Halstead Category Test and Wisconsin Card Sorting Test performances of children with attention deficit hyperactivity disorder and those exhibiting the syndrome of nonverbal learning disabilities.

Corinne Hardy-Morais
University of Windsor

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HALSTEAD CATEGORY TEST AND WISCONSIN CARD SORTING TEST PERFORMANCES OF CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER AND THOSE EXHIBITING THE SYNDROME OF NONVERBAL LEARNING DISABILITIES

By

Corinne Hardy-Morais

B.Sc. University of Michigan, 1994

A Thesis Submitted to the College of Graduate Studies and Research through the Department of Psychology in Partial Fulfillment of the Requirements for the Degree Of Master of Arts at the University of Windsor.

Windsor, Ontario, Canada 2000
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This work is dedicated in loving memory of my father,

Duane E. Hardy.
ABSTRACT

This study was designed to explore higher-order reasoning skills and executive-type functioning in children diagnosed with the syndrome of Nonverbal Learning Disabilities (NLD), and those evidencing Attention Deficit Hyperactivity Disorder (ADHD). To this end, Halstead Category Test (HCT) and Wisconsin Card Sorting Test (WCST) performances of 16 ADHD and 16 NLD children matched for verbal IQ and handedness were investigated. As predicted, the ADHD group made significantly fewer errors on the HCT than did the NLD group. In addition, the ADHD group significantly outperformed the NLD group on the majority of WCST variables with the exception of Failure to Maintain Set (FTMS) and Learning to Learn (LTL) scores. These findings suggest that while children with NLD exhibit difficulty reasoning abstractly and are perseverative in their approach to cognitive tasks, those with ADHD are quite adept at conceptual-level reasoning and display adequate cognitive flexibility. The results of this study support the notion that the behavior of individuals with NLD is guided more by internal mechanisms, whereas the behavior of individuals with ADHD appears to be more externally driven.
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CHAPTER 1
Introduction

The first scientific reference made to cognitive and behavioral difficulties in children can be traced to the turn of the century when Still (1902) reported a pattern of behaviors characterized by overactivity and impulsivity which he described as "morbid defects in moral control" (cited in Epstein, Shaywitz, Shaywitz, & Woolston, 1991). Although Still's notions of etiology remained poorly defined, implicit in his description was the idea that the observed behaviors were the result of neurological dysfunction as opposed to environmental influences. Predicated on this notion, during the 1930s researchers in this area began exploring the relationship between childhood behavioral problems and central nervous system injury (Goldstein, 1936), dysfunction (Kahn & Cohen, 1934), and disease (Bender, 1942).

In a series of papers published during the 1940s, Strauss and colleagues formulated the conceptual entity of the brain-injured child, a clinical syndrome characterized by a variety of behaviors similar to those described by Still (Werner & Strauss, 1941; Strauss & Lehtinen, 1947). By the middle of the century, the term minor brain damage was in vogue, but was quickly replaced by minimal brain
dysfunction (MBD), and was extended to incorporate a wide range of behaviors including emotional difficulties, hyperactivity, short attention span, and poor academic performance (Laufer & Denhoff, 1957; Clements & Peters, 1962).

Although the MBD paradigm enjoyed continued popularity well into the 1970s, it was eventually criticized for its lack of rigorous diagnostic criteria, and its "loose conglomerate of behavioral and learning symptomatology" created confusion in both scientific and clinical arenas (Epstein et al., 1991, p. 79). Reflecting this confusion, a clear division developed in the way educational and medical communities studied the disorder, with the former concentrating primarily on elucidating academic and language difficulties, and the latter focusing almost exclusively on investigating problems in sustained attention, hyperkinesis, and impulse control (Epstein et al., 1991). As a result of this schism, the term MBD was eventually abandoned in favor of "separate designation of children as 'learning disabled' or with 'attention deficit disorder'" (Fletcher, Shaywitz, & Shaywitz, 1994, p. 109). The fact that these disorders share a common history underscores the importance of elucidating the similarities and differences between ADHD and specific learning
disabilities (LD). Eventually, it is hoped that this process will lead to accurate diagnostic procedures, which will in turn assist in the development and implementation of appropriate and effective treatment protocols.

In recent years, considerable attempts have been made to differentiate ADHD from various learning disabilities in terms of physiological, behavioral, and cognitive manifestations. Despite these attempts, a great deal of controversy remains; particularly with respect to the cognitive substrates of each disorder. Over the course of the past decade, several studies have compared neuropsychological functioning of children with ADHD and children with various verbal learning disabilities (VLD) (e.g. Felton, Wood, Brown, & Campbell, 1987; McGee, Williams, Moffitt, & Anderson, 1989; Douglas & Benezra, 1990). In contrast, few, if any, studies have investigated neuropsychological functioning of children with ADHD as compared to children evidencing the syndrome of nonverbal learning disabilities (NLD). The present study will address this issue.

It is hypothesized that on two measures of higher order reasoning and executive functioning, namely the Halstead Category Test (HCT; Reitan & Davison, 1974) and the Wisconsin Card Sorting Test (WCST; Heaton, Chelune,
Talley, Kay, & Curtiss, 1993), each group of children will display a distinct pattern of performance. As will be discussed in greater detail later, based on the notion that children with ADHD demonstrate difficulty adhering to internally represented information within the context of well-developed exploratory skills, it is predicted that children with ADHD will outperform children with NLD on all aspects of both measures with the exception of Failure to Maintain Set and Learning to Learn indices of the WCST. We now turn to a review of the theoretical models and past findings giving rise to these predictions.

**The Syndrome of Nonverbal Learning Disabilities**

Children with NLD exhibit a distinct neuropsychological profile characterized by impaired tactile-perceptual skills, poor psychomotor coordination, diminished visuospatial abilities, and impaired problem solving skills, within the context of intact rote verbal abilities (Rourke, 1989). Given this neuropsychological ability structure, these children exhibit extreme difficulty adapting to novel and otherwise complex situations, and demonstrate an overreliance on prosaic, rote, and often inappropriate behaviors under such circumstances. As a result, children with NLD show significant deficits in social perception, social judgment,
and social interaction skills, and are at an increased risk for the development of 'internalized' forms of psychopathology (Harnadek & Rourke, 1994).

Based on Goldberg and Costa's (1981) model of hemispheric specialization, Rourke (1989) theorized that the NLD syndrome may result from white matter dysfunction, which is hypothesized to result in greater disruption to right hemisphere systems than to systems within the left hemisphere. Following is a review of the Goldberg-Costa (1981) model, and its relationship to the white matter model of NLD.

Research on hemispheric specialization has led to a well-accepted distinction between the two cerebral hemispheres: the left hemisphere is specialized for processing linguistic information, while the right hemisphere is better equipped to handle visuospatial material. Although this assumption has "acquired the entrenched status of a truism," Goldberg and Costa (1981) challenged this classic dichotomy (Goldberg & Podell, 1995 p. 85). These theorists introduced a unique approach to the topic of hemispheric specialization, commonly referred to as the novelty-routinization hypothesis. In an article addressing this topic, Goldberg and Costa (1981) reviewed neuroanatomical evidence indicating that the
cytoarchitecture of the left hemisphere makes it particularly well-suited for handling cognitive tasks involving intramodal processing, whereas the structural organization of the right hemisphere makes it particularly adept at intermodal integration. More specifically, Goldberg and Costa (1981) noted that the left hemisphere is more focally organized, given its prominent modality specific cortical areas (i.e. the opercula), and a predominantly intraregional pattern of connections. In contrast, the right hemisphere is considered to be more diffusely organized, given its greater representation of association areas, and a predominantly interregional pattern of connectivity (evidenced by a lower ratio of gray-to-white matter). These structural differences, coupled with neuropsychological and neurobehavioral evidence, led Goldberg and Costa to argue that the left hemisphere has a greater capacity for dealing with tasks involving storage and stereotypic application of well-routinized cognitive strategies, while the right hemisphere is particularly well-suited to handle exploratory processing of novel situations in which no preexisting descriptive system is available.

As mentioned previously, Rourke (1989) applied this theory of hemispheric specialization to his white matter
model of NLD. According to Rourke, the mechanism underlying the NLD syndrome (which as discussed earlier is characterized by deficiencies in the capacity to deal with novel, ambiguous, and nonroutinized material) may be white matter dysfunction which would, according to Goldberg and Costa, eventuate in greater compromise to right hemisphere systems than to systems within the left hemisphere.

Based on Piaget's (1954) theory of intellectual development, Rourke and his colleagues (Strang & Rourke, 1983) made specific predictions regarding nonverbal reasoning skills in children with NLD. According to Piaget (1954), the behavioral acquisitions made during the sensorimotor stage of development (the first two years of life) underlie the subsequent development of higher-order intellectual abilities. Piaget's description of the cardinal activities taking place during sensorimotor development "serves to highlight the significance of tactile-perceptual, psychomotor, and visual-perceptual-organizational functions for the infant and young child" (Strang & Rourke, 1983, p.35). Predicated on the assumption that the majority of children with NLD suffer the ill-effects of their cognitive deficiencies (tactile perceptual, psychomotor, and visual-perceptual-organizational impairment) from birth, Strang and Rourke
(1983) hypothesized that these deficits would have a profound negative impact on the subsequent development of cognitive skills not easily mediated by language (e.g. higher-order analysis, synthesis, and organization).

To test this hypothesis, Strang and Rourke (1983) conducted a study investigating higher order deductive reasoning in children with NLD. Consistent with their predictions, children with NLD in this study made significantly more errors on the HCT (a measure of nonverbal concept formation and higher-order reasoning) than did children with various reading and spelling disabilities. More recently, based on the idea that children with NLD evidence difficulty dealing with novelty, but are quite adept at applying routinized cognitive strategies, Fisher, DeLuca, and Rourke (1997) hypothesized that children with NLD would perform poorly on measures of abstract reasoning and 'cognitive flexibility', but would perform rather well on a measure requiring the continued application of a previously established cognitive rule. Supporting their hypotheses, the results of this investigation revealed that, relative to children exhibiting verbal learning disabilities, children with NLD performed poorly on the HCT, and produced a greater number of perseverative responses/errors on the WCST. In
contrast, but also in accord with their hypotheses, the NLD group did not differ significantly from the VLD group on those indices of the WCST measuring cognitive set maintenance (Failure to Maintain Set) and the ability to benefit from repeated exposure to nonverbal material (Learning in to Learn). Consistent with what would be predicted based on their behavioral pattern and neuropsychological ability structure, children with NLD appear to exhibit difficulty performing tasks requiring higher-order abstract reasoning and cognitive 'set switching', but demonstrate relative facility maintaining a correct pattern of responding once achieved.

With respect to the current investigation, it is of particular relevance to note that children who exhibit the syndrome of NLD are often perceived as hyperactive during early childhood, but become less so with advancing years (Rourke, 1989). Thus, in many cases, these children may initially appear to present with symptoms of ADHD, and are likely to be 'misdiagnosed' as such unless a full neuropsychological evaluation is conducted. Again, this occurrence underscores the necessity of differentiating these two groups in terms of neuropsychological patterns of performance, including performances on measures of higher order reasoning and executive functioning.
Attention Deficit Hyperactivity Disorder

Attention deficit disorder (ADD), or more recently attention deficit hyperactivity disorder (ADHD), is characterized by developmentally inappropriate levels of inattention, impulsivity, and/or hyperactivity. These behavioral deficits arise relatively early in childhood (before the age of 7 years), and are considered to be fairly chronic in nature (American Psychiatric Association, 1994; Barkley, 1997). ADHD represents one of the most common sources of referral to family physicians, neurologists, psychiatrists, pediatricians, and school psychologists in the United States (Biederman, Newcorn, & Sprich, 1991), and has been estimated to account for 30-40% of total referrals to child guidance clinics (Barkley, 1982). Although prevalence rates of ADHD vary according to the population sampled, the diagnostic instruments employed, and the specific diagnostic criteria used, it is generally accepted that ADHD occurs in approximately 3-7% of school-age children (Barkley, 1990; Cantwell, 1996). Based on these statistics, it has been suggested that at least one child in every classroom could be identified as suffering from ADHD (Goodyear & Hynd, 1992).

Over the course of development, individuals with ADHD remain at an increased risk for low academic achievement,
dysfunctional peer/family relationships, hostility, conduct problems/delinquency, early substance abuse, and difficulties adapting to social situations, marriage, and employment (Barkley, 1997; Boliek & Obrzut, 1997). It is not surprising, therefore, that ADHD has had a colossal impact on society in terms of family stress, classroom disruption, and monetary cost (Biederman et al., 1991).

Over the years, many theories have been developed to explain the cognitive and behavioral characteristics associated with ADHD. Initially, motoric hyperactivity was viewed as the cardinal feature of the disorder (Chess, 1960; Laufer & Denhoff, 1957). However, the notion of poor sustained attention and impaired impulse control was later moved to the forefront of research efforts in this area (e.g. Douglas & Peters, 1979). Douglas (1980; 1983) argued that ADHD results from problems in four specific areas; namely, deficient modulation of arousal, poor investment-organization-maintenance of effort, a tendency to seek immediate reinforcement, and an inability to effectively inhibit impulsive responses. These four deficiencies were later attributed to a more central deficit in what Douglas referred to as 'self-regulation' (Douglas, 1988 cited in Barkley, 1997). Other theories have attempted to explain ADHD in terms of diminished levels of central nervous
system arousal (arguing that hyperactivity serves to maintain an optimal level of arousal) (Zentall, 1985), deficient motivation (Glow & Glow, 1979), reduced sensitivity to reinforcement (Haenlein & Caul, 1987), ‘executive dysfunction’ (Denckla 1989, 1991), and poor behavioral inhibition (Barkley, 1990; 1997).

Shue and Douglas (1989) suggested that the primary deficit in ADHD is one of “inadequate integration of task-critical internal and external stimuli” (p. 498). In accordance with this hypothesis, based on a comprehensive review of the scientific literature, Barkley (1997) constructed a “unifying theory of ADHD.” According to this hierarchical model, the cognitive (i.e., poor sustained attention) and behavioral (i.e., motoric hyperactivity) characteristics of the disorder are ultimately attributed to a reduction in the control of behavior by internally-represented information and self-directed action. More specifically, from Barkley’s theoretical perspective, a deficiency in behavioral inhibition (i.e., the ability to inhibit responses to external/environmental stimuli) represents the fundamental impairment in ADHD. This primary deficit in response inhibition leads to secondary deficits in four neuropsychological functions that depend on this ability for their effective execution: (a) working
memory (i.e., the ability to hold information in mind and effectively act on it); (b) self-regulation of affect, motivation, and arousal; (c) internalization of speech (which is believed to contribute to the generation of internalized rules and rule-governed behavior); and (d) reconstitution (the ability to dissect mentally represented information and recombine it to form new sequences of behavior). According to Barkley (1997), these four executive functions serve to bring behavior under the control of internally represented information, ultimately permitting greater goal-directed action and task persistence. Thus, secondary deficits in these four executive functions lead to tertiary deficits in the control of behavior by internally-represented information. In short, according to Barkley's model, the primary symptoms of ADHD (inattention, impulsivity, and hyperactivity) result from the fact that these children are less controlled by internalized rules and strategies, and are guided to a greater extent by information available in the immediate external environment.

Supporting this hypothesis, the results of numerous studies indicate that children with ADHD exhibit the following behaviors: (a) an inordinate performance benefit from repeated exposure to task instructions (demonstrating
an over-reliance on external prompts) (Douglas, 1983); (b) highly developed exploratory skills (i.e., an excessive interest in investigating objects in the external environment) (Fiedler & Ullman, 1983); (c) improved performance on novel tasks and tasks performed in unfamiliar settings (demonstrating the ability to alter behavior in response to changing environmental demands) (Culbertson & Krull, 1996; Zentall, 1985); d) inordinate performance increments on tasks involving a high rate of immediate external reinforcement for compliance, or punishment for noncompliance (demonstrating the critical role of external consequences in shaping the behavior of these children) (Barkley, 1990; Douglas, 1983; Firestone & Douglas, 1975; Prior & Sanson, 1986); e) significant difficulty adhering to rules or instructions in the face of delayed, weak, or nonexistent external consequences for such behavior (suggesting difficulty internalizing rules/instructions) (Barkley, 1997); and f) difficulty sustaining responses to repetitive tasks and stimuli (demonstrating the need for environmental stimulation to promote sustained attention) (Barkley, 1990; 1997).

Given these cognitive and behavioral characteristics, children with ADHD would be expected to exhibit a distinct pattern of performance on neuropsychological measures of
higher-order reasoning and executive-type functioning. First, returning to Piaget's (1954) theory of intellectual development, given that children with ADHD evidence well-developed exploratory skills (as well as other skills/behaviors crucial for sensorimotor activities), it is likely that these children benefit significantly from the sensorimotor period of development. As a result, unlike children suffering NLD, children with ADHD would be expected to adequately develop subsequent higher-order intellectual abilities (e.g., nonverbal abstract reasoning/problem solving). This probability, coupled with the notion that the behavior of children with ADHD is guided to a great extent by external contingencies, leads to the prediction that these children would perform in an age-appropriate fashion on neuropsychological instruments measuring abstract reasoning, particularly when instructions are frequently repeated, and environmental cues (e.g., verbal prompts from the examiner) are provided to assist in the maintenance of correct response patterns (e.g., the HCT).

Similarly, because children with ADHD adapt well to novel situations, and are able to alter their behavior in accordance with changing environmental demands, these children would be expected to perform relatively well on
measures of 'cognitive flexibility' performed under novel and ambiguous conditions (i.e. the majority of WCST indices). Conversely, because children with ADHD demonstrate difficulty adhering to internally represented information, it is likely that these children would exhibit problems maintaining a correct pattern of responding in the absence of adequate external reinforcement. In sum, based on their neuropsychological and behavioral profiles, children with ADHD would be expected to perform near age-appropriate levels on measures of conceptual reasoning and 'cognitive flexibility', but would likely perform below age-expectation on those requiring the maintenance of a particular response set over time.

Although the above mentioned hypotheses have yet to be tested, several studies have examined nonverbal reasoning and executive-type functioning in children with ADHD (e.g. Carte, Nigg, & Hinshaw, 1996; Gorenstein, Mammoto, & Sandy, 1989). In contrast to the HCT which has been used only rarely in studies of ADHD, the WCST represents one of the most commonly used neuropsychological measures in ADHD research (Barkley & Grodzinsky, 1994). Although the majority of studies investigating WCST performances of children with ADHD suggest that these children exhibit difficulty successfully completing this test, the specific
nature of this impairment remains unclear. Following is a brief review of this research.

Chelune, Ferguson, Koon, and Dickey (1986) conducted one of the first studies exploring WCST performance in children with ADHD. The results of this investigation revealed that individuals with ADHD achieved fewer categories, committed more Perseverative Errors, and demonstrated significantly lower Percent Correct index scores than did unaffected control children. In a similar study, Reader, Harris, Schuerholz, and Denckla (1994) reported that while children with ADHD performed well below age-expectation with respect to Number of Categories Achieved, they performed within average limits on the Perseverative Error component of the WCST. Gorenstein et al. (1989) compared WCST performances of inattentive/overactive children to that of age-matched normal control children and reported that of the variables considered (Perseverative Errors, Nonperseverative Errors, and Total Categories), only the Perseverative Error index score was found to differentiate these two groups. Shue and Douglas (1992) reported that in their study, children with ADHD performed poorly relative to control children on Perseverative Errors, Nonperseverative Errors, and Categories Achieved, but performed in a manner similar to
control children on Unique Errors and Extra Correct Responses. In a study conducted by Grodzinsky and Diamond (1992), the performances of children with ADHD did not differ significantly from that of control children on the majority of WCST variables investigated (Categories Achieved, Nonperseverative Errors, Percent Perseverative Errors, and Perseverative Responses). However, the latter group did outperform the former group on two WCST indices; namely Trials to First Category and Failure to Maintain Set.

In contrast to the above described studies, Loge, Staton, and Beatty (1990) reported no differences between the performance of children with ADHD and that of control children with respect to Perseverative Responses, Perseverative Errors, Trials to First Category, and Failure to Maintain Set. Other studies support these findings (e.g., McGee et al., 1989; Pennington, Groisser, & Welsh, 1993; Seidman, Biederman, Faraone, Weber, Mennin & Jones, 1997).

In an attempt to more clearly define the neuropsychological deficits associated with ADHD, Barkley and Grodzinsky (1994) compared WCST performances of children exhibiting ADD with hyperactivity (ADD+H) to that of children displaying ADD without hyperactivity (ADD-H).
The results of this study indicated that while the ADD-H group evidenced significant impairment on Categories Completed and Perseverative Response indices, the ADD+H group exhibited significant difficulty on the Failure to Maintain Set component of the WCST. This pattern of performance is particularly interesting with respect to the current investigation, when one considers the following two points. First, Barkley (1997) specifically limited his 'unifying theory of ADHD' to those children with ADD exhibiting hyperactive symptoms. Second, several investigators have suggested that ADD-H may "represent a type of inattention believed to accompany the nonverbal learning disabilities" (Barkley, Costello, & Spitzer, 1989 cited in Epstein, Shaywitz et al., 1991). Thus, consistent with the predictions made in the current study, these findings suggest that relative to children exhibiting behaviors similar to NLD (ADD-H), children with ADHD perform better on measures of abstract reasoning and 'set switching', but perform poorly on measures of set maintenance.

The inconsistent results of past studies likely reflect differences in diagnostic criteria, referral source, age of participants, the presence of co-morbid conditions in ADHD or control groups, and the use of
psychostimulant medication (which has been shown to result in increased perseverative responding and decreased environmental curiosity) (Dyme, Sahakian, Golinko, & Rabe, 1982; Fiedler & Ullman, 1983). Moreover, as evidenced by the foregoing discussion, it is often the case that performances on various indices of the WCST are not reported (e.g., Failure to Maintain Set, and Nonperseverative Responses/Errors), and subtypes of ADHD are frequently not considered (i.e., predominantly hyperactive, predominantly inattentive, or combined type). Thus, in order to delineate the precise nature of impairment on measures of higher order reasoning and executive-type functioning in children with ADHD, it is imperative to employ rigorous diagnostic criteria, control for factors that may alter performance (e.g., the presence of comorbid disorders, medication, ADHD subtypes), use appropriate control groups, and investigate performance on a wide range of variables. The present study will attempt to accomplish these methodological goals.

Before stating the precise hypotheses of this investigation, it would be instructive to review the two neuropsychological tests to be employed, and discuss the similarities and differences between these two measures.
The Halstead Category Test

The HCT (Reitan & Davison, 1974) consists of various stimulus figures (e.g., letters, shapes, designs) visually presented on a screen. Below the screen lies an answer panel containing four levers numbered 1 to 4. Subjects are instructed to observe each visual item when it appears on the screen, decide which number it suggests to them (1, 2, 3, or 4), and depress the corresponding response lever. After each response, the subject hears a bell or buzzer indicating that his/her response was either correct or incorrect, respectively.

The HCT is comprised of several subtests. Subjects are informed at the beginning of each subtest that only one rule or principle runs throughout that portion of the test, and they are frequently reminded that once the correct rule has been identified, continued application of that principle will ensure correct responses for the remainder of the subtest. Examinees are never provided clues as to the correct principle. However, during test administration, the examiner is required to give several prompts that serve to facilitate an understanding of the task at hand. For example, during subtest II, the standardized instructions require the examiner to state "You will notice that we first saw squares, then lines, and now circles. Even
though the patterns change, you should continue to use the same idea to get the right answer" (Reitan & Wolfson, 1985 pp. 43-44). Upon completion of the second subtest, the examiner then explains “[A]s you probably noticed, you don’t necessarily have to see a number to have a number suggested to you. You saw squares, circles, and other figures. Also, you probably noticed in each of these subtests there was only one idea or principle which ran throughout. Once you figured out the idea you continued to apply it to get the right answer...” (Reitan & Wolfson, 1985, p. 44). With respect to the final subtest which is comprised of previously presented items, subjects are informed that they should not apply only one principle, but rather should use the rule that was in effect when the stimulus was first presented.

The Wisconsin Card Sorting Test

The WCST (Heaton et al., 1993) consists of 128 cards varying in color, form, and number. The subject is presented with four stimulus (key) cards depicting the following: (1) one red triangle; (2) two green stars; (3) three yellow crosses; (4) four blue circles. Subjects are instructed to ‘sort’ a set of additional cards by placing one card at a time below the key card which they believe it matches. After placing each card, subjects are provided
feedback as to the accuracy of their response. In other words, examinees are required to determine the sorting strategy (color, form, or number) based solely on evaluative feedback provided by the examiner.

The sorting principle is changed without the subjects' knowledge after 10 consecutive correct sorts, thereby requiring them to switch cognitive set in order to deduce the new criterion sorting rule. After all three categorization rules have been established and maintained (10 consecutive correct responses), they are repeated. The test is terminated after all six sorting rules have been identified and sufficiently maintained, or when all 128 cards have been sorted. At no time are subjects informed of the sorting principles, the order of presentation, or the number of correct responses necessary to change a sorting rule. In addition to Total Errors (TE), the following performance variables may be investigated: Categories Completed (CC), Perseverative Errors (PERE), Nonperseverative Errors (NPERE), Conceptual Level Responses (CONLEV), Learning to Learn (LTL), and Failure to Maintain Set (FTMS). For a description of these indices see Table 1.
Table 1

**Description of Wisconsin Card Sorting Test Indices**

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<td>Total Errors (TE)</td>
<td>Total number of responses that do not correspond with the sorting rule in effect at that time.</td>
</tr>
<tr>
<td>Categories Completed (CC)</td>
<td>Number of categories obtained by the subject. A category is considered achieved when 10 consecutive correct responses are made in accordance with the criterion sorting rule.</td>
</tr>
<tr>
<td>Conceptual Level Responses (CONLEV)</td>
<td>Percentage of responses suggesting insight into the correct sorting principles. These responses occur any time three or more correct responses are made consecutively.</td>
</tr>
<tr>
<td>Perseverative Errors (PERE)</td>
<td>Total number of times the subject continues to sort incorrectly after making three consecutive matches to either (a) the previous categorization rule; or (b) a new, yet still incorrect, sorting principle.</td>
</tr>
<tr>
<td>Nonperseverative Errors (NPERE)</td>
<td>Total number of errors that do not meet the criteria for a perseverative error.</td>
</tr>
<tr>
<td>Failure to Maintain Set (FTMS)</td>
<td>Total number of times a string of five or more consecutive correct responses is followed by an error, prior to achieving the category.</td>
</tr>
<tr>
<td>Learning to Learn (LTL)</td>
<td>Average change in conceptual efficiency with each successive category.</td>
</tr>
</tbody>
</table>
HCT versus WCST

Despite the fact that the HCT and the WCST are commonly used interchangeably in clinical practice, it is clear that the demands of each task differ significantly, and that each test measures distinct neuropsychological abilities (Donders & Kirsch, 1991; Fisher et al., 1997). Although these tests appear to require similar cognitive operations for successful completion (e.g., hypothesis testing, problem solving) (Bond & Buchtel, 1984), and both demonstrate similar levels of sensitivity to brain damage (Lezak, 1995), the shared variance between these tests is rather minimal. In fact, studies comparing these two measures have reported shared variances ranging from only 12% (Donders and Kirsch, 1991) to 33% (Fisher et al., 1997; Perrine, 1993).

The minimal overlap between the HCT and WCST in terms of shared variance can be attributed, at least in part, to differences in task demands, test administration, and stimuli presentation. First, in contrast to the WCST, which is an intentionally ambiguous test, the HCT is a more clearly defined task that promotes interaction between the examiner and the subject. More specifically, during administration of the WCST, the instructions provided to the examinee are at best limited, and the interaction
between the subject and the examiner is kept to a minimum. In fact, as indicated earlier, one of the most salient features of the WCST is that sorting principles are changed without warning to the subject. Conversely, during administration of the HCT, specific test instructions are provided at the beginning of each subtest, and "through judicious use of prompts, [the examiner] facilitate[s] the patient’s exploration of his/her abilities in organization and problem solving" (Finlayson, Sullivan, & Alfano, 1986, p. 709).

Second, while the WCST utilizes the same visual stimuli across test trials, the stimuli employed in the HCT continuously change both within and between subtests. Thus, it is possible that in contrast to the WCST, the stimuli used in the HCT provide external clues that serve to assist in the identification and maintenance of correct response patterns. Thus, while the WCST appears to be more sensitive to internally driven cognitive processes, the HCT does not seem to measure various aspects of internally initiated mechanisms, and may be more sensitive to behavior guided by information available in the external environment (Fisher et al., 1997; Perrine, 1993).

The results of past research suggest that the WCST is primarily a measure of attribute identification and
perseverative tendencies, whereas the HCT is considered to be a more conceptually demanding test that taps rule deduction and concept formation skills (Perrine, 1993). In short, the HCT is generally considered to be a measure of higher-order reasoning, while the WCST appears to gauge 'executive-type functioning' (Fisher et al., 1997).

Rationale for the Present Study

The goal of the current investigation is to explore possible differences in higher-order reasoning and executive-type functioning in children with ADHD and children exhibiting the syndrome of NLD. To this end, the performances of these two groups were compared on the HCT and the WCST.

A considerable body of research indicates that individuals with NLD exhibit a pattern of neuropsychological assets and deficits involving impaired tactile, psychomotor, and visual-spatial-organizational skills, within the context of intact rote verbal abilities. According to Rourke (1982, 1989, 1995), these children exhibit deficiencies in the ability to deal with novel, ambiguous, and nonroutinized situations, evidence difficulty altering their behavior in response to changing task demands, and demonstrate difficulty performing tasks requiring nonverbal abstract reasoning.
Studies investigating higher-order reasoning in children with NLD reveal that these children exhibit significant impairment on the HCT. Additionally, as would be predicted based on their neuropsychological ability structure, on the WCST, children with NLD have been reported to perform poorly on those indices measuring abstract reasoning and 'cognitive flexibility', but exhibit minimal difficulty maintaining a correct response set, and learning from repeated exposure to visual material.

In contradistinction to the behavioral and neuropsychological characteristics of NLD, children with ADHD exhibit well-developed exploratory skills, and are able to effectively alter their responses in accordance with changing environmental demands. Conversely, according to Barkley (1997) these children evidence extreme difficulty adhering to internally represented information. Given this cognitive profile, relative to children with NLD, those individuals exhibiting ADHD would be expected to display the 'opposite' pattern of performance on measures of higher-order reasoning and executive-type functioning.

Specifically, based on the notion that children with ADHD have likely developed higher-order intellectual abilities (given their well-developed exploratory skills), and appear to be guided to a great extent by external
contingencies, they would be expected to perform near age-appropriate levels on the HCT, a measure of higher-order reasoning in which instructions are frequently repeated, visual stimuli are continuously altered, and verbal prompts from the examiner are periodically provided. Additionally, because children with ADHD are able to respond appropriately to changing environmental demands, on the WCST, these children would be expected to make relatively few perseverative responses, and would be expected to perform in an age-appropriate fashion on those variables measuring conceptual-level reasoning. Conversely, based on Barkley's (1997) theory of ADHD, these children would be expected to demonstrate problems maintaining a correct response pattern over time, given their alleged difficulty adhering to internalized rules and information.

**Statement of Hypotheses**

As suggested previously, this investigation seeks to determine whether children with ADHD exhibit a pattern of performance on the HCT and WCST distinct from that evidenced by individuals exhibiting the syndrome of NLD. Specifically, children with ADHD are expected to outperform children with NLD on the HCT, and on those variables of the WCST measuring abstract reasoning and perseverative responding. In contrast, it is predicted that children
with NLD will outperform children with ADHD on that component of the WCST measuring the ability to maintain a correct response pattern.

The precise hypotheses of this investigation are as follows:

(1) It is hypothesized that relative to the NLD group, the ADHD group will make fewer Total Errors on the HCT.

(2) It is predicted that the ADHD group will outperform the NLD group on the following WCST variables: TE, CC, PERE, NPERE, CONLEV.

(3) It is hypothesized that the ADHD group will evidence significantly lower scores than the NLD group on the FTMS index of the WCST.

(4) No significant difference is predicted between the ADHD and NLD groups with respect to the LTL index of the WCST.
CHAPTER 2

Methods

Subjects

Archival WCST and HCT data from 16 children diagnosed with the syndrome of Nonverbal Learning Disabilities (NLD), and 16 children diagnosed with ADHD were analyzed in this study. All subjects were referred between the years of 1987 and 1999 to one of three metropolitan outpatient clinics for evaluation of academic, behavioral, and/or socioemotional difficulties. Based on the results of an extended Halstead-Reitan neuropsychological test battery, all subjects in this study were diagnosed by the same licensed clinical neuropsychologist (John W. DeLuca).

Participants in this study ranged in age from 9 to 16 and (a) showed no evidence of gross neurologic, motor, or sensory deficits; (b) had no history of severe psychiatric disturbance; (c) were free of psychostimulant medication at the time of testing; and (d) had no history of traumatic brain injury or disease. The two groups were matched in terms of handedness and verbal Intelligence (VIQ) as measured by the Wechsler Intelligence Scale for children (WISC-R or WISC-III: Wechsler, 1974; 1991).

NLD Group. Children in the NLD group met the majority of neuropsychological criteria for classification of
potential NLD subjects suggested by Harnadek and Rourke (1994) (see Table 2.) It should be noted that data from the majority of subjects in the NLD group were recently published by Fisher et al. (1997) in a study investigating higher-order reasoning skills of children with NLD and children with VLD.

ADHD Group. The ADHD group was selected using an abbreviated version of the Personality Inventory for Children - Revised (PIC-R) (Wirt, Lachar, Klinedinst, & Seat, 1984), a 280 item questionnaire completed by parents regarding child development and behavior. The results of this rating scale yield three validity scales: Lie, F, and Defensiveness; 12 clinical scales: Achievement (ACH), Intellectual Screening (IS), Development (DVL), Somatic Concern (SOM), Depression (D), Family Relations (FAM), Delinquency (DLQ), Withdrawal (WDL), Anxiety (ANX), Psychosis (PSY), Hyperactivity (HPR), Social Skills (SSK) and one general scale: Adjustment (ADJ). The utility of the PIC-R for identifying children with ADHD has been demonstrated consistently. For example, Hegeman (1976) reported that the Hyperactivity scale of the PIC significantly differentiated hyperactive children and non-hyperactive "maladjusted" children (cited in Breen & Barkley, 1983). Similarly, Voelker, Lachar, and Gdowski
Table 2

Criteria for Potential NLD Subjects (Harnadek & Rourke, 1994) met by the current sample

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Subject Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>WISC VIQ &gt; 79</td>
<td>+  +  +</td>
</tr>
<tr>
<td>VIQ &gt; PIQ (10 points or more)</td>
<td>+  +  -</td>
</tr>
<tr>
<td>GPT ≥ 1 SD below mean (either hand)</td>
<td>+  +  +</td>
</tr>
<tr>
<td>DG, FA, or AST ≥ 1 SD below mean</td>
<td>+  +  +  +</td>
</tr>
<tr>
<td>Target Test ≥ 1 SD below mean</td>
<td>+  +  +  +</td>
</tr>
<tr>
<td>SSPT or AC ≤ 1 SD below mean</td>
<td>+  +  +  +</td>
</tr>
<tr>
<td>WRAT R&amp;S &gt; A by 10 or more SS</td>
<td>+  +  +  +</td>
</tr>
<tr>
<td>% available criteria met</td>
<td>100 100 94</td>
</tr>
</tbody>
</table>

Note. NLD = Nonverbal Learning Disability; WISC = Wechsler Intelligence Scale for Children; VIQ = Verbal Intelligence Quotient; PIQ = Performance Intelligence Quotient; GPT = Grooved Pegboard Test; SD = Standard Deviation; DG = Dysgraphesthesia; FA = Finger Agnosia; AST = Asterognosia; SSPT = Speech Sounds Perception Test; AC = Auditory Closure Test; WRAT = Wide Range Achievement Test; R = Reading; S = Spelling; A = Arithmetic; SS = Scaled Score; N/A = Not Administered; + = met criterion; - = did not meet criterion.
(1983) compared PIC profiles of children exhibiting hyperactive behaviors to children suffering 'mixed psychiatric disorders', and reported that scores on the Hyperactivity and Intellectual Screening scales significantly differentiated these two groups of children. In contradistinction to the previously mentioned studies which relied solely on clinical judgment to define ADHD groups, Breen and Barkley (1983) tested the utility of the PIC using a sample of hyperactive children selected on the basis of their performance on several quantitative measures. In this well-controlled study, all 12 clinical scales of the PIC were found to discriminate hyperactive from non-hyperactive children. In fact, using these scales, 96% of the children in this study were correctly classified with respect to diagnostic group. Taken together, the results of these studies support the use of the PIC-R in identifying hyperactive children.

Given their rigorous diagnostic criteria, the ADHD group in the present study was selected on the basis of Breen and Barkley’s (1983) PIC profile of hyperactivity. Specifically, using T-scores for the Adjustment scale, as well as all 12 clinical scales, PIC profiles from the current ADHD group were correlated to those of Breen and Barkley’s sample of hyperactive children.
As previously mentioned, the current study employed the 280-item short form of the revised version of the PIC (PIC-R). The PIC-R includes all 600 of the original PIC items, however the items were rearranged to enable the administration of 130 and 280-item short forms. Within the normative sample, factor and profile scale correlations between the original and shortened versions of the PIC-R range from .89 to .98 (Lachar, 1982).

Measures

The Halstead Category Test

The adult version of the HCT (consisting of seven subtests) was administered to subjects 15 years and older. Those subjects under the age of 15 were administered the intermediate version of the HCT (consisting of six subtests). Levels of performance on the HCT (Total Errors) for subjects under the age of 15 years were determined based on normative data provided by Knights and Norwood (1980). Normative data provided by Fromm-Auch and Yeudall (1983) were used to determine levels of performance for subjects 15 years and older. Performance was considered to be within the impaired range if the T-score obtained was ≤ 40 (mean = 50, SD = 10), with higher scores indicating better performance.
The Wisconsin Card Sorting Test

In addition to TE on the WCST, the following performance variables were investigated: CC, PERE, NPERE, CONLEV, LTL, and FTMS (for a detailed description of each see Heaton, Chelune, Talley, Kay, & Curtiss, 1993). Normative data provided by Heaton et al. (1993) were used to determine levels of performance on the following variables: CC, FTMS, LTL, and TTFC. The remaining WCST performance variables (TE, PERE, NPERE, CONLEV) were obtained via normative data provided by the WCST computer scoring system (Heaton, Curtiss, & Tuttle, 1993). Performance on the WCST was considered impaired if the T-score obtained was < 40 (mean = 50; SD = 10). Higher scores indicate better performance on all variables of the WCST.
CHAPTER 3
Results

All children in the NLD group exhibited a VIQ > PIQ pattern of performance on the WISC-R/WISC-III. The mean difference between IQ scales for this group was 13.1 (SD = 7.96). Additionally, all members of the NLD group performed in an inferior fashion on a measure of arithmetic achievement relative to their performance on academic achievement tests of reading and spelling (measured by the Wide Range Achievement Test 2nd or 3rd Edition; WRAT-R/WRAT-III; Jastak & Wilkinson, 1984; Wilkinson, 1993). The mean difference between WRAT Standard Scores (SS) of verbal academic achievement and arithmetic achievement (i.e., \([(\text{Reading SS} + \text{Spelling SS})/2] - \text{Arithmetic SS}\)) was 23.34 (SD = 11.0). In contrast to the ADHD group, PIC profiles of the NLD group did not correlate significantly with Breen and Barkley’s (1983) profile of hyperactivity ($r$ (15) = .534).

Subjects in the ADHD group were selected on the basis of Breen and Barkley’s (1983) PIC profile of hyperactivity. The mean PIC/PIC-R T-score profile of individuals in the ADHD group was significantly correlated with the PIC profile of hyperactivity reported by Breen and Barkley (1983) ($r$ (15) = .976, $p < .01$). PIC/PIC-R T score profiles from each group are presented in Figure 1.
Figure 1. Mean PIC T score profiles: A comparison of the Breen and Barkley (1983) ADHD sample and the ADHD sample used in the present investigation. PIC = Personality inventory for Children; ADHD-BB = Attention Deficit Hyperactivity Disorder - Breen & Barkley (1983); ADHD-c = Attention Deficit Disorder - Current Sample. Correlation between groups was significant at the .01 level.
There was no significant difference between ADHD and NLD groups in terms of WISC-R/WISC-III verbal IQ (ADHD mean VIQ = 95.56 [SD = 13.15]; NLD mean VIQ = 90.13 [SD = 9.44] \( p = .189 \)). Seventy-five percent (12/16) of the subjects in each group were right handed. There were 14 boys and 2 girls in the ADHD group; the NLD group was comprised of 10 boys and 6 girls. With respect to age, the ADHD group was found to be significantly younger (mean age = 10.98 [SD = 1.61]) than the NLD group (mean age = 12.86 [2.05] \( p = .007 \)). However, given that age-based norms for the HCT and WCST were used in this study, it is unlikely that this age difference affected the results obtained.

The first goal of this investigation was to determine whether children with NLD demonstrate impairment on the HCT as distinct from children with ADHD. To evaluate this, mean HCT Total Error T-scores from both groups were subjected to between groups t tests for independent samples. Mean T-score performances of ADHD and NLD groups on this measure are presented in Figure 2. As predicted, HCT Total Error T scores for the ADHD group (mean = 51.65; SD = 12.04) were found to be significantly greater than those for the NLD sample (mean = 28.36; SD = 15.27) \( t (30) = 4.79. \ p < .001 \). Thus, the ADHD group committed fewer Total Errors on the HCT than did the NLD group.
The second goal of this study was to assess group differences in performance on seven variables of the WCST. To this end, between groups $t$ tests for independent samples were carried out using mean WCST index scores. These data are presented in Figure 2. In accordance with predictions, the ADHD group performed significantly better than the NLD group on TE [$t (30) = 3.80. \ p < .001$]; CC [$t (30) = 2.70. \ p < .01$]; NPERE [$t (30) = 3.48. \ p < .01$]; PERE [$t (30) = 2.40. \ p < .05$]; and CONLEV [$t (30) = 3.57. \ p < .001$], but did not differ significantly from the NLD group on the LTL index of the WCST [$t (30) = 1.78. \ p = .086$]. Contrary to the anticipated results of this study, the two groups did not differ significantly on the FTMS component of the WCST [$t (30) = -1.27. \ p = .215$]. However, it should be noted that the FTMS index was the only variable of the WCST on which the NLD group outperformed the ADHD group (NLD mean = 50. 58, SD = 13.71; ADHD mean = 44.46, SD = 13.59).
Figure 2. Mean HCT and WCST T-score performances of ADHD and NLD groups. HTOT = Halstead Category Test Total Errors; TE = WCST Total Errors; CC = Categories Completed; PERE = Perseverative Errors; NPERE = Nonperseverative Errors; CONLEV = Conceptual Level Responses; LTL = Learning to Learn; FTMS = Failure to Maintain Set. *p < .05  **p < .01
CHAPTER 4

Discussion

This investigation was designed to explore higher order reasoning and executive-type functioning in children with ADHD and those exhibiting the syndrome of NLD. To this end, performances were examined on two popular neuropsychological measures: the HCT and the WCST. Despite the fact that these tests are often used interchangeably, a significant body of research suggests that each test measures distinct higher-order cognitive functions. The HCT is thought to measure rule deduction and concept formation skills, while the WCST gauges executive-type functioning (i.e., cognitive flexibility; set maintenance; perseverative responding; ability to learn from experience). Based on the neuropsychological and behavioral profiles of children with ADHD and those individuals with NLD, it was hypothesized that each group of children would display a distinct pattern of performance on these two measures.

This chapter reviews the results of the current investigation with respect to the specific hypotheses made in the first chapter. The clinical implications of these results, limitations of this study, and suggestions for future research are also considered.
Hypothesis 1

As hypothesized, relative to children with NLD, those with ADHD made fewer Total Errors on the HCT. As a whole, the ADHD group performed within average limits on this measure while the NLD group demonstrated severely impaired performance. Based on these results, it appears that individuals with ADHD exhibit age-appropriate concept formation skills, whereas children with NLD demonstrate significant difficulty in this cognitive arena. As previously discussed, it is likely that this discrepancy in performance is related to differences in the ability to benefit from the sensorimotor period of development, which according to Piaget (1954) is critical for the subsequent development of formal cognitive operations.

Hypothesis 2

Similar to the foregoing hypothesis, the ADHD group performed significantly better than the NLD group on those variables of the WCST measuring nonverbal conceptualization. Specifically, children in the ADHD group made fewer Total Errors, completed more categories, and made fewer Nonperseverative Errors. Also in accordance with Hypothesis 2, children in the ADHD group made significantly fewer Perseverative Errors than did children in the NLD group. Again, while children with ADHD
performed within average limits on the aforementioned measures, those with NLD performed in a severely impaired manner. Thus, consistent with their behavioral profile, children in the ADHD group were able to reason abstractly, and were found to be cognitively 'flexible'. In contrast, those in the NLD group evidenced difficulty conceptualizing task-related information, and were more 'fixed' in their problem solving approach.

Hypothesis 3

Based on the observation that children with ADHD demonstrate difficulty adhering to rules and require a great deal of external reinforcement, it was hypothesized that these children would perform poorly on the FTMS variable of the WCST. That is, because these children appear more influenced by external events, the continued application of an internally derived rule would be expected to be problematic for them. Conversely, because children with NLD appear to be guided to a great extent by internal rules, these children would be expected to perform relatively well on a measure requiring them to maintain a specific response set over time.

Although the results were not statistically significant, the NLD group outperformed the ADHD group on the FTMS variable. In fact, while the children with NLD
performed in a mildly to severely impaired fashion on all other WCST variables, group performance on FTMS fell within average limits. Additionally, compared to their performance on other variables of the WCST, the ADHD group obtained a relatively low score on the FTMS portion of the WCST. Taken together, these results suggest that while maintaining cognitive set represents a relative weakness for individuals with ADHD, it appears to be a strength for children with NLD. It is possible that with a larger sample size, within-group variability would decrease, and the difference in performance between groups on FTMS would reach statistical significance. Additionally, because participants are provided verbal feedback on every trial of the WCST, the external reinforcement associated with this test may be too great to adequately test this hypothesis. Thus, comparing performance of these two groups on a measure providing less consistent reinforcement would likely show a significant difference with respect to the ability to maintain cognitive set.

Hypothesis 4

As discussed throughout this manuscript, children with ADHD rely to a great extent on information provided by the external environment; therefore, these children would be expected to benefit significantly from repeated exposure to
task-related material. Similarly, given that children with NLD perform better when tasks become less novel, the performance of these children would also be expected to improve as a function of stimuli exposure. These ideas led to the prediction that children with NLD and those with ADHD would perform in a similar fashion on LTL. As hypothesized, the groups did not differ significantly on this variable of the WCST. However, mean T-scores did differ considerably, with ADHD group performance falling within average limits and NLD group performance falling within the impaired range. It is possible that with a larger sample this difference would reach statistical significance, suggesting that children with ADHD may benefit to a greater extent from repeated exposure to visual material (or the benefits may be observed more quickly) than children with NLD.

**Clinical implications**

Taken together, the results of this study support the claims made by Barkley (1997) and Rourke (1988) respectively, that the behavior of children with ADHD is governed primarily by external stimuli, while those with NLD are guided primarily by internal information. These findings have several implications. First, these results lend support to the notion that NLD and ADHD represent
'opposite' developmental disorders in terms of behavioral and neuropsychological presentation. That is, while children with NLD exhibit impairment on tasks requiring abstract reasoning/concept formation, and the ability to shift between ideas, individuals with ADHD perform quite well under these conditions. In contrast, children with NLD perform better on tasks requiring adherence to internally-generated rules/strategies, whereas this represents a relative weakness for those presenting with ADHD.

The results of this investigation further serve to demonstrate the utility of higher order reasoning tests and measures of executive functioning in the process of differential diagnosis. This topic becomes particularly important when one considers that individuals with NLD often appear hyperactive in early years. Therefore, these children are at risk to be mislabeled as ADHD, a mistake which undermines remedial efforts for these youngsters. The results of this study support the notion that examining patterns of problem solving skills for the purposes of LD evaluation could decrease the frequency of misdiagnosis in these two populations.

In addition to aiding in differential diagnosis, closely examining the nature of HCT and WCST performances
can assist in the development and implementation of remedial strategies designed to target specific areas of cognitive weakness. Similarly, for those individuals teaching compensatory strategies to youngsters with ADHD and NLD, having a clear understanding of problem solving strengths and weaknesses is imperative. Specifics regarding higher-order reasoning and executive-type functioning in these children should also be provided to parents, classroom teachers, and vocational counselors in hopes of facilitating the use of effective teaching methods and job placement strategies. Based on the current results, it appears that information presented at abstract levels will not be effective for a child with NLD. Using a more concrete approach to education and vocational training will likely yield better results. Additionally, individuals with NLD should not be expected to change rapidly between ideas or tasks; rather, allowing these individuals time to gradually alter ideas and encouraging participation in more rote activities will ultimately be more productive. In contrast, individuals with ADHD should be taught in a dynamic fashion that encourages abstract reasoning and rapid fluctuation between ideas and tasks. Vocational training for these individuals should focus primarily on those careers involving rapidly changing job
requirements, and those offering frequent rewards and consequences for performance.

**Limitations of Study and Future Directions**

There are several limitations with respect to the current investigation. First, due to the limited availability of subjects with NLD, the current sample size is relatively small. Studies attempting to replicate these findings would do well to increase the number of subjects. Additionally, as previously noted, the NLD group was significantly older than the ADHD group. Due to the use of age-based norms, this difference is not likely to have affected the findings reported in this study. However, future investigations on this topic should attempt to match subjects according to age.

The present investigation focuses exclusively on nonverbal higher order reasoning skills; studies conducted in the future should examine patterns of verbal reasoning in these groups of children. An investigation of this type would allow us to determine whether the specific patterns described in this study are limited to the visuospatial arena, or rather represent a more pervasive pattern involving both nonverbal and verbal domains of functioning.

Additionally, according to Piaget's theory of cognitive development, the capacity to think in the
abstract, to reason logically, and to test predictions based on hypotheses begins to develop roughly between the ages of 11 and 15. Thus, a study focusing on older subjects may shed more light on the problem solving abilities of individuals exhibiting these disorders. Further, longitudinal and cross-sectional studies would facilitate an understanding of the developmental course of higher-order reasoning skills within these populations.

Future research efforts should also focus on the effect of specific patterns of higher-order reasoning skills on the development of coping mechanisms and the ability to deal with psychosocial stressors. Given their preoccupation and overreliance on internalized information, individuals with NLD are likely to be at higher risk for internalized forms of psychopathology (e.g., depression). In contrast, the pattern of reasoning skills associated with ADHD (i.e., preoccupation with external information) would be more likely to result in outward displays of psychopathology (e.g., aggression). Although these patterns have already been documented (e.g. Boliek & Obrzut, 1997; Harnadek & Rourke, 1994), it would be interesting to conduct a study specifically comparing these two populations in terms of psychopathology, and explore the
precise relationship between problem solving skills and psychosocial functioning.

The effect of medication on problem solving and abstract reasoning skills is also a viable topic for future research. Profiles of ADHD children undergoing psychopharmacological treatment are likely to resemble profiles of children with NLD given that psychostimulant medication reportedly increases perseverative tendencies (Dyme, Sahakian, Golinko, & Rabe, 1982). Extending this line of reasoning, it would be of interest to examine the long-term effects of using psychostimulant medication during sensitive periods of development (e.g., the sensorimotor period). Several studies indicate that ADHD children treated with psychostimulants exhibit diminished curiosity and reduced exploratory behaviors (e.g., Fiedler & Ullman, 1983). The question that arises is whether the use of these medications during critical stages of development results in a neuropsychological profile similar to that of NLD. It is hoped that future research in this area will shed light on these and other questions.
References


VITA AUTORIS

Corinne Hardy-Morais was born on May 5, 1971 in Detroit, Michigan. She is the daughter of Duane and Judith Hardy. She graduated from Clarkston High School in 1989, and obtained a Bachelor of Science degree in biopsychology from the University of Michigan in 1994. After spending two years employed as a Montessori teacher and as a cognitive psychology research assistant, she enrolled in the doctoral program in clinical neuropsychology at the University of Windsor. She is currently a candidate for the Master of Arts degree.