* 6.9**</td>
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<tr>
<td>Response Inhibition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Stop Task</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSRT</td>
<td>265.2 (86.1)</td>
<td>301.9 (88.7)</td>
<td>308.1 (131.7)</td>
<td>369.6 (162.5)</td>
<td>3.8b</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CPT</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Commission Errors</td>
<td>22.6 (6.1)</td>
<td>20.4 (7.5)</td>
<td>25.0 (5.6)</td>
<td>25.6 (4.7)</td>
<td>6.5*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commission Error RT</td>
<td>358.8 (67.3)</td>
<td>373.7 (77.4)</td>
<td>401.1 (81.6)</td>
<td>426.5 (126.9)</td>
<td>4.5*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *p < .05, **p < .001

* Post hoc comparison indicates ADHD+RD made more errors than all other groups

* trend, p = .055
Figure 3. CPT Reaction Time by Interstimulus Interval

- Controls
- RD
- ADHD
- ADHD+RD

rt (ms)

Interstimulus Interval

1 sec 2 sec 4 sec
Figure 4. CPT Standard Error by Interstimulus Interval

- Controls
- RD
- ADHD
- ADHD+RD

Interstimulus Interval

SE (ms)

1 sec
2 sec
4 sec
III.3. Intercorrelations Between Symptom Ratings and Cognitive Dependent Measures.

Correlations between the inhibitory control tasks and parent and teacher symptom ratings are presented in Tables 7 and 8. Table 7 contains correlations with go task variables, while Table 8 contains correlations with inhibition variables. Generally, the pattern of correlations reveals that performance on most variables of both the Stop task and CPT are significantly correlated with both parent and teacher ADHD ratings, not ratings of either ODD, CD or emotional symptoms. This was generally true for both go task and inhibition variables. These results support the validity of these tasks in tapping behaviors specific to ADHD, not general psychopathology.

Examination of the correlations between symptom ratings for response execution variables versus inhibition variables reveals a greater number of significant correlations between the response execution variables and ADHD symptom ratings than with response inhibition variables and ADHD symptoms.
Table 7. Correlations between Parent and Teacher Symptom Ratings and Go Task Variables

<table>
<thead>
<tr>
<th>Measure and Symptom Category</th>
<th>Stop Task</th>
<th>CPT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT P</td>
<td>SD T</td>
</tr>
<tr>
<td>ADHD Symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCHS - ADHD</td>
<td>.29*</td>
<td>.38*</td>
</tr>
<tr>
<td>Rutter - Hyperactivity</td>
<td>.44**</td>
<td>.31*</td>
</tr>
<tr>
<td>Snap - Impulsivity</td>
<td>.27*</td>
<td>.34*</td>
</tr>
<tr>
<td>Snap - Inattention</td>
<td>.43**</td>
<td>.33*</td>
</tr>
<tr>
<td>Snap - Hyperactivity</td>
<td>.46**</td>
<td>.38*</td>
</tr>
<tr>
<td>ODD/CD Symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCHS - Conduct</td>
<td>.21</td>
<td>.16</td>
</tr>
<tr>
<td>Rutter - Conduct</td>
<td>.21</td>
<td>.18</td>
</tr>
<tr>
<td>OCHS-Oppositional/Defiant</td>
<td>.19</td>
<td>.25</td>
</tr>
<tr>
<td>Emotional Symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCHS - Overanxious</td>
<td>.03</td>
<td>.23</td>
</tr>
<tr>
<td>OCHS-Separation Anxiety</td>
<td>.07</td>
<td>.17</td>
</tr>
<tr>
<td>OCHS - Depression</td>
<td>.21</td>
<td>.35*</td>
</tr>
<tr>
<td>Rutter - Emotional</td>
<td>.28*</td>
<td>.14</td>
</tr>
</tbody>
</table>

Note: * p<.05, ** p < .001.
Missing Parent Data: Rutter and Snap missing data for 1 ADHD-only and 1 ADHD+RD subject.
Missing Teacher Data: OCHS missing for 1 control, 1 RD, 2 ADHD-only, 4 ADHD+RD.
Rutter, SNAP missing for 1 control, 2 RD, 5 ADHD-only, 4 ADHD+RD.

P = Parent, T=Teacher
RT = reaction time, SD = standard deviation, SE = standard error, # Valid = # of valid trials, # Correct = # correct trials.
Table 8. Correlations between Parent and Teacher Symptom Ratings and Inhibition Variables

<table>
<thead>
<tr>
<th>Measure and Symptom Category</th>
<th>Stop Task</th>
<th>CPT</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean SSRT</td>
<td># Commission Errors</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>T</td>
</tr>
<tr>
<td>ADHD Symptoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCHS - ADHD</td>
<td>.07</td>
<td>.19</td>
<td>.29*</td>
<td>.27*</td>
</tr>
<tr>
<td>Rutter - Hyperactivity</td>
<td>.29*</td>
<td>.36*</td>
<td>.26*</td>
<td>.31*</td>
</tr>
<tr>
<td>Snap - Impulsivity</td>
<td>.09</td>
<td>.33*</td>
<td>.26*</td>
<td>.28*</td>
</tr>
<tr>
<td>Snap - Inattention</td>
<td>.26*</td>
<td>.27*</td>
<td>.28*</td>
<td>.13</td>
</tr>
<tr>
<td>Snap - Hyperactivity</td>
<td>.30*</td>
<td>.35*</td>
<td>.08</td>
<td>.27*</td>
</tr>
<tr>
<td>ODD/CD Symptoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCHS - Conduct</td>
<td>-.03</td>
<td>.01</td>
<td>.05</td>
<td>.13</td>
</tr>
<tr>
<td>Rutter - Conduct</td>
<td>.08</td>
<td>.06</td>
<td>.13</td>
<td>.16</td>
</tr>
<tr>
<td>OCHS - Oppositional/Defiant</td>
<td>-.02</td>
<td>.00</td>
<td>.21</td>
<td>.13</td>
</tr>
<tr>
<td>Emotional Symptoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCHS - Overanxious</td>
<td>.08</td>
<td>.09</td>
<td>-.02</td>
<td>-.02</td>
</tr>
<tr>
<td>OCHS - Separation Anxiety</td>
<td>.14</td>
<td>-</td>
<td>.09</td>
<td>-</td>
</tr>
<tr>
<td>OCHS - Depression</td>
<td>.05</td>
<td>.16</td>
<td>.13</td>
<td>.09</td>
</tr>
<tr>
<td>Rutter - Emotional</td>
<td>.17</td>
<td>.14</td>
<td>-.02</td>
<td>.16</td>
</tr>
</tbody>
</table>

Note: * p < .05, ** p < .001. P = Parent, T = Teacher
III. 4 Intercorrelations Between RD Diagnostic and Cognitive Dependent Measures.

Correlations between measures used to diagnose reading disability (WRAT-III Reading and PIAT Reading Recognition) and the dependent measures are presented in Table 9. As expected, the correlations between RD diagnostic measures and the phonological tasks are significantly correlated with all three scores on the phonological tasks. Correlations between WRAT Reading and the executive function variables produced a greater number of significant correlations compared to the PIAT Reading scores. Consistent with the findings of an RD effect on inhibition, WRAT reading is moderately but significantly correlated with SSRT.

III. 5 Locus of Control.

Means scores and standard deviations on the Nowicki-Strickland Internal External Locus of Control scale for the controls, RD, ADHD and ADHD+RD were found to be 15.6 (3.9), 16.5 (5.2), 18.5 (4.2) and 18.0 (4.2) respectively. Analysis of these scores revealed a main effect of ADHD ($F [1,63] = 4.1, p < .05$). Children with ADHD (ADHD, ADHD+RD) had higher scores, and were therefore more external in their attributions than children without ADHD (controls and RD).

Correlations between the Nowicki-Strickland and the cognitive dependent measures are presented in Table 10. As can be seen, this scale was modestly correlated with most variables on the Stop and CPT. It was moderately correlated with the phoneme segmentation task. The Nowicki was generally not strongly correlated with parent and teacher symptom ratings.
Table 9. Correlations between RD Diagnostic Variables and Dependent Variables

<table>
<thead>
<tr>
<th>Task and Variable</th>
<th>WRAT-III Reading</th>
<th>PIAT Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Response Execution</strong></td>
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<td></td>
</tr>
<tr>
<td>Stop Task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction time</td>
<td>-.14</td>
<td>-.03</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>-.27*</td>
<td>-.03</td>
</tr>
<tr>
<td># Correct</td>
<td>.23</td>
<td>.08</td>
</tr>
<tr>
<td># Valid Trials</td>
<td>.19</td>
<td>.12</td>
</tr>
<tr>
<td><strong>CPT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction Time</td>
<td>-.31*</td>
<td>-.19</td>
</tr>
<tr>
<td>Standard Error</td>
<td>-.35*</td>
<td>-.22</td>
</tr>
<tr>
<td># Omission Errors</td>
<td>-.40*</td>
<td>-.29*</td>
</tr>
<tr>
<td><strong>Response Inhibition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop Task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSRT</td>
<td>-.24*</td>
<td>-.05</td>
</tr>
<tr>
<td><strong>CPT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Commission Errors</td>
<td>.04</td>
<td>.14</td>
</tr>
<tr>
<td>Commission Error RT</td>
<td>-.22</td>
<td>-.07</td>
</tr>
<tr>
<td><strong>Phonological Tasks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosner</td>
<td>.72**</td>
<td>.53**</td>
</tr>
<tr>
<td>Phoneme Segmentation</td>
<td>.52**</td>
<td>.42**</td>
</tr>
<tr>
<td>Word Attack</td>
<td>.86**</td>
<td>.85**</td>
</tr>
</tbody>
</table>

Note: * p<.05, ** p < .001, two-tailed
Table 10. Correlations between Nowicki-Strickland Scale, Parent and Teacher Symptom Ratings, and Cognitive Dependent Measures

<table>
<thead>
<tr>
<th>Measure and Symptom Category</th>
<th>Nowicki-Strickland Parent&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Teacher</th>
<th>Computer Task and Variable</th>
<th>Nowicki-Strickland</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Response Execution</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stop Task</td>
<td></td>
</tr>
<tr>
<td>ADHD Symptoms</td>
<td></td>
<td></td>
<td>Reaction time .26&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>OCHS - ADHD</td>
<td>.18</td>
<td>.20</td>
<td>Standard Deviation .36&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Rutter - Hyperactivity</td>
<td>.28&lt;sup&gt;*&lt;/sup&gt;</td>
<td>.22</td>
<td># Correct -.24&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Snap - Impulsivity</td>
<td>.24</td>
<td>.19</td>
<td># Valid Trials -.28&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Snap - Inattention</td>
<td>.29&lt;sup&gt;*&lt;/sup&gt;</td>
<td>.17</td>
<td>CPT</td>
<td></td>
</tr>
<tr>
<td>Snap - Hyperactivity</td>
<td>.35&lt;sup&gt;*&lt;/sup&gt;</td>
<td>.29&lt;sup&gt;*&lt;/sup&gt;</td>
<td>Reaction Time .33&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Standard Error .35&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td># Omission Errors .28&lt;sup&gt;*&lt;/sup&gt;</td>
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<tr>
<td>ODD/CD Symptoms</td>
<td></td>
<td></td>
<td>Response Inhibition</td>
<td></td>
</tr>
<tr>
<td>OCHS - Conduct</td>
<td>.31&lt;sup&gt;*&lt;/sup&gt;</td>
<td>.21</td>
<td>Stop Task</td>
<td></td>
</tr>
<tr>
<td>Rutter - Conduct</td>
<td>.32&lt;sup&gt;*&lt;/sup&gt;</td>
<td>.14</td>
<td>SSRT .28&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>OCHS - Oppositional/Defi</td>
<td>.19</td>
<td>.19</td>
<td>CPT</td>
<td></td>
</tr>
<tr>
<td>Emotional Symptoms</td>
<td></td>
<td></td>
<td># Commission Errors .16</td>
<td></td>
</tr>
<tr>
<td>OCHS - Overanxious</td>
<td>.07</td>
<td>.12</td>
<td>Commission Error RT .33&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>OCHS-Separation Anxiety</td>
<td>.11</td>
<td></td>
<td>Phonological Tasks</td>
<td></td>
</tr>
<tr>
<td>OCHS - Depression</td>
<td>.21</td>
<td>.19</td>
<td>Rosner -.22</td>
<td></td>
</tr>
<tr>
<td>Rutter - Emotional</td>
<td>.15</td>
<td>.05</td>
<td>Phoneme Segmentation -.28&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Word Attack -.01</td>
<td></td>
</tr>
</tbody>
</table>

Note: *p < .05, **p < .001, two-tailed
<sup>a</sup> Data presented as correlations between Nowicki and parent and Nowicki and teacher ratings.
IV Discussion

IV. 1 Overview

The main purpose of this study was to examine the comorbidity of ADHD and RD using a classic double dissociation design which contrasted two cognitive domains, executive function and phonological processing, each of which were proposed as central to one disorder and not the other. A comparison of the profile of the comorbid group (ADHD+RD) to those of the single groups (ADHD-only, RD-only) on these cognitive domains afforded an examination of the phenocopy hypothesis (i.e., that one disorder leads to secondary symptoms of the other in children in which the two disorders co-occur) or the etiologic subtype hypothesis (i.e., that the comorbid group’s profile resembles additive or greater than additive deficits of both single disorders). A second purpose of this study was to help determine if a deficit specific to ADHD could be found. In addition, this study examined the relationship of a personality variable, locus of control, to performance on these measures, since secondary attitudinal variables have been implicated in the performance deficits of both ADHD and RD children. Based on previous research, it was predicted that; a) there would be a double dissociation of deficits between the ADHD and RD children; b) that the comorbid group would exhibit the deficits of both single disorders in an additive, not synergistic fashion and c) that greater externality in terms of locus of control (i.e., greater feelings of helplessness) would be associated with the presence of RD.

In regards to the first prediction, a dissociation was found between the ADHD and RD children in terms of phonological processing. Children with RD, regardless of ADHD status exhibited deficiencies relative to non-RD children in phonological processing on all three measures employed. A dissociation was also found between ADHD and RD children in terms of
simple response execution (go-task responding). Children with ADHD were slower, more variable, and more frequently made invalid responses when responding to the primary task. However, contrary to predictions, a dissociation of deficits between ADHD and RD in response inhibition was not consistently found. On the CPT, poorer response inhibition as indicated by more commission errors (responding when given the signal to stop, and longer commission error reaction times) was associated with ADHD, not RD. However, on the Stop task, poorer inhibition as indicated by longer reaction times to the stop-signal was associated with both ADHD and RD but to a greater extent with RD.

The second prediction, that children comorbid for both ADHD and RD would exhibit the deficits of both single groups in an additive fashion was supported, with only a few minor exceptions, as evinced by the absence of simple 2-way interactions. In other words, the ADHD+RD group were impaired on both inhibitory control, response execution, and phonological processing. The fact that the comorbid group did not differ from the ADHD group on inhibitory control and did not differ from the RD group in phonological processing indicates that the effect of having both disorders is generally not synergistic, but merely additive. Lastly, the third prediction was not supported. It was predicted that an external locus of control would be associated with the presence of RD, not ADHD, but the reverse was found. Children with ADHD scored higher in terms of belief about external control over events than children without ADHD.

**IV. 2 Dissociation of ADHD and RD**

The dissociation of deficits found between ADHD and RD supports the research which suggests that these disorders represent two distinct clinical syndromes with separable cognitive
profiles (Faraone et al., 1993; Gilger et al., 1992; Gillis et al., 1992; Pennington et al., 1993; Shaywitz, et al., 1995). Clearly the diagnosis of reading disability, not ADHD, is associated with deficits in phonological processing. Poorer response execution processes were found to be associated with ADHD. However, the failure to dissociate ADHD and RD in terms of inhibition on both tasks suggests that deficits in response inhibition in all situations may not be specific to ADHD. As will be discussed later, it is possible that longer stop-signal reaction times may arise for different reasons in the two diagnostic groups, but these findings still undermine current theory which emphasizes poorer response inhibition as an ADHD-specific phenomenon, chiefly responsible for the observed difficulties of children with ADHD. Clearly, there is a continued need to search for primary underlying deficits in ADHD which can be shown to be universal, specific, persistent, and most importantly, exhibit causal priority in longitudinal studies of the disorder.

IV. 2. 1 Phonological Processing and Reading Disability

The RD main effect findings on the three phonological tasks are consistent with previous research and support the concept of RD as a relatively discrete neurodevelopmental deficiency in linguistic abilities, particularly phonological processes (Adams, 1990; Bradley & Bryant, 1983; Stanovich, 1992; Wagner & Torgesen, 1987). The three tasks were chosen based on different task requirements, particularly working memory load. The Word Attack subtest did not require holding items in memory but simply translating grapheme to phonemes and only differentiated RD from non-RD children, with no effect of ADHD. This supports previous research indicating that pseudoword reading is one of the tasks that most clearly differentiates good and poor readers (Jorm & Share, 1983; Rack et al., 1992). The Rosner and Phoneme Segmentation tasks were
both solely auditory tasks which required holding items in memory. The Rosner involved the additional component of performing a manipulation in one's head. The ADHD children were less able than controls on both tasks but still clearly more able than children with RD. This ability to maintain and manipulate short-term information to produce a response (working memory) is becoming increasingly recognized as a key component of executive functions (Roberts & Pennington, 1996). Therefore, it is not surprising that children with ADHD would have some difficulty relative to controls. Examination of the correlations between the phonological tasks and the Stop and CPT revealed the moderate correlations between the Rosner and Phoneme Segmentation tasks (not Word Attack) and the two inhibition tasks, supporting the suggestion that these phonological tasks involve working memory more heavily than pseudoword reading. The manipulation of difficulty level within the Rosner and Phoneme Segmentation tasks were successful as indicated by the main effects of level. The lack of interaction between groups of children and these levels on the Phoneme Segmentation tasks suggests that the manipulation of this limited number of phonemes was not addressing difficulties specific to either disorder. However, the interaction between RD and level on the Rosner suggests that placement of phoneme affected the difficulty level. Children with RD had difficulty deleting the second phoneme in a consonant blend and deleting a medial phoneme.

IV. 2. 2 Inhibitory Control in ADHD and RD

In this sample of children, ADHD and RD were found to be associated with poor inhibitory control. Main effects of ADHD were found for CPT measures of inhibition, while a main effect of RD and a trend for ADHD were found on the Stop task. Findings of increased impulsivity (commission errors) on CPT measures in ADHD but not learning disabled children is consistent
with previous research (Corkum & Siegel, 1993; Losier, McGrath, Klein, 1996; Richards, Samuels, Turnure, Ysseldyke, 1990). The longer commission error reaction time in ADHD children may also indicate inhibitory difficulties. When the stop-signal is given (the letter X), children suddenly have to inhibit their tendency to press the button. This requires executive motor decision/response organization processes to the stop-signal and is similar to the findings of Hall et al. (1997), in which children with ADHD had longer latencies when required to give an incompatible response. Thus, a longer commission error latency reflects executive difficulties in motor decision/response organization when required to inhibit a prepotent response.

On the Stop task, main effects of RD and a trend for ADHD were found for stop-signal reaction time. Both diagnoses were associated with longer SSRTs, indicating less efficient inhibitory control. The slower inhibitory process in ADHD children supports previous work using similar paradigms (Oosterlaan & Sergeant, 1996, 1998; Pliszka & Borcherding, 1995; Schachar & Logan, 1990; Schachar & Tannock, 1995; Schachar et al., 1995). The finding of longer SSRTs in children with RD contradicts the findings of Schachar and Logan (1990) which found deficient inhibitory control in ADHD, but not LD children. That study however, did not control for the presence of LD in their ADHD samples making it difficult to compare the relative performance of the two diagnostic categories.

The fact that deficient inhibition was found to be specific to the diagnosis of ADHD on the CPT, but was associated with both ADHD and RD on the Stop task may in part be related to different methodologies. The CPT requires responding to one stimulus, a letter. The stop task requires responding to two stimuli, a letter, followed by an auditory tone. The processing of two stimuli in rapid succession may be affected by what is termed the psychological refractory period
(Davis, 1957). If a subject has not finished attending and responding to one stimulus before the next appears, the response to the second stimulus will be affected. The refractory period is approximately 0 to 500 msec (Kantowitz, 1974), and indeed the average delay between first stimulus and the signal to stop was approximately 288 ms. Since the RD effect on inhibition was found only on the Stop, it is possible that the RD group was differentially affected by the processing of two stimuli in rapid succession. Studies of children with RD have found that problems on rapid serial naming tasks are characteristic of this disorder (Cornwall, 1992; Denckla & Rudel, 1976; Wagner & Torgesen, 1987). In addition, deficits in processing rapidly presented auditory stimuli occur in a subset of poor readers (Tallal & Stark, 1982). Further evidence for RD deficiencies in processing rapid sequential information comes from A - X version of the CPT in which children respond to the second stimulus in a two sequence target. Children with ADHD tend to make A-O commission errors in which they respond impulsively to the first stimulus in a target sequence, whereas RD children make O-X commission errors, responding to the second stimulus in a target sequence (Beale, Matthew, Oliver, & Corballis, 1987; Kupietz, 1990). O-X commission errors are interpreted to reflect difficulty in processing rapid sequential information. Therefore, it is possible that RD children take longer to respond to the stop-signal because they have not finished processing the go stimulus. Thus, ADHD children may have a more pervasive inhibitory deficit resulting in behavioral impulsivity, whereas RD children may have difficulty inhibiting due to difficulties processing rapidly presented information.

Despite the findings of a stronger main effect of RD (vs. ADHD) on SSRT, the inhibition variables of both the Stop and CPT produced a greater number of significant correlations with ADHD symptom ratings than with variables associated with RD (reading scores and phonological
variables). This pattern of correlations suggests performance on these tasks is more closely associated with the observed behavioral deficits of ADHD than with the performance deficits of RD. This supports the position that deficient inhibition in ADHD may be related to impulsivity, while in RD inhibition on the Stop task is related to sequential processing skills. To test this hypothesis it would have been beneficial to have a measure of rapid sequential processing to determine if inhibition in RD children is related to this skill.

**IV. 2.3 Inhibitory Control, Response Execution and ADHD**

According to the race model of inhibition, poor inhibitory control could result from responding too quickly to the go-signal or responding too slowly to the stop-signal (Logan, 1994). Children with RD did not differ in terms of primary task reaction times; therefore their longer stop-signal reaction times do not appear to be a result of generally slowed motor processing. However, children with ADHD, in addition to having longer SSRTs, were slower and more variable in responding to the go-signal. This slowed choice reaction time has been found in many studies with ADHD children (e.g., Corkum & Siegel, 1993; Oosterlaan & Sergeant, 1998; Sergeant & Scholten, 1985, Schachar, et al., 1995). As well, a significant correlation ($r = .48$) was found between primary (go-task) and inhibition latencies. This raises the question about the nature of the cognitive deficit underlying ADHD: whether it is a generalized deficit in the speed of processing and responding or whether it is a more specific deficit in inhibitory control. Previous studies using different versions of the Stop task have suggested that slow stop-signal reaction time is responsible for poor impulse control and that inhibition and go-task latencies are independent (Schachar & Logan, 1990; Schachar et al., 1995). For instance these studies have shown that ADHD children inhibit less often than control children, even though their go-signal
reaction times are longer than those of controls, and they did not find a significant correlation between go-signal reaction time and SSRT (Schachar & Logan, 1990; Schachar et al., 1995). In addition, in an acute trial of methylphenidate with ADHD children, a different dose-response relationship between go-task and stop-task latencies was found (Tannock, Schachar & Logan, 1995).

Examination of the results of the CPT also found children with ADHD to be slower than non-ADHD children in responding to the primary task at 2 and 4 second interstimulus intervals. Moreover, the number of commission errors and commission error reaction time were found to be significantly correlated with primary task reaction time on both the Stop task and CPT. These results argue against a specific deficit in inhibition, and support the position of a more generalized deficit in speed of motor responses or response organization. Examination of simple correlations between parent and teacher behavior ratings and Stop Task and CPT measures also argue against inhibitory control, and point to a more generalized deficit in response organization. Although significant correlations were found between parent and teacher ratings and both inhibition and primary task measures, the inhibition measures were not always significantly correlated with the behavior ratings. If inhibitory control were the main deficit underlying the various difficulties of ADHD children as Barkley (1997) has argued, one would expect inhibition measures to be closely related to the observed behavioral difficulties.

IV. 3 Specificity of ADHD Deficits

Despite the findings of an inhibitory deficit in RD, a dissociation between ADHD and RD was still found. Only main effects of ADHD (no main effects of RD) were found for speed or variability of primary task response, number of valid responses, number of commission errors and
commission error reaction time. On the executive function tasks, children with RD, were only found to exhibit a longer SSRT. The generalized deficits in response organization were not only dissociated from RD, but they also appear to be unrelated to other comorbid disorders as reflected in the lack of significant correlations between parent and teacher behavior ratings and performance on all aspects of the Stop task and CPT. As described earlier, significant correlations were found between ADHD ratings and both primary and inhibitory aspects of the two tasks. No significant relationships were found between symptoms of Oppositional Defiant Disorder, Conduct disorder, Overanxious disorder, Separation Anxiety disorder or general emotional dysfunction and performance on the Stop and CPT. Significant correlations were found between ratings of Depression and performance but as stated earlier, there is considerable overlap between ADHD and depressive behaviors. These findings support the specificity of the generalized response deficits found on these two tasks with ADHD and not just with the presence of clinical status. In addition, they confirm the literature which suggests that tasks such as the CPT and those involving motor response, rather than general neuropsychological tasks, produce the most consistent deficits in ADHD children (Barkley & Grodzinsky, 1994; Barkley et al., 1992; Pennington & Ozonoff, 1996).

IV. 4 Specificity of Inhibitory Control

Inhibitory control, or the inability to inhibit inappropriate responding has been posited to be a fundamental component of executive functions (Barkley, 1994; 1997; Milich et al., 1997, Pennington & Ozonoff, 1996; Quay, 1997). Barkley (1997) has argued that deficits in response inhibition lead to secondary impairments in four executive functions including working memory, internalization of speech, self-regulation of affect, motivation, arousal and reconstitution.
Impairment in these executive functions result in disturbances in self-control and goal directed behavior and in generally less adaptive behavior (Pennington & Ozonoff, 1996; Torgesen, 1994). Although poorer inhibitory control has been posited as a marker of externalizing disorders in general (Oosterlaan & Sergeant, 1996), other researchers have suggested that it is more characteristic of ADHD than other disturbances such as conduct disorders, emotional disturbance and autism (Barkley, 1997; Milich et al., 1994; Pennington & Ozonoff, 1996; Schachar, & Logan, 1990; Werry, Elkind & Reeves 1987). Clearly if an individual is slower or less able to inhibit a response, there is decreased control of behavior, that individual will appear impulsive in a range of situations. It is this behavioral impulsivity that has been linked most closely with the clinical diagnosis, degree of impairment and negative outcomes of ADHD children (Fischer et al., 1993; Frick et al., 1993). However, the link between behavioral impulsivity as reported by parents and teachers and cognitive inhibition on these laboratory measures is as yet unclear. Not all children labeled as ADHD exhibit deficits on laboratory measures of inhibition. In this study, all clinical groups were roughly equivalent in terms of the number of children being 1 standard deviation above the mean in terms of stop-signal reaction time (approximately half of all clinical groups), indicating that performance on this task, as it stands, cannot be used as a cognitive marker for ADHD. In addition, ADHD children were found to exhibit deficits on non-inhibitory aspects of both the Stop and CPT tasks.

One of the strongest findings of this study in relation to ADHD was variability of reaction time. This variability is often considered noise but in the ADHD literature it is the most consistent finding associated with ADHD particularly when motor decision or effortful response organization is required (e.g., Barkley, 1997; Chee, Logan, Schachar, Lindsay & Wachsmuth,
1989). Even in terms of the ability to inhibit on versions of the Stop paradigm, children with ADHD have been shown to exhibit more variable inhibitory control than non-ADHD children (Chee et al., 1989). High degrees of variable responding may account, in part, for the striking inability of the vast literature on ADHD to pinpoint specific and unique cognitive markers of ADHD. One can hypothesize how this variability may be related to executive functions. These functions generally refer to self-regulatory processes involved in the planning of thought and action to flexibly guide actions in the pursuit of goal-directed behavior (Dennis, 1991; Logan, 1985; Luria 1966). This encompasses a wide range of behaviors and the inability to consistently maintain, control, and apply all necessary internal and external components quickly and efficiently, could result in inconsistent failures as well as inconsistent successes. In other words, this inconsistency reflects failures of self-regulation. Unfortunately, variability remains a description of observations, not a theory of the basic nature of ADHD. Future research would benefit from the examination of the role of variability itself in the performance of ADHD children.

IV. 5 Hypotheses of Comorbidity

With regard to comorbidity, this study did not support the phenocopy hypothesis put forward by Pennington and associates (Pennington et al., 1993), that suggested that in children diagnosed with both ADHD and RD, primary RD leads to secondary ADHD symptomatology but not the core cognitive deficits. Rather, the current study supported the etiologic subtype hypothesis in which the comorbid group exhibited the deficits of both single groups in a generally additive fashion. In other words, children diagnosed with both ADHD and RD exhibited the phonological deficits and inhibitory control deficits associated with RD-only and the motor response deficits of the ADHD-only group. The only exception was in terms of omission errors on the CPT (which
are thought to reflect attentional difficulties) wherein the ADHD+RD group were impaired relative to all other groups. The results reported in this study may have differed, in part, due to sample source. Subjects from Pennington et al. (1993) were children referred to a University clinic to which many children with learning disabilities were referred. ADHD subjects in the current study were clinic referred, resulting in children who have a higher likelihood of overlapping cognitive deficits (Shaywitz et al., 1994). However, these results also differ from those of Hall and colleagues (1997) who found executive function deficits in terms of motor/decision response organization in ADHD-only children but not in those with ADHD+RD in clinic-referred children. This study consisted of only 11 ADHD+RD children and additional diagnoses are not given, nor are symptom counts for ADHD so it is unclear if the two ADHD groups were equivalent in terms of severity of ADHD symptomatology.

The finding that the comorbid group exhibited the deficits of both single groups in a purely additive fashion suggests that the effect of having both disorders is generally not synergistic. With the sole exception of omission errors, the comorbid group did not differ significantly from either the ADHD-only or the RD-only groups. However, examination of the means for variability, stop-signal reaction time, and commission error reaction time suggests that the comorbid group was in fact more variable, and had longer reaction times than either of the two single disorders. It is possible that a differences were not detected due to small sample sizes. Future research with larger samples or with different statistical techniques (e.g. planned contrasts) may find that the effect of having both ADHD and RD is greater than the sum of impairments of the two disorders alone.
In this study, the two ADHD groups were equated in terms of severity of ADHD symptoms. Unfortunately, many of the studies published which have found the comorbid group to exhibit deficits distinct from either the two single groups have not reported severity levels in terms of ADHD symptoms, making it difficult to determine whether the results are related to severity or to comorbidity (e.g., Hall et al., 1997). The possible confounding of severity and comorbidity highlights the need for investigators to clearly identify and describe groups of children both in terms of classification systems and in terms of actual degrees of impairment on independent measures.

IV. 6 Locus of Control

In addition to deficits in motor response organization, children with ADHD were found to be differentiated from children with RD in terms of locus of control. ADHD children were more likely than non-ADHD children to believe that, in general, causes for success and failure are external and uncontrollable. Previous studies which have examined ADHD and LD separately, have found greater externality in both these disorders but they did not control for the presence of overlapping disorders (e.g., Linn & Hodge, 1982; Lufi & Parish-Plass, 1995; Pearl et al., 1982). These findings contradict the one other study with a similar design, comparing ADHD and LD children which found children with LD (LD and ADHD+LD) to have a more external locus of control (Tarnowski & Nay, 1989). This study did not report mean ADHD symptoms or scores for each group so it is not clear how differentiated the groups were in terms of severity. In addition, LD was defined simply as a discrepancy between IQ and achievement, which can result in some children, labeled as LD who are achieving in the normal range. Thus it is not clear how the groups of children compared to the groups in the current study.
The locus of control measure used in the current study assessed general attributions for success and failure. Other measures tap attributions related to specific areas of functioning such as those related to learning situations. It is possible that ADHD and RD children differ in terms of the areas about which they feel more or less in control of events. Future studies investigating attributional style would benefit from investigating specific areas of functioning to determine the role of attributions on performance in different domains.

It has been hypothesized that the failure experiences of the typical ADHD child can lead to the development of beliefs about inevitable helplessness and to a lower sense of self-efficacy (Bandura, 1977; Reid & Borkowski, 1987). Moreover, attributional training, designed to alter beliefs about causes for success and failure has been demonstrated to increase the use of complex strategies, increase beliefs in effort and reduce impulsivity in severely hyperactive children (Reid & Borkowski, 1987). The question now arises as to the relationship between locus of control and executive control in ADHD children. Are the executive control deficits purely a result of a neurological dysfunction or in time do basic cognitive deficits result in more generalized and cumulative difficulties (Stanovich, 1986)? In other words, it is unclear whether external attributions contribute to impaired performance in ADHD children, or whether the external attributions reflect an accurate assessment of their difficulties in controlling their behavior. Examination of the correlations between locus of control and both cognitive measures and behavior ratings found significant but low correlations with all cognitive measures in the study suggesting some non-specific relationship between attributions and performance. Moreover, despite the higher external beliefs of ADHD children, locus of control was not generally correlated with ADHD symptoms or emotional ratings and only a small relationship with parent
rated conduct problems was found. These correlations suggest a relationship between attributions and performance on cognitive tasks but not with behavioral measures of ADHD.

IV. 7 Limitations

The findings of this study should be interpreted in view of its limitations. Differences existed in terms of comorbidity for other disorders such as higher rates of Overanxious disorder in RD children and as expected, higher rates of conduct and oppositional disorders in ADHD children. In a meta-analysis of studies of inhibition, Oosterlaan, Logan and Sergeant (1998) have found anxiety disorders not to be associated with impaired inhibition and that children with ADHD did not differ from those with co-occurring CD. These results suggest that patterns of comorbidity may not have impacted on the findings but future research controlling for comorbidities would be more conclusive. In addition, the groups in this study differed in terms of proportion of males to females with more males in the two ADHD groups. In a developmental study, no differences were found between males and females in terms of stop-signal reaction time (Williams et al., 1999). However, a recent study examining the differences in males and females found longer SSRTs in females diagnosed with ADHD (Vigod & Ickowicz, 1998). In the current study, the presence of a larger percentage of males in the ADHD groups may have lead to more conservative findings with regard to SSRTs. Future research would benefit from controlling for gender differences between groups.

In addition, to investigating the influence of further classifications according to comorbidity and gender, future research based on DSM-IV subtypes may provide unique insights into inhibitory control and hyperactivity/impulsivity versus inattention. Inhibitory control is posited to underlie the behavioral symptoms of impulsivity; therefore research investigating inhibitory
control in inattentive versus the combined type of children with ADHD may provide a test of this hypothesis.

A further limitation with respect to diagnostic issues lies in the different procedure by which the RD-only group was ascertained. The two ADHD groups were obtained from clinical samples, whereas the RD-only group consisted of a non-clinical sample of volunteers. As stated earlier, clinical samples may reflect a more severely impaired subgroup of children than non-referred children. In addition, clinical samples are also more likely to include children with comorbid diagnoses. Thus, the RD-only and ADHD-only children may have differed in more areas than those upon which group classification was decided. This in turn may have artificially inflated differences between the groups.

In terms of the phonologicaI processing, performance on these tasks may have been confounded with spelling ability, particularly for the more complex tasks. Although the subjects were instructed to work with the sounds in words, it is possible that the ability to visualize a written form of the word offered assistance to children performing the task. Further, although spelling ability was not assessed, it is likely that the non-RD children were better spellers and thus may have had an added advantage. This confounding of spelling and phonological abilities may be inherent in all but the most simple of phonological tasks. Future studies would benefit from examining the spelling abilities of subjects and the contribution of this skill to performance on phonological processing tasks.

Lastly, this study presented the relationships between variables (both independent and dependent) in terms of correlations. More flexible regression procedures would allow for the investigation of the interrelationships amongst the variables and might provide more information
concerning their relative influence. Regression models require larger sample sizes than those used in this study, and thus future studies may be better able to address these relationships.

IV. 8 Implications

Attention Deficit Hyperactivity Disorder is one of the most common sources of referrals to child mental health facilities and is one of the most intensively studied disorders in childhood psychopathology. Despite this high profile, ADHD remains a behaviorally diagnosed disorder. Recently, theories of ADHD have emerged which have attempted to address the underlying basic nature of the behavioral disturbances observed in children diagnosed with this disorder. In particular, deficient response inhibition has been posited to be specifically and uniquely associated with ADHD and to underlie neuropsychological processes referred to as executive functions. Although the present study yielded evidence in support of a response inhibition deficit in ADHD, it was also found to be associated with RD. In addition, the findings of general slowed motor responding and high variability suggest that perhaps a broader explanation is required. Descriptions of what constitutes executive functions and particularly self-regulation appear on the surface to capture the inconsistent nature of ADHD. Perhaps it is the inconsistency itself which has plagued researchers across and within studies that is the appropriate locus for further research into the basic underlying cognitive nature of ADHD.

It should be noted that this research would benefit from investigations into modular cognitive processes, rather than global ones involving many underlying cognitive processes which confound interpretation of deficits. Since non-modular tasks involve a range of abilities, they will less likely result in disorder-specific deficits. The Stop task possibly confounded sequential processing with inhibition, but it stands as a good model for future paradigms since it involved very simple and
specific requirements which were quantifiable. The goal for future research should be to develop theory-driven paradigms such as this which will advance our understanding of the basic nature of ADHD.

The finding that children with ADHD tend to have more external attributions raises the question as to what degree are impairments in performance the result of hard-wired neuropsychological impairments and to what degree personality variables are involved. Longitudinal research investigating the development of attributions over time may help clarify cause and effect relationships between these variables.

No doubt, some of the inconsistency across studies has resulted from issues of classification, which makes it imperative that researchers clearly define groups and subgroups of ADHD children. Critical issues of definition are central to all other considerations if appropriate interpretations and comparisons are to be drawn from multiple studies. Understanding comorbidity is one way in which researchers attempt to define more homogeneous subgroups of ADHD children. In the current study, the cognitive deficits of RD were clearly differentiated from those of children with ADHD. The finding that the comorbid children exhibited deficits associated with both single disorders has both implications for treatment and practice. Underachievement in ADHD children should not be merely attributed to behavioral difficulties, but rather should be investigated independently. Further, it would be advisable in children in which the two disorders co-occur, that each set of difficulties be addressed in treatment. Not only does ADHD overlap to a considerable degree with reading and learning disorders but it has considerable comorbidity with other disorders such as anxiety and conduct disorder. Further research examining patterns of comorbidity with other disorders, particularly with regard to
inhibition could help to revise and improve existing methods of classification and the understanding of the nature of ADHD.
V References


APPENDIX A

DIAGNOSTIC CRITERIA FOR DISORDERS

ATTENTION DEFICIT HYPERACTIVITY DISORDER (ADHD)

Parent Variables:
1. Parent OCHS ADHD (sum ≥ 15)
2. Rutter HYPER (sum ≥ 4)
3. Snap INATTENTIVE (sum ≥ 3)
4. Snap IMPULSIVITY (sum ≥ 3) and HYPERACTIVITY (sum ≥ 2)

Teacher Variables:
1. Teacher OCHS ADHD (sum ≥ 16)
2. Rutter HYPER (sum ≥ 4)
3. Snap INATTENTIVE (sum ≥ 3)
4. SNAP IMPULSIVITY (sum ≥ 3) and HYPERACTIVITY (sum ≥ 2)

Criteria: Child must achieve a cut-off score on at least 2 of 4 variables on Parent or Teacher variables plus at least 1 from other situation (home or school). Child can also be previously diagnosed at Hospital for Sick Children.

OPPOSITIONAL DEFIANT DISORDER (ODD)

Parent Variables:
   a) Parent OCHS ODD (sum ≥ 8.5)
   b) Rutter CD (sum ≥ 4) (this refers to oppositional, not conduct disorder)

Teacher Variables:
   a) Teacher OCHS ODD (sum ≥ 7.2)
   b) Rutter CD (sum ≥ 4)

Criteria: Child must meet cut-off score on 2 of 4 of these variables.

CONDUCT DISORDER (CD)

Parent Variables:
   a) Parent OCHS CD (sum ≥ 3)

Teacher Variables:
   a) Teacher OCHS CD (sum ≥ 3)

Criterion: Child must meet cut-off on 1 of these variables.
Appendix A (cont’d)

OVERANXIOUS DISORDER/GENERALIZED ANXIETY DISORDER (OANX)

Parent Variables:
  a) Parent OCHS OANX (sum ≥ 6)
  b) Rutter EMOTIONAL (sum ≥ 4)

Teacher Variables:
  a) Teacher OCHS OANX (sum ≥ 5)
  b) Rutter EMOTIONAL (sum ≥ 4)

Criteria: Child must meet cut-off on at least 1 of 4 of these variables.

CHILD IDENTIFIED ANXIETY DISORDER (CANX)

1. Revised Children’s Manifest Anxiety Scale (RCMAS) (t-score ≥ 60)

SEPARATION ANXIETY DISORDER (SAD)

Parent Variables:
  a) Parent OCHS SANX (sum ≥ 6)
**APPENDIX B**

ID#: ______  1st Name: ___________  C.A. = ______  Date: ______  Day: ____

(d/m/y)

**ROSNER AUDITORY ANALYSIS TEST - FORM 1**

Instructions and Examples:

A. Say "cowboy". Now say it again without the "boy".
B. Say "toothbrush". Now say it again without "tooth".

**Scoring**: Circle number for correct response; slash for incorrect and write response.

**Ceiling**: Discontinue after four consecutive errors.

<table>
<thead>
<tr>
<th>1. birth(day)</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. (car)pet</td>
<td>II</td>
</tr>
<tr>
<td>3. bel(t)</td>
<td>III</td>
</tr>
<tr>
<td>4. (m)an</td>
<td>IV</td>
</tr>
<tr>
<td>5. (b)lock</td>
<td>V</td>
</tr>
<tr>
<td>6. to(ne)</td>
<td>III</td>
</tr>
<tr>
<td>7. (s)our</td>
<td>IV</td>
</tr>
<tr>
<td>8. (p)ray</td>
<td>V</td>
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<tr>
<td>9. stea(k)</td>
<td>III</td>
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<tr>
<td>10. (l)end</td>
<td>IV</td>
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<tr>
<td>11. (s)mile</td>
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<tr>
<td>12. plea(se)</td>
<td>III</td>
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<td>13. (g)ate</td>
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<td>14. (c)lip</td>
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<tr>
<td>15. ti(me)</td>
<td>III</td>
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<tr>
<td>16. (sc)old</td>
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<tr>
<td>17. (b)reak</td>
<td>V</td>
</tr>
<tr>
<td>18. ro(de)</td>
<td>III</td>
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<tr>
<td>19. (w)ill</td>
<td>IV</td>
</tr>
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<td>20. (t)rail</td>
<td>V</td>
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</table>

| 21. (sh)rug   | V  |
| 22. g(l)ow    | VI |
| 23. cr(e)ate  | VII|
| 24. (st)rain  | V  |
| 25. s(m)ell   | VI |
| 26. Es(ki)mo  | VII|
| 27. de(s)k    | VI |
| 28. Ger(ma)ny | VII|
| 29. st(r)eam  | VI |
| 30. auto(mo)ble | VII |
| 31. re(pro)duce | VII |
| 32. s(m)ack   | VI |
| 33. phi(lo)sophy | VII |
| 34. s(k)in    | VI |
| 35. lo(ca)tion | VII|
| 36. cont(in)ent | VII |
| 37. s(w)ing   | VI |
| 38. car(pen)ter | VII |
| 39. c(l)utter | VI |
| 40. off(er)ing | VII |
**Phoneme Segmentation Task**

**Instructions:** I'm going to ask you to tell me what sounds you hear in nonsense words. For example, in the word "fod", the sounds you hear are f-o-d. Say "bip". What sounds do you hear in "bip".

<table>
<thead>
<tr>
<th>3 Sounds</th>
<th>5 Sounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. hib</td>
<td>17. dobit</td>
</tr>
<tr>
<td></td>
<td>d-o-b-i-t</td>
</tr>
<tr>
<td>2. zun</td>
<td>18. tegop</td>
</tr>
<tr>
<td></td>
<td>t-e-g-o-p</td>
</tr>
<tr>
<td>3. yek</td>
<td>19. sappon</td>
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<tr>
<td></td>
<td>s-a-p-o-n</td>
</tr>
<tr>
<td>4. hif</td>
<td>20. fabbin</td>
</tr>
<tr>
<td></td>
<td>f-a-b-i-n</td>
</tr>
<tr>
<td>5. kun</td>
<td>21. videb</td>
</tr>
<tr>
<td></td>
<td>v-i-d-e-b</td>
</tr>
<tr>
<td>6. yev</td>
<td>22. zokis</td>
</tr>
<tr>
<td></td>
<td>z-o-k-i-s</td>
</tr>
<tr>
<td>7. sek</td>
<td>23. pillad</td>
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<tr>
<td></td>
<td>p-i-l-a-d</td>
</tr>
<tr>
<td>8. keb</td>
<td>24. guddif</td>
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<td></td>
<td>g-u-d-i-f</td>
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<th>4 Sounds</th>
<th>5 Sounds</th>
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<tr>
<td>9. fless</td>
<td>25. glefs</td>
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<tr>
<td></td>
<td>g-l-e-f-s</td>
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<tr>
<td>10. dibl</td>
<td>26. krilm</td>
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<td></td>
<td>k-r-i-l-m</td>
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<td>11. lekt</td>
<td>27. prots</td>
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<td></td>
<td>p-r-o-t-s</td>
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<td>12. plin</td>
<td>28. stind</td>
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<td></td>
<td>s-t-i-n-d</td>
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<td>13. gless</td>
<td>29. zlaft</td>
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<td>14. kefl</td>
<td>30. vrilm</td>
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<td>v-r-i-l-m</td>
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<tr>
<td>15. leks</td>
<td>31. skilp</td>
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<td></td>
<td>s-k-i-l-p</td>
</tr>
<tr>
<td>16. slod</td>
<td>32. plist</td>
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<td></td>
<td>p-l-i-s-t</td>
</tr>
</tbody>
</table>
The Nowicki-Strickland Internal-External Control Scale for Children

1. Do you believe that most problems will solve themselves if you just don’t fool with them?

   (YES)   (NO)

2. Do you believe that you can stop yourself from catching a cold?  (N)

3. Are some kids just born lucky?  (Y)

4. Most of the time do you feel that getting good grades means a great deal to you?  (N)

5. Are you often blamed for things that just aren’t your fault?  (Y)

6. Do you believe that if somebody studies hard enough he or she can pass any subject?  (N)

7. Do you feel that most of the time it doesn’t pay to try hard because things never turn out right anyway?  (Y)

8. Do you feel that if things start out well in the morning that it’s going to be a good day no matter what you do?  (Y)

9. Do you feel that most of the time parents listen to what their children have to say?  (N)

10. Do you believe that wishing can make good things happen?  (Y)

11. When you get punished does it usually seem it’s for no good reason at all?  (Y)

12. Most of the time do you find it hard to change a friend’s (mind) opinion?  (Y)

13. Do you think that cheering more than luck helps a team to win?  (N)

14. Do you feel that it’s nearly impossible to change your parent’s mind about anything?  (Y)

15. Do you believe that your parents should allow you to make most of your own decisions?  (N)

16. Do you feel that when you do something wrong there’s very little you can do to make it right?  (Y)

17. Do you believe that most kids are just born good at sports?  (Y)

18. Are most of the other kids your age stronger than you are?  (Y)

19. Do you feel that one of the best ways to handle most problems is just not to think about them?  (Y)
20. Do you feel that you have a lot of choice in deciding who your friends are? (N)

21. If you find a four leaf clover do you believe that it might bring you good luck? (Y)

22. Do you often feel that whether you do your homework has much to do with what kind of grades you get? (N)

23. Do you feel that when a kid your age decides to hit you, there's little you can do to stop him or her? (Y)

24. Have you ever had a good luck charm? (Y)

25. Do you believe that whether or not people like you depends on how you act? (N)

26. Will your parents usually help you if you ask them to? (N)

27. Have you felt that when people were mean to you it was usually for no reason at all? (Y)

28. Most of the time, do you feel that you can change what might happen tomorrow by what you do today? (N)

29. Do you believe that when bad things are going to happen they just are going to happen no matter what you try to do to stop them? (Y)

30. Do you think that kids can get their own way if they just keep trying? (N)

31. Most of the time do you find it useless to try to get your own way at home? (Y)

32. Do you feel that when good things happen they happen because of hard work? (N)

33. Do you feel that when somebody your age wants to be your enemy there's little you can do to change matters? (Y)

34. Do you feel that it's easy to get friends to do what you want them to? (N)

35. Do you usually feel that you have little to say about what you get to eat at home? (Y)

36. Do you feel that when someone doesn't like you there's little you can do about it? (Y)

37. Do you usually feel that it's almost useless to try in school because most other children are just plain smarter than you are? (Y)

38. Are you the kind of person who believes that planning ahead makes things turn out better? (N)

39. Most of the time, do you feel that you have little to say about what your family decides to do? (Y)

40. Do you think it's better to be smart than to be lucky? (N)

Note: External response shown in parentheses; Item 1, External response = YES