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The utility of a computerized assessment battery to evaluate cognitive functioning and attention

Carl Richard Ellis

College of William & Mary - School of Education

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The utility of a computerized assessment battery to evaluate cognitive functioning and attention

Ellis, Carl Richard, Ed.D.
The College of William and Mary, 1991

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The Utility of a Computerized Assessment Battery to Evaluate Cognitive Functioning and Attention

A Dissertation Presented To The Faculty of the School of Education The College of William and Mary in Virginia

In Partial Fulfillment Of the Requirements for the Degree Doctor of Education

By: Carl Richard Ellis

February 1991
The Utility of a Computerized Assessment Battery to Evaluate Cognitive Functioning and Attention

by
Carl Richard Ellis

Approved February 1991 by

John Lavach, Ed.D.
Chair of Doctoral Committee

George Bass, Ph.D.

Roger Ries, Ph.D.
DEDICATION

This work
is dedicated to Art, Shelly, Lybbi and all-
whose selfless love and caring
was there when I, and many others,
needed them.

They told me that someday I could
help other people
and I did not believe them.
They will forever remain
in my heart and mind.

I Love You.

This work is also dedicated
to the memory of my Grandmother,
Alice Mulligan Stead
without whose support this goal would never have
been achieved. My only regret is that she will not
be here for graduation day.
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CHAPTER I

Introduction

In recent years much investigation and attention has been given to the application of computer technology to psychometric methods (Brown, 1984; Edwards, 1980 & Butcher, 1987). While the equivalence of computerized and traditional methods of psychological testing is well documented through correlational research (Brown, 1984) researchers have concentrated on adapting traditional methods of psychological testing to the new technology instead of utilizing it to develop innovative methods of assessment based on the computer. In addition to saving clinician time and providing a more standardized method of assessment (Johnson & Williams, 1980; Space, 1981), computerized testing may improve the quality of cognitive assessment as compared to traditional methods (Lushene, O'Neil, & Dunn, 1974; Skiller & Allen, 1983).

Present methods of cognitive assessment are under close scrutiny due to their lack of consistency with newly developed models of cognition (Sternberg, 1986b). While current tests are able to predict potential for school achievement, their relationships to cognitive schemas or neurological substrates have yet to be documented. Kaufman (1979) provides some direction toward obtaining information from IQ tests beyond a global IQ, but his method requires significant analysis time and considerable clinical interpretation. Despite numerous theoretical advances in the areas of memory, neuropsychology, and information
processing, little change has taken place in the assessment of intelligence
in the last half century (Sternberg, 1986a).

The potential of computerized testing in the field of psychology has
yet to be empirically established. Golden (1987) indicates that the
adoption of computer technology will revolutionize the assessment of
cognitive functioning. Golden (1985) has also indicated that while the
application of computer technology in the field of psychology is on the
rise, the debate regarding the relationship between computer models and
human cognition will continue. Adams and Heaton (1987) question
whether computerized tests are appropriate in terms of man-machine
interface and whether they are able to take into account the
characteristics of the examinee. Before computerized testing can become
a reality, the characteristics that may prohibit the development of
reliable and valid scales should be evaluated.

One factor that may negatively influence children's performance on
computerized tasks is attention, or arousal level. Despite the widespread
application of computer technology, research in education and psychology
has yet to document the relationship between attention problems and
children's performance on computerized tasks. Gordon (1987) has
developed an automated assessment device that purports to aid in the
assessment process to identify children with attention problems. While
research has been conducted with this instrument and the clinical
syndrome of Attention Deficit Hyperactivity Disorder (Gordon, 1979;
McClure & Gordon, 1984), its relationship to learning has not been
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systematically evaluated. By furthering the understanding of factors affecting the performance of children on computerized tasks, methods of cognitive assessment along with instructional methodologies utilizing computer technology could be improved.

Before innovative methods of assessment using this technology can be implemented, the following must occur: adaptable human-computer interface must be developed (Adams and Heaton, 1987); an appropriate theoretical model of intelligence such as that of Naglieri and Das (1988) must be formalized; and the possible influence of extraneous factors such as attention must be assessed (Ellis & Hart, 1985). At present, the area of direct computerized psychological assessment is in its infancy. Through an increased understanding of factors such as attention affecting children's performance on computerized tasks, methods of cognitive assessment could be improved and their application in clinical and educational settings may become a reality.

This study made an initial effort toward addressing the above stated requirements of computerized testing by using a Macintosh computer to create tests to provide an adaptable child-computer interface. The tests developed for this study were adaptations of traditional pencil and paper tasks based on the PASS Model of cognitive functioning (Naglieri and Das, 1988). Test performance of a group of children with attention problems was compared to a group of randomly chosen children. This effort attempted to determine: whether the scales can demonstrate reliability and internal consistency; if the response style variables (response times
and mouse movement characteristics) are related to measures of behavioral functioning (Conners' Teacher and Parent Rating Scales; Conners, 1973); whether the attention component of the newly developed computerized test can discriminate between children with attention problems and a random group of children as well as the Gordon Diagnostic System; and whether results are consistent with the PASS model of cognitive functioning (Naglieri and Das, 1988).

Theoretical Rationale

Sternberg (1986b) asserts that in the area of measurement, the field of psychology has paid little attention to cognitive theory in the development of its measures. IQ tests have been validated on criterion measures such as school achievement, but assumptions as to what makes up "intelligence", as assessed by popular tests, have been inconclusive. At a time where these measures are being seriously challenged due to theoretical and conceptual difficulties (Reschly & Wilson, 1990), the field can no longer continue claiming that "Intelligence is what the test measures" (Boring, 1923, p.35).

Sternberg (1984) defines intelligence as mental activity in the context of its purposive adaptation to, shaping of, and selection of real-world environments relevant to one's life. Sternberg (1984) and Glaser (1981) believe that present methods of cognitive assessment, intelligence tests, are inadequate in their measurement of metacognitive and self-regulatory skills, the basis of intelligent action. Self-regulatory skills
are the generalized skills that are used for approaching problems and monitoring one's performance. Metacognitive skills are defined as knowledge concerning one's own cognitive processes and products (Flavell, 1976). These metacognitive abilities are present in mature learners and take on the characteristics of an executive control process, acting as an overseer in many of the current models of memory (Glaser, 1981). Naglieri and Das (1988) indicate that arousal (attention level) is another significant factor that impacts on executive functioning, storage, and retrieval of information. Glaser (1981) feels that adequate evaluation of these skills is missing in present measures of ability. He speculates that through the inclusion of the above noted factors, important psychometric issues such as the differential test validity between blacks and whites may be better understood. Glaser (1981) calls for a more sophisticated diagnosis of levels of performance with emphasis on the nature and methods in which to assess competence and an improved understanding of learning aptitude.

The Planning, Attention, Simultaneous and Successive (PASS) Model of cognitive processing developed by Das, et. al. (1979) and formalized by Naglieri and Das (1988), is a model of intellectual functioning which purports usefulness in understanding cognitive competence. The PASS model addresses the criticisms of those such as Glaser (1981) by including the Planning Component. This model is based on the neuropsychological work of Luria (1966, 1980) which links cognitive components to localized areas of the brain.
There are three functional units of the PASS Model (Naglieri and Das (1988). The first functional unit is responsible for arousal or Attention. Arousal level is important because too much or too little can interfere with planning and processing information. The second unit involves Simultaneous and Successive processing. Simultaneous processing involves the integration of information into synchronous and primarily spatial groups. Successive processing involves the integration of information in a temporally organized serial order. The third unit consists of the executive function of Planning which is responsible for programming, regulation, and verification of activity. A variety of tasks assessing the components of this model have been developed by Das, et al. (1979), Naglieri and Das (1988) and others, and extensive research has been conducted assessing the validity of the model's components (Das, 1972; Kirby, 1976; Ashman & Das, 1980; Das 1984; Naglieri, 1989).

Das and Naglieri (in press, cited in Telzrow, 1990) are in the process of developing a new test based on the PASS Model. This test, the Cognitive Assessment System (CAS), attempts to formalize previous research on Luria's neuropsychological work. Telzrow (1990), concludes that the authors "are to be commended" for their work (p. 354), but has some reservations with regard to the technical requirements of the test. On the Planning tasks of the test she states that the precise timing requirements for item presentation and subject response may contribute to examiner error and lower test reliabilities. Also, concern is noted because the examiner is required not only to record response times on brief tasks, but to observe response style characteristics. Telzrow
(1990) also notes that these response style characteristics may not be easily observed by examiners, and inferring the strategies used by the child may be another source of test error. Naglieri (1989), however, implies that such information may aid in understanding individual differences in cognitive functioning. The assessment of these response style characteristics are felt to be consistent with the metacomponent of cognitive functioning. According to Telzrow (1990), their measurement through traditional testing methods seem difficult, at best. Computers, however, have the potential to achieve consistency and precision with regard to item presentation, scoring, and the measurement of response style characteristics.

Definition of Terms

Computerized Cognitive Assessment Battery (CCAB)- A microcomputer-based (Apple Macintosh) assessment system developed for this study. The PASS Battery is based on the Planning, Attention, Simultaneous and Successive Model of cognitive processing operationalized by Naglieri and Das (1988) which is a model of intellectual functioning and cognitive competence. This Battery is composed of the Computerized Trails Test, the Computerized Continuous Performance Test, the Computerized Sequential Memory Test and the Computerized Continuous Performance Test.
Computerized Trails- The Planning Component of the CCAB was measured through a specially developed Computerized Trails Test. The number of items, size of the items and complexity of the task is consistent with the pencil and paper version of the test which was originally a part of the Army Individual Test of General Ability (1944). On the computerized version of this task, the subjects were presented with quasi-randomly distributed circles on the computer screen. Each circle had a number or letter depending on the level of the task. The subjects were required to connect the circles in the correct numerical or numerical/ alphabetical order by clicking the mouse on each item.

Computerized Raven's Standard Progressive Matrices (CRSPM)- This Computerized version of the Raven's Standard Progressive Matrices measures the Simultaneous component of the CCAB. In this study the subjects were presented with a graphic representation of the standard Raven's items.

Computerized Sequential Memory Test (CSMT) The Computerized Sequential Memory Test was developed specifically for this study in order to measure Successive Processing. Stimulus designs were presented to the subject one at a time and the subject was then required to choose the items in their correct order from an array of designs on the computer screen.

Computerized Continuous Performance Task (CCPT) This measure is an adaptation of the automated Continuous Performance Task (CPT:
Rosvold et. al., 1956). On this test subjects were required to respond to a target sequence of two symbols flashing on the computer screen. An additional attention task required the subjects to make a response after a six second delay period was included. This additional task was added to the original Continuous Performance Task to remain consistent with present measures of attention such as the Gordon Diagnostic System (Gordon, 1983).

Statement of the Problem

While a number of psychological assessment instruments have been adapted for computerized administration (Brown, 1984), and a number of traditional tasks have been developed consistent with an empirically validated neuropsychological model of cognition (Das, et. al.,1979), there has been minimal effort toward the development and evaluation of a fully computerized cognitive assessment tasks based on such a model. Given this fact, the present study attempted to answer the following research question:

To what degree can a battery of computerized tests be developed to provide a measure of cognitive functioning with acceptable reliability, internal consistency, concurrent and construct validity?
Specific Hypotheses

The following directional research hypotheses were evaluated by this study:

**Hypothesis One** The computerized tasks will demonstrate reliability and internal consistency within acceptable limits.

**Hypothesis Two** Significant positive correlations will be obtained between computer derived measures (response latencies and mouse movement factors) on the applicable Computerized CCAB tasks (Computerized Trails, CRPM, and the CSMT) and behavioral measures of attention (Conners' Teacher and Parent Rating Scales).

**Hypothesis Three** The computerized measure of attention, CCPT, will be able to discriminate between a group of children with attention problems and a random group of children.

**Hypothesis Four** There will be no significant difference between the ability of the CCPT to discriminate between a group of children with attention problems and a random group of children, and the ability of the Gordon Diagnostic System (GDS) to discriminate between these two groups.
**Hypothesis Five** The attention component (CCPT) of the CCAB will show the greatest difference between the two groups of children on the four computerized PASS Battery tests.

**Sample Description and General Data Gathering Procedures**

The population for this study was students attending public school in a large metropolitan city in southeastern Virginia. Of the thirty-six elementary schools in this district, three were chosen since they were accessible to this examiner on a daily basis, thus facilitating cooperation from students, school staff, and parents. An evaluation of the group test scores of these three schools indicates that they fall within the average for the school district. With a goal of sixty students in the study, four teachers at each of the three schools were randomly selected for participation.

A random sample of public school children (N=29) and a group of children identified by their teachers as having attention problems (N=25) in grades three through five were used in the study. Not all of the selected students participated in the study. Some of the parents did not return the permission forms and a number of students moved out of the school district before all data was collected. In order to identify the
children with attention problems, a questionnaire was developed based on the fourteen characteristics of Attention Deficit-Hyperactivity Disorder of the DSM-III-R (American Psychiatric Association, 1987). The identification process is discussed further in the Methodology section.

The majority of the data collection took approximately 5 weeks. An additional two weeks were required due to student moves and school changes. Students suspected of mental retardation (MR) were not included in the study due to the conceptual level required for performance on computerized tasks.

All subjects were administered individual tasks via a computer and the Gordon Diagnostic System. Parent and teacher instruments (Conners, 1973) and background information were obtained for all subjects through the use of traditional pencil and paper questionnaires, both standardized and specifically designed for this study. The DSM-III-R rating scale was completed only for the attention problem group for identification purposes.

An Apple Macintosh Computer was used to administer the computerized measures of cognitive functioning and attention developed for this study. Presentation of materials took into consideration size and height of the subjects to ensure adequate vision and response capability. The subjects were presented with the various experimental tasks via the computer screen. The subject's responses were made using a mouse device attached to the computer which directs an arrow on the screen.
When the child was required to respond, he/she moved the mouse, pressed a button on the mouse, or did both.

Limitations

The major limitation of this study was the population on which the sample was drawn. The three schools participating in the study were of predominantly working class and active duty military families. Higher socio-economic status (SES) pupils were not represented in this study at the level found in the general population. This fact limits the generalizations that can be made as a result of these findings. While t-test analysis of the two groups using the race variable was not significant, a higher proportion of black students were present in the attention problem group. T-test results did, however, reveal differences in number of siblings, and birth placement. The attention problem group tended to be from larger families and lower in family birth order. The relationship between race, these two characteristics and attention problems should be considered when making generalization based on these results. This information is discussed further in the Chapter III-Methodology.

Another limitation of this study is that the subjects selected were in grades three through five, resulting in chronological ages of nine thru twelve. According to Piagetian concepts (Piaget & Inhelder, 1969), most children in this age range are functioning at
the concrete operations stage (7-11) and are able to use logical operations such as reversibility, classification and seriation. Children younger than this are functioning in the intuitive phase of the preoperational thought period (ages 4-7) and may have difficulty with the conceptual requirements of the CCAB, particularly those required by the Raven Scale. Caution should be used when generalizing these findings to younger children especially because of these developmental concerns. Also, generalizations should not be made to older children and adults until validity and reliability of this test are evaluated for these populations.

While assessment procedures could involve presentation of information via auditory, visual and tactile modes, the computerized assessment battery developed for this study presents only visual information via a computer screen. Responses are made by moving a mouse or pressing a button on the mouse. Areas that were not directly evaluated by this instrument include: gross motor, visual-motor perception, auditory memory, and language concepts. The assessment battery used in this study should not be viewed as all encompassing, but limited to cognitive functioning assessed by visual input and motor output.
CHAPTER II
Review of the Literature

The material in this section is organized into four parts. Section One is the historical overview of assessment procedures in the field of psychology. Section Two reviews research related to the foundations and utility of the PASS model of cognitive processing. Section Three addresses the assessment of attention difficulties as related to children's performance. Section Four discusses the application of computer technology to psychological assessment. A summary of the literature concludes this chapter.

Historical Concepts

The often used phrase that psychology has a long past and a short history (Boring, 1950) also applies well to the area of psychological testing. DuBoise (1970) points out that in 2200 BC evaluations were conducted in China for the retention and promotion of government officials. Unlike Europe, China had no hereditary ruling class and there was a need to determine the best suited candidates for important positions. Depending upon Chinese society's emphasis at a given time period, their tests and evaluations conducted at "assessment centers" would focus on civil law, military affairs, agriculture, "moral character", Confusion classics, poetry, etc. Since that time, testing efforts have responded to current societal needs in order to answer important
questions regarding individual performance. Around the 19th century European countries began using tests for the evaluation of civil servants. While far removed from what was to be known as the roots of psychological thinking, the need to determine individual strengths and weaknesses did not spring forth with Francis Galton, Alfred Binet or during WW I. The Zeitgiest for improved individual appraisal had been building for many centuries.

Boring (1950) identified the work of Galton as the beginning of scientific, individual psychology and mental tests. Galton's motive in studying individual differences was to justify his belief that we should control heredity to improve the species. Galton, Charles Darwin's cousin, subscribed to the latter's theory of natural selection. Before developing means to modify the species, he first needed to prove its importance and influence in mental functioning. His famous laboratory assessed thousands of people using tasks which were predominantly psycho-physical in nature. While paving the way for future developments in the field of psychology, he did little to influence appropriate methods of cognitive assessment for application to real world problems. Binet is given credit for severing the tie with the Wundtian tradition of psycho-physical measurement. Binet, along with Henri, addressed issues related to higher mental functioning. Their main research question was: "What skills and abilities are important for success in life?" (Binet & Henri, 1896; cited in Dubois, 1970). Measurement efforts in the field of psychology before this time were far removed from providing answers to practical problems facing society.
In 1904, Binet was given the challenge of developing a procedure to determine which children were most likely to benefit from "special" schooling. To meet this need Binet, along with Simon, developed the first intelligence scale. They felt their method was able to identify retarded individuals with near certainty (Binet & Simon, 1905; cited in Dubois, 1970). Twenty years later, Thorndike (1926) criticized this and subsequent cognitive measures since they did not determine an individual's ability to learn more information, or the same information, faster than another individual. Despite numerous theoretical advances in the study of cognition, little change has taken place in the assessment of intelligence since the the time of Binet (Sternberg, 1986a). Emphasis has been placed on the development of reliable scales with empirical validity as opposed to determining construct validity and developing a clear picture of what is actually being assessed. Intelligence tests have been found to correlate well with academic achievement, but the constructs that underlie the performance has been a matter of speculation, debate and disagreement.

Theoretical Constructs of the PASS Model

The Planning, Attention, Simultaneous and Successive (PASS) Model of cognitive processing operationalized by Das, et al. (1979) and Naglieri and Das (1988) is a model of intellectual functioning and cognitive competence. This model is based on the neuropsychological work of Luria (1966, 1970, 1976, 1980).
Luria (1966, 1980) has hypothesized that the cortex is organized in levels, with excitatory and inhibitory relationships among and between the levels. The basis of Luria's findings is his work with injured soldiers and tumor patients (1966). His thesis regarding functional units of the cortex and cognitive functioning come from the exact location of lesions, results of psychometric tests, and through factor analysis procedures.

According to Luria, the organization of the cortex is divided into three basic levels. If an isolated neuron in the first level of the occipital cortex fires, it may be only in response to a horizontal line, another to a vertical line. At the second level, an isolated neuron working in an all or none fashion will fire only when it detects two horizontal lines forming an edge; another may fire when two vertical lines are detected. The third level organizes and integrates the visual input into a complete image (Hubel and Wiesel, 1963). Luria (1980) refers to these three levels as perceptual (primary), mnestic (secondary), and tertiary. The primary zone sorts and records sensory information, the secondary zone combines, organizes and codes the information, and the tertiary zone analyzes information from the lower levels as well as from zones of overlap from the frontal, temporal, occipital, and parital lobes. Analysis of information from these areas of overlap is required for intelligent action.

Based on his numerous investigations, Luria has identified three functional units of the brain. According to his model, the three functional units of the brain are concerned with Arousal (attention), two types of
Coding, Simultaneous and Successive, and Planning. The first of the three functional units of the PASS Model is responsible for arousal or attention. Arousal level is important because an optimum level is required for intelligent action and arousal level interacts with the other components of cognitive processing. This unit is based on the most primitive part of the brain, including the reticular activating system, brain-stem, and the hippocampus (Luria, 1966).

The second unit, according to Luria (1966), involves simultaneous and successive processing. Simultaneous processing involves the integration of information into synchronous and primarily spatial groups, maintaining relationships and proportions among elements. Simultaneous coding appears to be primarily located in the occipital-parietal tertiary zone of overlap in the left hemisphere. There is a similar zone of overlap in the right occipital-parietal tertiary zone of overlap. Successive processing involves the integration of information in a temporally organized serial order. The functional unit primarily responsible for Successive processing is located in the frontal-temporal tertiary overlap of the left hemisphere. To a lesser extent, there appears to be a similar Successive coding area in the frontal-temporal tertiary overlap of the right hemisphere.

Simultaneous and Successive processing take place, to a lesser extent, at the lower levels of the cortex and within the perceptual and mnemonic levels. Successive processing also takes place within the auditory and acoustic areas. Simultaneous processing also takes place
within the perceptual and mnestic areas of the visual kinesthetic, and vestibular systems responsible for orientation in space. Luria (1970, 1976) states that these two processes are used to synthesize information, but are dependent upon the nature of environmental stimuli and the habitual use by the individual.

The third unit consists of the executive function of Planning which is responsible for programming, regulation, and verification of activity. Luria (1970) found that individuals having difficulty with goal oriented behavior, or planning, also have damaged frontal lobes.

In summary, according to the PASS Model, the three functional units are concerned with Arousal (attention), two types of Coding, Simultaneous and Successive, and Planning. Through his work with injured soldiers and tumor patients Luria was able to link cognitive components to physiological areas of the brain. His functional units of the cortex and cognitive functioning come from the exact location of lesions, results of psychometric tests, and factor analysis procedures.

The PASS Information Processing Battery

The PASS Model (Planning, Attention, Simultaneous Processing and Successive Processing: Naglieri & Das, 1988), based on the research of Luria (1966, 1970, 1976, 1980) discussed above, has evolved from the work of Das and others. A variety of tasks assessing the components of
this model have been developed and evaluated and extensive research has been conducted assessing the validity of its components (Naglieri and Das, 1988). Das et. al. (1979) report over 20 studies with children and adults validating these constructs as valid factors.

The Planning Component has often been measured through the use of the Trail Making task. The Trail Making task requires subjects to connect circles in numeric or a combination of numerical/alphabetical order. This task was originally a part of the Army Individual Test of General Ability (1944). It was used by Reitan (1955) and Spreen and Benton (1965) to assess cortical functioning, and by Ashman and Das (1980) and Naglieri and Das (1988) to evaluate Planning. The Trail Making task was computerized previously as a part of the SAINT computerized neuropsychological battery by Swiercinsky (1983) for Compu-Psych, Inc.

The Raven's Standard Progressive Matrices (RSPM) task is often used as a measure of simultaneous processing. On this task the subjects are asked to complete a matrix of geometric shapes from a number of alternatives. Although this standardized device in its pencil and paper version was originally developed and is currently in use as a culture-reduced test of reasoning, Das et al. (1979) found that it is a good measure of Simultaneous Processing with factor loadings from .75 to .88. Jensen (1980) describes the Progressive Matrices as the "most extensively researched, and most widely used of all culture-reduced tests" (p.645). Knights et. al. (1973), Rock and Nolan (1982) and Buxton (1985) have developed computerized versions of the Raven Scales finding
strong positive relationships between the traditional versions and computerized adaptations.

The Continuous Performance Task (CPT: Rosvold et al., 1956) is a measure of attention that was initially developed to differentiate between brain-damaged individuals and normal subjects based on evidence that the former demonstrated inferior ability on tasks requiring sustained attention or alertness. On this task subjects are required to respond when a target letter or combination of two letters are presented. Due to the sustained attention required on the task it has been utilized in various forms to assess attention level in children (Gordon, 1987). Other versions of this task have been computerized to assess attention and have proven effective (Klee & Garfinkel, 1983; Gordon, 1987).

Attention Difficulties

According to DSM-III-R (American Psychiatric Association, 1987) Attention Deficit Hyperactive Disorder (ADHD) is defined as "developmentally inappropriate degrees of inattention, impulsiveness, and hyperactivity". DSM-III-R also includes the category of Undifferentiated Attention-Deficit Disorder. This category includes disturbances that previously, in DSM-III (American Psychiatric Association, 1980), would have been categorized as Attention Deficit Disorder without hyperactivity. The DSM-III-R description of this category states that further research is
indicated to determine the defining characteristics of this category and their validity.

The number of children diagnosed as ADHD is increasing. According to Love and Thompson (1988) using standardized DSM-III (American Psychiatric Association, 1980) criteria found that 73.3 percent of children referred for psychiatric outpatient services were found to possess Attention Deficit Disorders. The gender ratio estimates for attention deficit disorder reported in the literature are found to range from 10:1 to 3:1 for males to females (Gersten & Gersten, 1978; Lambert, Sandoval, & Sasone, 1978; Ross & Ross, 1976; Wendler 1971).

Despite the fact that many children meet the diagnostic criterion of ADHD, they are not all the same. Levine (1987) indicates that children showing signs of ADHD constitute a widely diverse group. He believes that children suffering from this disorder differ in their clinical manifestations such as overt behavioral difficulties, cognitive factors such as ability level, etiologies as to whether neurological or psychosocial indicators are present, responses to intervention such as ritalin or behavior modification, and prognoses. Yet he believes that there are shared attributes that justify using a unified conceptual category for these varied symptoms.

Not only is it difficult to develop a generalized picture of children suffering from attention problems, but experts do not agree as to what aspect of the disorder is of primary concern. Ross (1976) argues it is not
necessary to address the activity level (impulsivity) component of the problem, but that a conceptualization dealing with attention alone may be sufficient. In testing this hypothesis, Brown and Conrad (1982) found that addressing the inhibitory control component is not sufficient for enhancing cognitive performance.

The Conners' Scales are widely used indirect measures of attention. This pencil and paper task requires a parent and/or teacher familiar with the child to rate the child on a number of behavioral descriptors. These measures are the Revised Conners Teacher Questionnaire (CTQ: Goyette, et al, 1978) and the Revised Conners Parent Questionnaire (CPQ: Goyette, et al, 1978). These scales provide discrimination of behavior related to hyperactivity/attention level. A cutoff score approximately two standard deviations above the mean is generally used to determine whether attention difficulties are significant. These two measures have been used extensively in research evaluating activity level and attention span in relation to cognitive therapy (Borden et al., 1987), identification and assessment (Zarski et al., 1987; Satin, 1985), differentiating diagnostic categories (Kuehne et al. 1987), addressing neuropsychological issues (Chelune et al., 1986), and response to medication (Rapport et al., 1986).

Kuehne et al. (1987), in a study designed to evaluate the effectiveness of various psychometric measures to differentiate ADHD, LD and normals found indirect measures more efficient than direct measures of attention. The CTQ and CPQ were found to be more effective at differentiating the groups than the Matching Familiar Figures Test (Kagan
et al., 1964), the Porteus Maze Test (Porteus, 1959); and the Jumbled Numbers Game (Homatedis & Konstantareas, 1981).

One widely used, automated measure developed to assess attention skills is the Gordon Diagnostic System (GDS: Gordon, 1982). This measure is composed of a small box with three Liquid Crystal Diode (LCD) digit displays and a button. The GDS is composed of the Vigilance Task, the Distractibility Task, and the Delay Task. The Vigilance Task requires the child to inhibit responding under conditions that make demands for sustained attention. The Distractibility Task requires the child to sustain attention when distractors are present and the Delay Task requires the child to inhibit responding. A series of validation studies have shown that these tasks differentiate at a significant level between hyperactive and non-hyperactive children from both outpatient and day treatment settings (Gordon, 1979; McClure & Gordon, 1984). They also distinguished ADHD from reading disabled, overanxious, and normals (Gordon & McClure, 1983, cited in Gordon, 1987), and determined the effectiveness of pharmacotherapy (Rapport et al., 1985).

In summary, Love and Thompson (1988) note the number of children referred for outpatient services diagnosed as having attention problems is increasing. With this increase, further understanding of the population would assist in the diagnosis and subsequent treatment of these children. Rating scales and individual measures attempt to assess this widely diverse pathology with varying success. Since the experts in the field are
unable to develop a precise definition of this category (Levine, 1987), it is felt that innovative methods of assessment may provide insight into the varying conditions that constitute this category.

In reviewing the literature in this area a definite lack of precision is indicated with regard to the assessment of attention problems. An absolute need is established to determine the utility of innovative assessment procedures and to determine the interrelationship of cognitive functioning and behavior. Once these needs are met, methods of diagnosis may be improved, providing professionals with direction with regard to treatment.

*Computerized Assessment*

The application of computer technology to the field of psychology has taken on a variety of forms (Edwards, 1980; Golden, 1987). Computer systems have been developed to score and interpret traditional tests (Ellis, 1982), perform interpretive analysis of standardized tests (Brown, 1984), and score and/or administer multiple choice instruments such as the MMPI (Lushene, et al., 1974), the California Psychological Inventory (Scissons, 1976) and the 16PF (Karson & O'Dells, 1975). It also assists in the administration of ability measures (Ellis, 1983) such as the Wechsler Intelligence Scale for Children-Revised (Wechsler, 1974: WISC-R), administers tests such as the Peabody Picture Vocabulary Test (Dunn, 1963: PPVT) in their traditional form (Knights et al., 1973), and
administer tests utilizing the characteristics of the computer to improve diagnostic information (Buxton, 1985: Ellis & Buxton, 1988).

In traditional testing situations, Space (1981) indicated that a computerized battery of psychological tests coupled with automated scoring, interpretation and report writing could reduce the typical "turn-around time" between testing and reporting from 14 days to thirty minutes or less. The computerization of traditional pencil and paper tasks can result in time and financial savings for the clinician, but the ability of computers to improve the quality of assessment procedures has yet to be established.

Previous evaluations of computerized assessment measures have been correlational in nature, documenting equivalence between computerized and traditional methods (Lukin, et. al., 1985). The majority of research in this area addresses personality measures presented in a multiple choice format (Dunn et. al., 1972: Scisson, 1976 and Karson & O'Dells, 1975). These initial efforts to computerize psychological procedures have concentrated on adapting older, less effective methods of psychological testing to the new technology. Two decades ago Miller (1968) asserted that automated testing offers the potential for psychologists to obtain equivalent or greater amounts of psychometric data than traditional testing methods without spending as much time. Golden (1987) predicts that the adoption of computer technology will revolutionize the assessment of cognitive functioning.
Research addressing fully automated ability testing has been minimal and instrumentation has been varied. Elwood & Griffin (1972) examined the relationship between traditional and automated versions of the WAIS. Forty subjects were administered the WAIS in a counterbalanced manner. No significant differences were noted between the two methods \( r = .95 \) despite the novelty of such methods at the time the study was conducted.

Knights et. al. (1973) examined the relationship between automated and traditional administration of the PPVT and the Raven's Coloured Progressive Matrices (Raven, 1965: RCPM) for a group of severely to mildly retarded children, ages 12-18. Two matched groups of 16 took part in the study. Equipment was similar to the present day touch screen computer and responses were made by touching the correct choices. Results indicated that children receiving the automated versions first did poorly, but scores improved at the second (traditional) testing. Difficulty adapting to novel situations for retarded children was hypothesized as the cause of the poorer performance. More difficulty was encountered by the group receiving the automated version of the RSPM first. This finding was attributed to the difficulty encountered during the demonstration items, and novelty of computers at the time may have contributed to the difficulty on initial items for the subjects.

Also using a group of mentally retarded children \( N=240 \), Overton & Scott (1972) obtained correlations ranging from .91 to .94 between manual and automated versions of two forms of the PPVT. The authors
conclude from these results that the manual administration of such measures will soon become a thing of the past. They do indicate, however, that even with the promising results obtained in the study, careful training procedures should be utilized to ensure valid responses on initial test items. In an evaluation of a brief measure of ability, Hedl, et. al. (1973) obtained a correlation of .75 between the traditional and computer versions of the Slosson Intelligence Test (SIT).

Rock and Nolen (1982) conducted a pilot study to examine the relationship between the Standard and Computerized versions of the Raven's Coloured Progressive Matrices Test (RCPM). Using an Apple II Plus microcomputer version of the RCPM with 15 children ages 7 to 14, the authors compared the computer version with manually obtained scores (norm sample) and WISC-R IQ results. Method of response on the computerized task involved pressing a color coded key on the traditional keyboard which matched one of the response choices presented on the screen. An appropriate comparison group was not utilized in this study, but the authors claim validity of the computerized RCPM as they found no difference between the computerized RCPM and the normative sample of the test. This evidence should be viewed with caution. With regard to concurrent validity, a correlation of .59 was obtained between the computerized RCPM and the WISC-R. Results indicate that the first of the RCPM Subscales-A (the beginning of the test) did not contribute as expected to the total test score. They attributed this finding to the novelty of the hardware and mediating key-response requirements of their computerized version of the test. No mention was made whether the
subjects were required to confirm their choice nor did they describe the method used to introduce the computerized version.

While the concurrence between traditional and automated versions of psychological tests have been well established for over fifteen years, little or no research has been conducted examining the factors that account for the variance between groups to determine what underlying conceptual skills account for such differences. There is a serious void between the above noted correlational research and the validation of computerized methods which will improve the quality of assessment procedures.

In a counter-balanced, test-retest design using the computerized version of the RSPM, Buxton (1985) demonstrated a high degree of reliability ($r = .88$) with a two week period between testing sessions indicating a "high degree of concurrence" between the computerized RSPM and the manual version of the test. Significant positive correlations ($p < .01$) were obtained between the Computerized RSPM and the WISC-R. Using a stepwise multiple regression, RSPM IQ and Motoric Efficiency (Mouse movement Total) were found to account for forty-nine percent of the variance in WISC-R Verbal IQ. Final Response Time (Time 3) and Raven IQ were found to account for sixty-six percent of the variance in WISC-R Performance IQ. Computerized RSPM IQ and Motoric Efficiency I (Length 1) were found to account for fifty-nine percent of the variance in the WISC-R Full Scale IQ.
The Trail Making Task has been previously computerized as a part of the SAINT computerized neuropsychological battery by Swiercinsky (1983) for Compu-Psych, Inc. to run exclusively on the Psychometer 300-A computer. Golden (1987), while praising the Compu-Psych system as a milestone in computerized cognitive assessment, finds it limited. The battery was developed only for the Psychometer 300-A computer, limiting its potential use. Golden (1987) further indicates that assessment systems should be developed for more available, flexible and innovative equipment. Another potential difficulty specific to the Swiercinsky (1983) version of the computerized Trails task is its use of a joystick as the subject control mechanism.

In addition to saving clinician time and providing a more standardized method of assessment (Johnson & Williams, 1980; Space 1981), computerized testing may improve the quality of cognitive assessment as compared to traditional measures (Lushene, O'Neil, & Dunn, 1974; Skiller & Allen, 1983). Normally, variables such as cognitive style, motivation and attention span are assessed informally and discussed as observations or "clinical impressions" in diagnostic evaluations, or they are assessed through the use of rating scales. Thus, the relationship between test behavior and important underlying cognitive processes are only speculated and not directly assessed. The computer's extensive processing power can "split up" tasks into their components and analyze them in accordance with an appropriate model(s) of cognition to provide improved diagnostic information. Hofer and Green (1985) note that the primary concern regarding the implementation of computerized
assessment systems is that irrelevant factors incidental to the computerized administration may adversely affect test performance. The converse would be that well-designed systems will provide greater amounts of information about the child, thus giving insight to areas of functioning not previously assessed directly.

Elithorn et. al. (1982) provide a model to evaluate test performance factors not systematically evaluated using traditional assessment procedures. The authors utilized an automated version of the Perceptual Maze Test (PMT: Elithorn et. al., 1963) which requires subjects to connect dots contained within a maze using a two response format. The subjects were required to make a directional choice of left or right when a "fork" in the maze was encountered. Elithorn et. al. (1982) were able to dissect the motor responses of subjects to evaluate response time characteristics. The time variables evaluated using this test include search time- the time until the first motor response is made, track time- the time from the first motor response until the final response is made, and check time- the time it takes from the final response until the responses are confirmed. Additional characteristics evaluated on this measure include errors, average of the fastest ten percent key responses, the number of pauses greater than one second, the percent of right direction preferences and the number of sections of the task processed per second.

Using the above noted response style variables Elithorn et. al. (1982) has found the PMT to be sensitive to changes in both physiological and
psychological states. Elithorn et. al. (1982) reports noticeable changes in
test performance as a result of changes in psychotropic medication
regimen. Weinman (1982) found that more extroverted subjects spend
proportionally shorter initial search time on the PMT. While providing a
model for covert measurement on automated tasks, the procedures
utilized by Elithorn et. al. (1982) involve a relatively simple perceptual
maze task and has only been evaluated on a limited basis. The use of
covert measures in assessment may significantly add to computerized
methods, but the exact nature of such characteristics has yet to be
evaluated in a systematic manner.

Present face-to-face methods of assessment include the "personal
touch", where a "relationship" is established. If the child-assessor
interaction is looked at solely as a clinical interaction with the focus of
the assessment on interpersonal functioning, then the computer should not
be included in the process. While diagnostic impressions and clinical
information are obtained during the administration of the IQ tests,
information about functioning in these ancillary areas is not the primary
purpose for giving the tests. If the purpose of the assessment is to obtain
a reliable and valid measure of cognitive functioning, then computerized
testing may very well be the most viable method for improving
assessment methods.

In summary, as early as Elwood (1969), research has shown that
there are generally no significant differences between students'
performances on manual and automated versions of the most detailed
psychological tests. Subsequent evaluations of the concurrence between traditional tests and computerized versions by researchers such as Rock and Nolen (1982) and Buxton (1985) have found equivalent or improved psychometric properties of the computer versions. Initial efforts to computerize psychological procedures have concentrated on adapting older, less effective methods of psychological testing to the new technology. While the means have been available for a number of years to improve the methods of cognitive assessment through the use of computers, efforts have been minimal when compared to industrial and military applications discussed by Bartram & Bayliss (1984) and Hammer (1983).

**Summary of Previous Research**

While intelligence tests are able to predict academic achievement and their psychometric properties have improved since their inception, these tests have failed to grow conceptually with advents in the field of cognitive psychology, neuropsychology and learning theory. The PASS Model (Planning, Attention, Simultaneous Processing and Successive Processing: Naglieri & Das, 1988), based on the neuropsychology research of Luria, is felt to be a valid model of cognitive processing. A variety of tasks have been utilized to assess its components.

Furthermore, the number of children diagnosed as having attention problems is increasing. With this increase, further understanding of the population would assist in the diagnosis and subsequent treatment of
these children. Since diagnosing and evaluating children with attention problems continues to pose difficulties to professionals, it is felt that innovative methods of assessment may provide insight into the varying conditions that constitute this category.

In addition, research over the last two decades has found that automated/computerized methods of cognitive assessment are equivalent or, potentially, better than manual methods. The field of psychology has failed to embrace this technology and take full use of its potential to improve its methods.
CHAPTER III
Methodology

This chapter describes the population and the sample, procedures of data gathering, ethical safeguards, instrumentation, research design, and statistical analysis.

Population and Sample

The target population for this study is urban school children in the United States. The accessible population for this study was students attending public school in a large metropolitan city in southeastern Virginia. A random sample of public school children (N=29) and a group of children with attention problems (N=25) in grades three through five were used in the study. The subjects attended one of three elementary schools located in a large metropolitan area in southeastern Virginia. The school district is composed of forty percent minority students and also has a high proportion of parents on active military status. While all SES categories attend the public school system used in this study, a large number of private schools in the area serve the upper end of the continuum. The students attending the three schools used in this study were from predominantly working class families with a large proportion of fathers on active duty military status, but a variety of occupations and SES were represented. Examination of group test scores for the three schools revealed scores within the average range for both the district and
the nation. Classrooms for inclusion in the study were determined through the use of a random number table. Teachers were given an instruction sheet (Appendix A) which requested they read a behavioral description of children with attention problems (DSM-III-R Checklist; Appendix A) and were asked to "nominate" the three children in their class that best fit the criterion (Group A). Another group of subjects was selected randomly from class lists after the attention problem group had been chosen (Group B). Each student was assigned a number and using a random number table, three students per class were chosen to be a part of the group. Permission forms were sent home to seventy-two parents (thirty six from each group) and permission was obtained for sixty three of the subjects. Eight had moved before data collection could be completed and one of the children in the attention problem group refused to take part in the testing.

The group of children attention problems was composed of 18 boys and 7 girls, 7 whites, 17 blacks and 1 "other". Average age of the attention problem group was 128 months with a grade point average (GPA) of 1.4 out of a maximum of 4.0. The random group was composed of 18 boys and 11 girls, 14 whites, 14 blacks and 1 "other". Average age of the random group was 127 months with a GPA of 2.6. T-tests revealed that the two groups differed significantly on GPA, number of siblings (2.00 vs. 1.34), position in family birth order and likelihood of meeting promotion standards.

In order to determine whether the attention problem group was skewed on any of the behavioral characteristics of the DSM-III-R Rating Scale, an analysis was performed on the scores. Over two thirds of the
children were rated as displaying 13 of the 14 characteristic "often". The fourteenth characteristic that was not rated as consistently as the others was "Often engages in physically dangerous activities without considering consequences". According to the DSM-III-R, the discriminating characteristics are in descending order of importance, thus this characteristic is the least important of the fourteen.

This public school system's computer literacy program is consistent with the national trend to provide experiences for children beginning at the kindergarten level, exposing them to applications such as drill and practice programs and learning games. Exposure is provided in both the classroom setting and through the schools' media centers. This basic literacy program ensures that all subjects have had an opportunity to develop a familiarity with computers and their operation.

This investigator trained and supervised the subjects on the computerized tasks used in the study. The duration of the data collection process was 5 weeks with an additional two weeks to obtain information from subjects who had moved or transferred to different schools. Students suspected of mental retardation (MR) were not considered for inclusion in the study due to the conceptual level required for performance on computerized tasks. When the random procedure for classroom selection was conducted, the MR classrooms were not included. Any student who had been referred to the Special Education Screening Committee was not included in the study. This was done to alleviate the chance of a MR student participating in the study.
Procedures

Data Gathering Methods  Parents of the sample selected were contacted for their permission by this investigator via a note sent home with the student (appendix B). The reason for the research was explained and a description of the procedures was provided.

The Apple Macintosh Computer was used to administer the computerized measures of cognitive functioning and attention developed for this study. Egyhazy and Hutson (1985) in a review of technical reports and publications addressing newer computer systems such as the Macintosh, claimed that windows and pointing devices (mice) are obvious improvements over older systems with regard to the interface between computers and young children. For the individualized assessment component of the research, the subjects were seated in a secluded room located in the school building of attendance. While perfectly quiet conditions were difficult to achieve, the setting and conditions provided were the same as would be provided during the administration of traditional cognitive assessment procedures by the district's special education staff. The Gordon Diagnostic System (Gordon 1986), an automated measure of attention, was also used in the study. This measure was administered under the same conditions as described above.

Consideration of size and height was necessary in presentation of materials to ensure adequate vision and response capability. Acceptable
parameters were estimated during the pilot testing phase. Adjustments of table height, computer location and mousepad placement were made to account for subjects' individual differences. The subjects were presented with the various experimental tasks via the computer screen. The subject's responses were made using a mouse device attached to the computer which directed an arrow on the screen. When the child was required to respond, he/she moved the mouse, pressed a button on the mouse, or did both tasks. Depending on the nature of the task, a confirmation of the choice was required.

The traditional criterion variables with regard to the measure of attention were pencil and paper tasks completed by the subjects' teachers and parents (Conners' Rating Scales). Demographic and school achievement information were obtained through the use of an instrument designed specifically for this study (appendix A). Variables that were collected using this instrument included race, gender, socio-economic status, parent(s) marital status, number of siblings, birth placement, and grades. These data were utilized to perform a post hoc analysis to determine the possible influence on the subjects' scores on the various measures. An attempt was made to counterbalance the order in which the GDS and CCAB were administered to the subjects, but perfectly equal division was not achieved due to logistical difficulties. Sixteen of the twenty-nine random group subjects received the CCAB first and thirteen of the twenty-five attention problem group received the CCAB first.
Ethical Safeguards and Considerations

The Ethical Principles In the Conduct of Research with Human Participants (American Psychological Association: APA, 1982) was followed to ensure protection of the rights of the participants. Subjects and parents were advised of the benefits involved in the children's involvement. Parents and subjects were informed that they could terminate their participation without consequence at any time (appendix B). Approval was obtained by the human subjects review committees of the School of Education, College of William and Mary, and the Planning and Research Department of Norfolk Public Schools (appendix C). Confidentiality, informed-consent and necessary follow-up were the responsibility of this researcher.

The needs and rights of the children were given priority over research efforts and if participation or specific measures used as a part of this study were deemed inappropriate for any given child, the subject was not included in the study. Only one of the experimental subjects was not included due to her refusal and uncooperative attitude. She was told that it was her choice and that there would be no negative sanctions as a result of her refusal.
Instrumentation

Computerized tasks included a measure of Planning, Attention, Simultaneous Processing and Successive Processing (Naglieri & Das, 1988). To ensure adequate task orientation and to provide familiarity with the computerized procedures, sample items of each test were presented first. Subjects were given the opportunity to repeat the practice items until correct responses were obtained. Previous studies have encountered difficulty with initial training of subjects on computerized measures of ability (Overton & Scott, 1972) and extended practice time was allowed to counteract this effect. Mastery was assumed when the subjects were able to perform the task unaided by the examiner. Subjects were also allowed to continue taking the practice items until they felt comfortable.

Computerized Cognitive Assessment Battery

Computerized Trails  The Planning Component was measured through the use of the Computerized Trails task. This task is similar to the Trail Making task which was originally a part of the Army Individual Test of General Ability (1944). It was used by Reitan (1955) and Spreen and Benton (1965) to assess cortical functioning, and by Ashman and Das (1980) and Naglieri and Das (1988) to evaluate Planning. Lezak (1982) found a high degree of concordance throughout three administrations of Parts A (W= .78) and B (W= .67), but did find a practice effect for the third administration of Part A. Lezak (1983) supports the utility of the Trail
Making test because of the possible insight obtained from analysis of tracking efficiency and errors. Das (1984) reports factor loadings for the Trail Making task from .61 to .83 on the Planning Component.

A Macintosh computer version of the Trails task was developed specifically for this study. On the computerized version of this task, the subjects were required to connect numbers and letters that appear in circles, quasi-randomly distributed on the computer screen, in the correct numerical or numerical/alphabetical order using an arrow controlled by the mouse. On Part A of the test the subjects were required to connect the circles in numerical order. On Part B the subjects were required to connect the circles in the order of "1, A, 2, B, etc.". The task was scored for errors, total time to complete the task and mouse movement efficiency. This last measurement reflects the length of the line drawn with the mouse (cursor) by the subject. A long line drawn by the subject would indicate that an inefficient method of task completion was utilized where a short line would indicate an efficient method. Appendix E contains a description of this task.

**Computerized Raven's Standard Progressive Matrices (CRSPM)**

Computerized version of the Raven's Standard Progressive Matrices have been developed by Knights et. al. (1973), Rock and Nolan (1982) and Buxton (1985). The CRSPM was adapted to fulfill the procedural requirements of this study. Permission was obtained by this investigator from the publisher to utilize the RSPM in computerized form for experimental purposes with specific procedural requirements (J.C. Raven Jr., personal
communication 12/5/85, Appendix D). Retest reliabilities of the pencil and paper version of this test have been found to range from .70 to .90 (Eichorn, 1975). Lezak (1982) has indicated that the RSPM is a stable instrument with no significant shift in mean scores between three administrations. Das et al. (1979) found that it is an "excellent" measure of Simultaneous Processing with factor loadings from .75 to .88. Jensen (1980) describes the Progressive Matrices as the "best known, most extensively researched, and most widely used of all culture-reduced tests" (p.645). He also notes correlations between traditional measures of ability such as the Stanford-Binet and WISC-R from .50 to .79 along with internal consistency reliabilities close to .90. Using computerized versions of the Raven's Scales, Knights et. al. (1973), Rock and Nolan (1982) and Buxton (1985) have found strong positive relationships between the traditional versions and computerized adaptations.

In the present study the subjects were presented with a graphic representation of the standard Raven's items. The Raven's test is a series of designs arranged in a 2 X 2 or 3 X 3 matrix with the bottom right design missing. Across the bottom and right side of the display area is a row of six or eight designs, one of which is the correct item to complete the matrix. The subject was required to move the arrow to the correct answer and "click" the button on the mouse. The subject controlled the arrow on the computer screen by moving a mouse on the desk next to the machine. The "click" response requires the subject to press a large button on the upper surface of the mouse. Once the subject made an initial choice, a textual display indicated that the subject should verify the
choice by moving the arrow to the upper right corner of the display screen and make a click. On the CRSPM two sample items (A-1 and A-2) were administered first as required on the traditional version. The CRSPM also contains additional response parameters of Response Times and Mouse Movement Efficiency. Response Times are determined in milliseconds and indicate how long the subject takes to initially move the mouse (arrow) from the starting point, the time until a response is made and the duration until the choice is confirmed. Appendix F contains a description of this task.

*Computerized Sequential Memory Test* (CSMT) The Computerized Sequential Memory Test was developed specifically for this study in order to measure Successive Processing. This task is similar to the Memory for Objects subtest of the Short Term Memory Scale of the Stanford-Binet Intelligence Scale, Fourth Edition (Thorndike et al., 1986). On the Binet:IV task stimulus items were presented to the subject individually and the subject was then required to choose the items in their correct order from an array of objects common to North American children. In order to alleviate possible cultural bias of the Binet:IV Test, geometric shapes were utilized on the CSMT. Naglieri and Das (1988) developed a similar non-computerized test known as the Successive Ordering task to assess Sequential Processing as a part of the PASS battery.

While the CSMT was developed specifically for this study, Kuder Richardson Formula 20 reliabilities of similar tasks (Memory for Designs
of the SB:IV) have ranged from .66 to .78. Test-retest reliability on the SB:IV measure was found to be .61 (Thorndike et al., 1986).

On the CSMT the subject was presented with a varying number of geometric shapes one at a time for one second. Once the stimulus shapes were presented to the subject, one or two rows of geometric shapes were presented depending on the difficulty level of that particular task. The subject was then required to move the mouse and click when the arrow was on the correct shape. Correct order was required on this task. After the subject clicked on each of the shapes, a numeral appeared below the shape corresponding to the order of the subject's choice. After the correct number of choices had been made, the subject was required to confirm the order of the choices or was then given the opportunity to change the choices. Response latencies, errors and mouse movement efficiency were recorded on this task. Appendix G contains a description of this task.

Computerized Continuous Performance Task (CCPT) This measure is an adaptation of the automated Continuous Performance Task (CPT: (Rosvold et al., 1956) and computerized specifically for this study to measure Attention. The CPT required extensive control mechanisms to provide and display stimulus material efficiently and to evaluate subjects' responses. Split-half reliability of the original version of this test was found to range from .86 to .88. Test-retest reliability was found to range from .74 to .90.
Two tasks following the specifications of Rosvold et. al. (1956) were developed. On Task One, the subjects were provided with a visual display of geometric symbols randomly flashing one at a time and the subjects were required to make a response (mouse click) when a target symbol was displayed. On Task Two of the CCPT the subjects were required to respond to a target sequence of two symbols in the middle of three sets of randomly flashing symbols. An additional attention task involving a delayed response was administered. On this task the subjects' increased a counter (number) on the screen by making a response only after a delay period (six seconds). This task measured the subjects' ability to inhibit responding. This particular task was similar to the Delay Task (Gordon, 1982) discussed below. Appendix H contains a description of this test.

Automated Measure of Attention

Gordon Diagnostic System (GDS) The Gordon Diagnostic System is a widely used automated measure of attention skills (Gordon, 1982; 1987). The hardware component of the GDS is a small microprocessor controlled box with three numeric displays behind a single button. Counters and interface equipment are located in the rear of the box, out of sight of the subject. The GDS is composed of the Vigilance Task, the Distractibility Task and the Delay Task. The Vigilance Task requires the child to inhibit responding under conditions that make demands for sustained attention. Test-retest reliability correlations from 2-45 day range from .60 to .85,
and for a one year period range from .52 to .94. All scores were found to be significant at the p< .001 level (Gordon & Mettelman, 1988).

On this task a series of digits flash one at a time on a single LCD display screen and the subject is to press a button every time a "1" is followed by a "9". Correct responses are counted along with errors of "omission" and errors of "commission". The Distractibility Task is based on the Vigilance section of the Continuous Performance Task, but two LCD displays flash random digits on each side of the target stimulus while the subject attempt to respond correctly to a "1" and "9" pattern in the middle area only. The Delay Task requires the subject to inhibit responding in order to receive points. Credit is given if the duration of the delay is at least 6 seconds. The Delay Task yields three primary scores: the total number of responses (button presses), the number of correct responses, and the percentage of correct responses (efficiency ratio). This task is divided into three sections on the Distractibility and Vigilance tasks and four sections on the Delay task. The number of responses, the number correct and the efficiency ratio are computed for each of the sections. These variables are then used to compute between block variability and overall slope. Variability determines whether the subject was consistent throughout the task and slope is used to evaluate whether performance increased or decreased throughout the task.
Behavioral Measures of Attention

Conners Scales Attention level was assessed by traditional observational measures: Revised Conners Teacher Questionnaire (CTQ: Goyette, et al, 1978) and the Revised Conners Parent Questionnaire (CPQ: Goyette, et al, 1978). These two measures have been used extensively in research evaluating activity level and attention span in relation to cognitive therapy (Borden et al., 1987), identification and assessment (Zarski et al., 1987; Satin, 1985), differentiating diagnostic categories (Kuehne et al. 1987), addressing neuropsychological issues (Chelune et al., 1986) and response to medication (Rapport et al., 1986). Conners (1973) has found the test-retest reliabilities of the teacher version of this instrument to range from .70 to .90, and reliabilities of the parent version were assumed to be similar, but no documentation is available (Goyette, et al, 1978). These same examiners found the correlation between mother and father ratings on the hyperkinesis index of this instrument to be .55.

In order to identify the subjects for inclusion in Group A (attention problems), a scale was developed using the DSM-III-R criterion for Attention Deficit Hyperactivity Disorder. The fourteen characteristics were listed and a three point Likert scale utilized for ratings. All nominated subjects received a rating of "often" on at least seven of the fourteen characteristics. Possession of seven DSM-III-R characteristics is the criterion for Attention-Deficit Hyperactivity Disorder on the DSM-
III-R, thus no further analysis of the ratings was required nor were additional nominations necessary.

Research Design

Initially, the computerized items were evaluated to determine their reliability and internal consistency. For the next part of the study a multivariate 2-group design was utilized to examine the relationship between distractibility and performance on the PASS model tests (CCAB). Performance of a randomly selected group of students (Group A) was compared to a group of students with attention problems (Group B). For the third part of the study the relationship of newly developed computerized measures of attention and response characteristics on the CCAB tests were compared to the behavioral ratings of attention and the widely used automated measure of attention.

Statistical Analysis

Thousands of data points were generated on the computerized measures for each of the 54 subjects. An exact count is not possible due to the variable nature of the tasks and as with any measure of cognitive functioning, all subjects are not administered the same number of items. These data were condensed, summarized and totaled using Hypercard Scripts and BASIC language programs yielding a format conducive to answering the above stated research hypotheses. The SAS:Version 6 program (SAS, 1989) and SPSS-X (SPSS Inc, 1983) were used for final
data analysis and generation of statistics in this study. Data was analyzed through the generation of correlation coefficients, the use of t-tests and discriminant function analyses as appropriate. An alpha or significance level of $p < .05$ was used for acceptance or rejection of the hypotheses.

**Summary of Methodology**

A random sample of public school children ($N=29$) and a group of children with attention problems ($N=25$) in grades three through five in a large metropolitan area in southeastern Virginia were used in the study. Ethical Principles (APA, 1982) were followed to ensure protection of the rights of the participants. Using the PASS Model of cognitive processing (Naglieri & Das, 1988), computerized tasks were developed to evaluate each of the components of this model. Their effectiveness in discriminating between normal students and those having difficulty with attention was determined. The relationship between the computerized measures of attention and traditional methods were also evaluated. In summary, this study integrated and attempted to improve upon previous cognitive assessment methods by developing a comprehensive psychological screening battery which was administered via computer.
CHAPTER IV

Results

This section will provide each of the five research hypotheses, statistical methodology employed to evaluate the hypotheses, the results of the statistical analyses and whether the directional hypotheses were accepted or rejected.

Hypothesis One

The computerized tasks will demonstrate reliability and internal consistency within acceptable limits.

COMPUTERIZED TRAILS TEST

Statistical Analyses  The Computerized Trails Test is composed of two separate tasks (Trails A and B), yields twelve sectional scores (three per test per variable) and six total, or summative scores. Half of the scores reflect response times and the other half lengths of responses. This test does not yield discrete scores indicating correct or incorrect responses. In order to evaluate internal consistency of this measure, correlation coefficients of sectional scores and totals of both scales of the Computerized Trails were calculated for the total sample.
**Statistical Results**  Table 4.1 and 4.2 show the correlation matrix of the Computerized Trails Test scores. These results indicate correlations ranging from .08 (NS) to .40 (p<.01) for the sectional time variables on Trails A (table 4.1). Only one of the correlations did not reach significance (Time 2 with Time 3). The three sectional time variables correlation coefficients with the total time for Trails A ranged from .61 to .75 (p<.01). On Trails B,(table 4.2) results indicate correlations ranging from .17 (NS) to .78 (p<.01) for the sectional time variables. Only one of the correlations did not reach significance (Time 2 with Time 3). Results indicate correlations ranging from .21 (NS) to .47 (p<.01) for the sectional length variables on Trails A. Again, only one of the correlations did not reach significance (Length 2 with Length 3). On Trails B, results indicate correlations ranging from .23 (NS) to .50 (p<.01) for the sectional length variables. Lengths 2 and 3 did not reach significance. Between task correlations were found to be .44 (p<.01) for total times and .67 (p<.01) for total lengths. Correlation between Length A and Time A was found to be .63 (p<.01). Correlation between Length B and Time B was found to be .64 (p<.01).On the basis of the above results, the directional hypothesis was accepted with regard to the internal consistency of the Computerized Trails Test.

While all intercorrelations were not found to be significant (p<.05), significant positive relationships (p<.01) were found between all sectional variables and their totals, and significant positive relationships (p<.01) were found between all total scores on both scales of this measure. Time 3 and Length 3 on both Trails A and B did not
Table 4.1
Pearson Correlation Coefficients of Computerized Trails Task Section A

<table>
<thead>
<tr>
<th></th>
<th>Length1</th>
<th>Length2</th>
<th>Length3</th>
<th>L.Total</th>
<th>Time1</th>
<th>Time2</th>
<th>Time3</th>
<th>T. Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length1</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length2</td>
<td>0.277 *</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length3</td>
<td>0.469**</td>
<td>0.213</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length Total</td>
<td>0.682**</td>
<td>0.637**</td>
<td>0.854**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time1</td>
<td>0.453**</td>
<td>0.289 *</td>
<td>0.011</td>
<td>0.253</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time2</td>
<td>0.273 *</td>
<td>0.715**</td>
<td>0.107</td>
<td>0.447**</td>
<td>0.397**</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time3</td>
<td>0.380**</td>
<td>0.150</td>
<td>0.837**</td>
<td>0.700**</td>
<td>0.253</td>
<td>0.081</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Time Total</td>
<td>0.479**</td>
<td>0.566**</td>
<td>0.409**</td>
<td>0.631**</td>
<td>0.749**</td>
<td>0.721**</td>
<td>0.613**</td>
<td>1.0</td>
</tr>
</tbody>
</table>

* indicates p<.05  ** indicates p<.01

Length Total= L. Total,  Time Total= T. Total
### TABLE 4.2

Pearson Correlation Coefficients of Computerized Trails Task B

<table>
<thead>
<tr>
<th></th>
<th>Length1</th>
<th>Length2</th>
<th>Length3</th>
<th>Length Total</th>
<th>Time1</th>
<th>Time2</th>
<th>Time3</th>
<th>Time Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length1</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length2</td>
<td>0.502**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length3</td>
<td>0.234</td>
<td>0.346**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length Total</td>
<td>0.738**</td>
<td>0.873**</td>
<td>0.645**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time1</td>
<td>0.719**</td>
<td>0.249</td>
<td>0.160</td>
<td>0.465**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time2</td>
<td>0.252</td>
<td>0.653**</td>
<td>0.128</td>
<td>0.506**</td>
<td>0.291*</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time3</td>
<td>0.135</td>
<td>0.083</td>
<td>0.765**</td>
<td>0.376**</td>
<td>0.294*</td>
<td>0.179</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Time Total</td>
<td>0.469**</td>
<td>0.513**</td>
<td>0.480**</td>
<td>0.637**</td>
<td>0.665**</td>
<td>0.776**</td>
<td>0.665**</td>
<td>1.0</td>
</tr>
</tbody>
</table>

* indicates p<.05  ** indicates p<.01
consistently reach significance with their corresponding sectional variables, but this may be due to added complexity of this section of the test as opposed to faulty test design. If improper design was the reason for this pattern of scores, low correlations between the third sectional variables and total scores would be expected. This is not the case, however. While the correlation between Length 2 and Length 3 of Trails A did not reach significance, the correlation between Length 3 of Trails A and Total Length A (.85, p<.01), was found to be higher than the correlations of Total Length A and Length 2 (.68, p<.01) and Length 3 (.64, p<.01) of Trails A.

COMPUTERIZED SEQUENTIAL MEMORY TEST

Statistical Analyses The Computerized Sequential Memory Test is composed of two scales that yield raw scores representing the number of items correct. In order to evaluate the internal consistency of this scale, reliability coefficients were calculated for the two scales. In order to evaluate the relationship among and between the response time variables and length variables, correlation coefficients were calculated to evaluate internal consistency of this scale.

Statistical Results With regard to the reliability of the individual items of the scale, the index of reliability for scale A was found to be as follows: Cronbach’s alpha equals .90 and standardized item alpha equals
TABLE 4.3
Pearson Correlation Coefficients for
The Computerized Sequential Memory Test

<table>
<thead>
<tr>
<th></th>
<th>Length1</th>
<th>Length2</th>
<th>Length Total</th>
<th>Time1</th>
<th>Time2</th>
<th>Time3</th>
<th>Time Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length1</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length2</td>
<td>0.359**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length Total</td>
<td>0.583**</td>
<td>0.967**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time1</td>
<td>-0.363**</td>
<td>-0.022</td>
<td>-0.118</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time2</td>
<td>0.469**</td>
<td>0.009</td>
<td>0.135</td>
<td>-0.074</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time3</td>
<td>-0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Time Total</td>
<td>-0.131</td>
<td>0.163</td>
<td>0.106</td>
<td>0.762**</td>
<td>0.446**</td>
<td>0.002</td>
<td>1.0</td>
</tr>
</tbody>
</table>

* indicates p<.05    ** indicates p<.01
The index of reliability for scale B was found to be as follows: Cronbach's alpha equals .83 and standardized item alpha equals .84. Table 4.3 shows the correlation matrix of Computerized Sequential Memory Test scores. These results indicate correlations ranging from -.07 to .01 (NS) for the sectional time variables. Correlations ranged from .01 (NS) to .76 (p>.01) for the sectional time variables when compared with the total time. Results indicate a correlation of .36 (p<.01) for the two sectional length variables. Correlations ranged from .58 (p>.01) to .97 (p>.01) for the sectional length variables when compared with the Total Length. A correlation of -.36 (p>.01) was found between Length 1 and Time 1. The directional hypothesis was accepted with regard to the Computerized Sequential Memory Test, but the utility of Sequential Length 3 has yet to be demonstrated.

**COMPUTERIZED CONTINUOUS PERFORMANCE TEST**

**Statistical Analyses** The Computerized Continuous Performance Test is composed of three separate tasks (Delay, Vigilance and Distractibility). The Delay Task yields the following scores: total correct and total responses per block for four blocks of two minutes each, and total correct and total responses. In order to evaluate the relationship between the block scores, totals and scales, correlation coefficients were calculated. The Vigilance task yields number correct, omissions, and errors of commissions for three blocks of three minutes each. The Distractibility
Task also yields number correct, omissions, and errors of commissions for three blocks of three minutes. In order to evaluate the relationship between the sectional (block) scores, totals and scales, correlation coefficients were calculated.

**Statistical Results**  Table 4.4 shows the correlation matrix of Computerized Continuous Performance Test Delay scores. These results indicate correlations ranging from .34 to .72 (p<.01) for the four sectional Number Correct variables on the Delay Task and correlations from .76 to .91 (p<.01) with the Total Correct. These results indicate correlations ranging from .47 to .76 (p<.01) for the four sectional Number of Commissions variables on the Delay Task and correlations from .67 to .91 (p<.01) with the Total Commissions.

Table 4.5 shows the correlation matrix of Computerized Continuous Performance Test Vigilance scores. These results indicate correlations ranging from .65 to .86 (p<.01) for the three sectional Number Correct variables on the Vigilance Task and correlations from .86 to .92 (p<.01) with the Total Correct. These results indicate correlations ranging from .68 to .80 (p<.01) for the three sectional Errors of Commissions variables on the Vigilance Task.

Table 4.6 shows the correlation matrix of Computerized Continuous Performance Test Distractibility scores. These results indicate correlations ranging from .78 to .89 (p<.01) for the three sectional
### TABLE 4.4

Correlations of the Delay Task of the Computerized Continuous Performance Test

<table>
<thead>
<tr>
<th></th>
<th>Efficiency Ratio</th>
<th>Block Var.</th>
<th>Slope</th>
<th>Total Correct Responses</th>
<th>Total Correct Responses</th>
<th>Correct Responses Block 1</th>
<th>Correct Responses Block 2</th>
<th>Correct Responses Block 3</th>
<th>Correct Responses Block 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eff. Ratio</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block Var.</td>
<td>-0.637**</td>
<td>0.596**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>-0.297</td>
<td>0.596**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tot. Cor.</td>
<td>0.049</td>
<td>0.002</td>
<td>-0.154</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tot. Res.</td>
<td>-0.755**</td>
<td>0.513**</td>
<td>0.105</td>
<td>0.517**</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cor. B1</td>
<td>0.212</td>
<td>-0.185</td>
<td>-0.242</td>
<td>0.765**</td>
<td>0.246</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Res. B1</td>
<td>-0.726**</td>
<td>0.526**</td>
<td>0.267*</td>
<td>0.423**</td>
<td>0.898**</td>
<td>0.308*</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cor. B2</td>
<td>0.053</td>
<td>0.007</td>
<td>-0.231</td>
<td>0.91**</td>
<td>0.496**</td>
<td>0.631**</td>
<td>0.394**</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Res. B2</td>
<td>-0.705**</td>
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<td>0.274*</td>
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* indicates p<.05  ** indicates p<.01

Correct= Cor., Responses= Res., Block= Bl., Variability= Var., Total= Tot.
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* indicates p<.05  ** indicates p<.01

Correct= Corr., Ommissions= Omm., Commissions= Comm., Block= Bl., Variability= Var.
### TABLE 4.6

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<td>-0.308*</td>
<td>0.950**</td>
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<td>0.308*</td>
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<td>-0.778**</td>
<td>0.778**</td>
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<td>-0.357**</td>
<td>0.958**</td>
<td>0.804**</td>
<td>-0.804**</td>
<td>-0.213</td>
<td>0.888**</td>
<td>-0.888**</td>
<td>-0.165</td>
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<tr>
<td>Omm. Bl 3</td>
<td>0.180</td>
<td>0.209</td>
<td>0.357**</td>
<td>-0.958**</td>
<td>-0.804**</td>
<td>0.804**</td>
<td>0.213</td>
<td>-0.888**</td>
<td>0.888**</td>
<td>0.165</td>
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* indicates p<.05  ** indicates p<.01

Correct= Corr., Omissions= Omm., Commissions= Comm., Block= Bl., Variability= Var.
**Number Correct** variables on the Distractibility Task and correlations from .90 to .96 (p<.01) with the **Total Correct**. These results indicate correlations ranging from .77 to .85 (p<.01) for the three sectional **Errors of Commissions** variables on the Vigilance Task. On the basis of the above results, a high degree of internal consistency was demonstrated by the Computerized Continuous Performance Test.

Hypothesis Two

Significant positive correlations will be obtained between computer derived measures (response latencies and mouse movement factors) on the applicable Computerized CCAB tasks (Computerized Trails, CRPM, and the CSMT) and behavioral measures of attention (Conners' Teacher and Parent Rating Scales).

**Statistical Analyses** The derived measures (response latencies and mouse movement factors) totaled on the CCAB are as follows: The Computerized Trails Test- Trails A and B each yield two total, or summative, scores for time and length; The Computerized Raven's Progressive Matrices- yields two total, or summative, scores for time and length; and The Computerized Sequential Memory Test- yields two total scores for time and length. The Conners' Teacher Scale yields the original Hyperkinetic index in raw score form and the Conduct Problem, Hyperactivity, Inattentive-Passive, and Hyperactivity Index scores, which
were converted to scaled scores. The Parent Rating Scale yields the original Hyperkinetic index in raw score form and the Conduct Problem, Learning Problem, Psychosomatic, Impulsive-Hyperactive, Anxiety and Hyperactivity Index scores, which were converted to scaled scores.

**Statistical Results** Table 4.7 shows the correlation matrix of CCAB derived scores with Conners' Teacher Scale scores. No significant correlations were obtained between the CCAB scores and the Conners' Teacher Scale scores. Table 4.8 shows the correlation matrix of CCAB derived scores with Conners' Parent Scale scores. No significant correlations were obtained between the CCAB scores and the Conners' Parent Scale scores. On the basis of the above results, the directional hypothesis was rejected with regard to concurrence between the CCAB derived scores and the Conners' Teacher and Parent Rating Scales.

Hypothesis Three

The computerized measure of attention, CCPT, will be able to discriminate between a group of children with attention problems and a random group of children.

**Statistical Analyses** Using the discriminant function analysis procedure, the ability of the CCPT scores to distinguish between a group of children with attention problems and a random group of children will be evaluated.
TABLE 4.7

Correlations Between the Computerized Cognitive Assessment Battery and the Conners Teacher Rating Scale

<table>
<thead>
<tr>
<th></th>
<th>Trails Length A</th>
<th>Trails Time A</th>
<th>Trails Length B</th>
<th>Trails Time B</th>
<th>Raven Length</th>
<th>Raven Time</th>
<th>Sequential Length</th>
<th>Sequential Time</th>
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<tr>
<td>Hyperkinetic Index</td>
<td>0.059</td>
<td>-0.065</td>
<td>0.262</td>
<td>0.140</td>
<td>0.007</td>
<td>-0.004</td>
<td>0.219</td>
<td>0.088</td>
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<tr>
<td>Conduct Problems</td>
<td>-0.013</td>
<td>0.005</td>
<td>0.068</td>
<td>0.176</td>
<td>-0.026</td>
<td>-0.032</td>
<td>0.178</td>
<td>0.046</td>
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<tr>
<td>Hyperactivity</td>
<td>0.002</td>
<td>-0.183</td>
<td>0.239</td>
<td>0.110</td>
<td>-0.064</td>
<td>-0.072</td>
<td>0.242</td>
<td>0.021</td>
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<tr>
<td>Inattentive Passive</td>
<td>-0.016</td>
<td>-0.011</td>
<td>0.141</td>
<td>0.098</td>
<td>0.010</td>
<td>0.001</td>
<td>0.171</td>
<td>0.137</td>
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<tr>
<td>Hyperactivity Index</td>
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<td>-0.069</td>
<td>0.225</td>
<td>0.174</td>
<td>-0.056</td>
<td>-0.066</td>
<td>0.218</td>
<td>0.023</td>
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</table>

Note: No correlations reached significance
## TABLE 4.8

Correlations Between the Computerized Cognitive Assessment Battery and the Conners Parent Rating Scale

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<tr>
<th></th>
<th>Trails Length A</th>
<th>Trails Time A</th>
<th>Trails Length B</th>
<th>Trails Time B</th>
<th>Raven Length</th>
<th>Raven Time</th>
<th>Sequential Length</th>
<th>Sequential Time</th>
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<tr>
<td>Hyperkinetic Index</td>
<td>-0.009</td>
<td>0.071</td>
<td>0.067</td>
<td>-0.140</td>
<td>0.061</td>
<td>0.057</td>
<td>0.028</td>
<td>0.212</td>
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<tr>
<td>Conduct Problem</td>
<td>0.168</td>
<td>0.260</td>
<td>0.162</td>
<td>-0.070</td>
<td>0.098</td>
<td>0.097</td>
<td>0.127</td>
<td>0.164</td>
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<tr>
<td>Learning Problem</td>
<td>-0.056</td>
<td>0.088</td>
<td>0.049</td>
<td>-0.101</td>
<td>-0.018</td>
<td>-0.023</td>
<td>0.016</td>
<td>0.127</td>
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<td>Psychosomatic</td>
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<td>-0.101</td>
<td>0.035</td>
<td>0.039</td>
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<td>0.013</td>
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<td>0.008</td>
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Note: No correlations reached significance
Statistical Results Table 4.9 shows the results of the discrimination function for the CCPT scores using group membership as criterion. These results indicate that the CCPT was able to correctly categorize forty eight of the fifty four, or 89 percent of the subjects. Also, the results of the discriminant function only made one false positive identification compared to five false negative classifications. On the basis of the above results, the CCPT was able to discriminate between the two groups with acceptable accuracy.

Hypothesis Four

There will be no significant difference between the ability of the CCPT to discriminate between the two groups, and the ability of the Gordon Diagnostic System (GDS) to discriminate between the two groups.

Statistical Results Table 4.10 shows the results of the discrimination function for the GDS scores using group membership as criterion. These results indicate that the GDS was able to correctly categorize forty seven of the fifty four, or 87 percent of the subjects. Also, the results of the discriminant function made no false positive identification compared to seven false negative classifications. Comparing this level of accuracy with the eighty-nine percent accuracy of the CCPT, the CCPT was able to discriminate at a level equal to the GDS.
## Table 4.9

**Discriminant Function Results using Computerized Continuous Performance Test Scores to Predict Group Membership**

### Number of Observations and Percents Classified

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<td>2</td>
<td>25 (N)</td>
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<td>5</td>
<td>80.00</td>
<td>20.00</td>
<td>100.00 (percent)</td>
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<tr>
<td>3.45</td>
<td>96.55</td>
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<tr>
<td>TOTAL</td>
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<td>33</td>
<td>54</td>
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<tr>
<td>PERCENT</td>
<td>38.89</td>
<td>61.11</td>
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</table>
TABLE 4.10

Discriminant Function Results using Gordon Diagnostic System Scores to Predict Group Membership

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<th>NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED</th>
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</table>

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<tr>
<th>FROM GROUP</th>
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<th>TOTAL</th>
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<td>Attention (1)</td>
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<td>7</td>
<td>25</td>
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<tr>
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<td>100.00</td>
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<tr>
<td>Random (2)</td>
<td>0</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Probability</td>
<td>0.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>18</td>
<td>36</td>
<td>54</td>
</tr>
<tr>
<td>PERCENT</td>
<td>33.33</td>
<td>66.67</td>
<td>100.00</td>
</tr>
</tbody>
</table>


**Additional Analysis** In order to evaluate the ability of the entire CCAB to categorize the subjects in this study according to group membership, an additional discriminant function was performed using the CCPT and the totals and summary variables (total times and total lengths) of the other three CCAB tests. Table 4.11 shows the results of the discrimination function for the CCAB scores using group membership as criterion. These results indicate that the CCAB was able to correctly categorize fifty-four of the fifty-four, or one hundred percent of the subjects.

Hypothesis Five

The attention component (CCPT) of the CCAB will show the greatest difference between the two groups of children on the four computerized PASS Battery tests.

**Statistical Analyses** Comparisons were performed on the following total scores: Trails Length A, Trails Time A, Trails Length B, Trails Time B, Trails Length A and B combined score, Trails Time A and B combined score, Raven Raw Score, Raven IQ, Raven Length, Raven Time, Sequential Raw Score, Sequential Length, Sequential Time, CCPT Delay Efficiency Ratio, CCPT Delay Efficiency Ratio Block Variability, CCPT Delay Slope, CCPT Delay Correct, CCPT Delay Commissions, CCPT Vigilance Commissions, CCPT Vigilance Commissions Block Variability, CCPT Vigilance Correct, CCPT Vigilance Correct Block Variability, CCPT Delay
**TABLE 4.11**

Discriminant Function Results using The Computerized Cognitive Assessment Battery Scores to Predict Group Membership

<table>
<thead>
<tr>
<th>NUMBER OF OBSERVATIONS AND PERCENTS CLASSIFIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM GROUP</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Attention Problems (1)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Random (2)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
<tr>
<td>PERCENT</td>
</tr>
</tbody>
</table>
Commissions, CCPT Delay Commissions Block Variability, CCPT Delay Correct and CCPT Delay Correct Block Variability.

**Statistical Results** Table 4.12 shows the results of the t-tests performed to evaluate this hypothesis. These tests compared the attention problem group to the random group on the four Computerized PASS Battery Tests. The results of the t-test analyses indicate that significance ($p<.05$) was obtained between the two groups on three of the thirteen CCPT variables: Vigilance-Number Correct ($t= 2.06$); Vigilance- Block Variability ($t= 2.34$); and Vigilance- Total Correct ($t= -2.46$).

An additional variable was computed on the CCPT in order to evaluate this hypothesis. The CCPT test has thirteen scores that can be used for comparison with chronological peers. Gordon (1983) provides a method to determine whether these scores fall within the average range by using the standard deviation of each of the scores. Each of the thirteen CCPT codes were classified as to whether the code was in the average or below average range. The two groups were then compared on this computed variable, Number of Codes Below Average, and analysis yielded the most significant of the t-test comparisons ($2.68; p<.01$). On the basis of the above results, the attention problem group and the random group differed only on the Attention component of the CCPT.
## Table 4.12

### T-Tests by Group

For Computerized Cognitive Assessment Battery Total Scores

| VARIABLE | ATTENTION PROBLEM N=25 | RANDOM N=29 | T | PROB > |T| |
|----------|------------------------|-------------|---|---------|---|
| TRAILS  |                        |             |   |         |   |
| LENGTH A TOTAL | 132.0 | 61.9 | 129.3 | 66.9 | 0.15 | 0.88 |
| TIME A TOTAL | 108.2 | 35.4 | 117.2 | 33.7 | -0.95 | 0.34 |
| LENGTH B TOTAL | 238.3 | 124.2 | 198.8 | 105.6 | 1.26 | 0.21 |
| TIME B TOTAL | 175.9 | 74.2 | 172.2 | 56.8 | 0.20 | 0.84 |
| LENGTH TOTAL | 370.3 | 173.8 | 328.1 | 157.8 | 0.94 | 0.35 |
| TIME TOTAL | 284.1 | 97.9 | 289.4 | 75.6 | -0.22 | 0.82 |
| RAVEN RAW SCORE | 28.0 | 11.5 | 31.3 | 8.5 | -1.18 | 0.24 |
| IQ | 90.2 | 5.2 | 94.4 | 12.3 | -0.99 | 0.33 |
| TIME TOTAL | 110.20 | 34.4 | 106.6 | 23.1 | -1.06 | 0.29 |
| SEQUENTIAL  |             |             |   |         |   |
| LENGTH TOTAL | 27.5 | 9.4 | 23.3 | 5.7 | 1.93 | 0.06 |
| CORRECT | 7.4 | 3.3 | 8.3 | 3.2 | -1.07 | 0.28 |
| TIME TOTAL | 11.0 | 2.4 | 10.9 | 2.2 | 0.32 | 0.75 |
| CCPT DELAY |             |             |   |         |   |
| EFFICIENCY RATIO | 0.75 | 0.19 | 0.75 | 0.17 | 0.13 | 0.90 |
| BLOCK VARIABILITY | 0.12 | 0.07 | 0.12 | 0.08 | 0.06 | 0.95 |
| SLOPE | 0.11 | 0.12 | 0.02 | 0.06 | 1.56 | 0.13 |
| CORRECT | 45.0 | 9.8 | 49.6 | 11.7 | -1.55 | 0.13 |
| COMMISSIONS | 65.4 | 26.4 | 70.7 | 28.6 | -0.69 | 0.49 |
| VIGILANCE |             |             |   |         |   |
| COMMISSIONS | 36.8 | 46.6 | 15.2 | 25.6 | 2.06* | 0.04 |
| COMMISSIONS | 6.2 | 7.9 | 2.3 | 2.3 | 2.33* | 0.02 |
| BLOCK VARIABILITY | 1.4 | 3.0 | 0.8 | 0.6 | 1.92 | 0.06 |
| CORRECT | 38.7 | 4.4 | 43.3 | 8.9 | -2.46* | 0.02 |
| DISTRACTABILITY COMMISSIONS | 33.0 | 37.9 | 16.7 | 24.7 | 1.85 | 0.07 |
| COMMISSIONS | 4.8 | 5.1 | 2.7 | 3.4 | 1.78 | 0.09 |
| BLOCK VARIABILITY | 33.1 | 12.6 | 33.0 | 9.8 | 0.02 | 0.98 |
| CORRECT | 1.0 | 1.15 | 2.68** | 0.01 |

* INDICATES P<.05 ** INDICATES P<.01
While not statistically significant at the .05 level, the two groups differed on three other CCPT variables. The variables and their t-values are as follows: Vigilance Correct Block Variability- 1.92 (p<.10), Distractibility Commissions- 1.85 (p<.10), and Distractibility Commissions Block Variability- 1.78 (p<.10). This lends further evidence to the finding that the two groups differed most on the CCPT.
CHAPTER V
Summary, Conclusions and Implications

This chapter summarizes the present investigation, states the findings, discusses the hypotheses and conclusions and provides recommendations for future research.

Summary

The purpose of this study was to determine whether a computerized assessment battery designed to evaluate cognitive functioning and attention could demonstrate reliability and validity. The Computerized Cognitive Assessment Battery was developed for this study to assess Planning through the Computerized Trails Test, Attention through the Computerized Continuous Performance Test, Simultaneous Processing through the Computerized Raven's Standard Progressive Matrices and Successive Processing through the Computerized Sequential Memory Test. This investigation was conducted to develop new assessment procedures utilizing advanced computer technology to determine whether methods of cognitive assessment could be developed according to an acceptable neuropsychological model of cognitive functioning. This study was also conducted to assess the relationship between the results obtained on the novel computer measure and other assessment procedures.
and to determine whether the computerized test could aid in making diagnostic decisions about children.

A random sample of public school children (N=29) and a group of children identified by their teachers as having difficulty attending to classroom instruction (N=25) in grades three through five were used in the study. The subjects attended one of three elementary schools located in a large metropolitan area in southeastern Virginia. The subjects were administered the PASS Battery Tests on a Macintosh computer. All subjects were also individually administered the Gordon Diagnostic System. Behavior rating scales (Conners, 1973) were completed by each subject's parent and teacher. A background information questionnaire was developed specifically for this study and completed for each subject by his/her teacher.

The computerized items were evaluated to determine their reliability and internal consistency. A multivariate two group design was utilized in the study to examine the relationship between distractibility and performance on the PASS model tests. Performance of a group of children with attention problems (Group A) was compared to a randomly selected group of students (Group B). The relationship of newly developed computerized measures of attention and response characteristics on the PASS model tasks was compared to behavioral ratings of attention and a widely used automated measure of attention. The SAS:Version 6 program (SAS, 1989) and SPSS-X (SPSS Inc, 1983) were used for final data analysis and generation of statistics in this study. Data were analyzed
through the generation of correlation coefficients, the use of t-tests and discriminant function analyses as appropriate. An alpha or significance level of \( p < .05 \) was used for acceptance or rejection of the hypotheses.

Specific Hypotheses

The following directional research hypotheses were evaluated by this study:

**Hypothesis One** The computerized tasks will demonstrate reliability and internal consistency within acceptable limits.

**Hypothesis Two** Significant positive correlations will be obtained between computer derived measures (response latencies and mouse movement factors) on the applicable Computerized CCAB tasks (Computerized Trails, CRPM, and the CSMT) and behavioral measures of attention (Conners' Teacher and Parent Rating Scales).

**Hypothesis Three** The computerized measure of attention, CCPT, will be able to discriminate between a group of children with attention problems and a random group of children.

**Hypothesis Four** There will be no significant difference between the ability of the CCPT to discriminate between the two groups, and the ability of the Gordon Diagnostic System (GDS) to discriminate between the two groups.
**Hypothesis Five** The attention component (CCPT) of the CCAB will show the greatest difference between the two groups of children on the four computerized PASS Battery tests.

Conclusions

From the analysis of the statistical data presented in Chapter Four, the following results were established:

1. On the newly developed Computerized Trails Test, the majority of the sectional variables displayed significant intercorrelations (p<.01) indicating internal consistency of this measure. This shows that, overall, the length and time variables of this measure are measuring the same construct. These preliminary results indicate reliability of this CCAB scale.

2. The reliability of the Computerized Sequential Memory Test was found to be acceptable for both Scales. Cronbach Alpha coefficients for Scale 1 was .90 and Scale 2 was .83. These levels are well within the range considered acceptable for measures of cognitive assessment. The reliability coefficients of the CSMT equaled or surpassed those obtained on similar tasks which are as follows: Memory for Design subtest of the Binet:IV (Thorndike, et al., 1986) range from .66 to .78 and Digit Span subtest of the WISC-R (Wechsler, 1974) range from .71 to .84. The results obtained for the Computerized Sequential Memory Test indicate that the
items on this measure evaluated the same construct and did so in a consistent manner.

3. Internal consistency (correlations) of the Computerized Sequential Memory Test covert measures (time and length) was found to be variable. A significant positive relationship was found between the length variables (p<.01), but no relationship was established between the time variables. A significant negative relationship (p<.01) was noted between Length 1 and Time 1 indicating that the longer it took the subject to initially move the cursor out of the "start" area, the more efficient was the following motor response, and vice versa.

4. A high degree of concurrence was established between the sectional, or block scores of the Computerized Continuous Performance Test (p<.01) with correlations ranging to .96. This finding was not surprising since the method of presentation used on this test is consistent with that of Rosvold et. al. (1956) and Gordon (1983) who obtained similar high correlations.

5. There was found to be no relationship between the covert measures (response times and response lengths) of the CCAB (Computerized Trails; Computerized Sequential Memory Test; and the Computerized Raven) and the behavior rating scales (Conners' Parent Scale and Conners' Teacher Scale). The assumption that these measures would be related to attention and behavioral correlates was incorrect. There is
some evidence that the covert measures are related to the Planning Factor.

6. The Computerized Continuous Performance Test was able to discriminate between the two groups at a level approximately equivalent to the Gordon Diagnostic System. Eighty nine percent of the subjects were correctly classified by the Computerized Continuous Performance Test and eighty seven percent by the Gordon Diagnostic System. The Computerized Continuous Performance Test did make one false positive classification and the Gordon Diagnostic System made none.

7. The total CCAB was able to predict group membership with one hundred percent accuracy using the classification results of the discriminant function analysis. This level of accuracy was surprising since such accuracy is difficult to achieve without the inclusion of behavioral rating scales.

8. Consistent with the prediction of the PASS model, the Attention component (CCPT) was the only area in which the scores of the two groups differed. Three of the Vigilance Task parameters yielded significant group comparisons (p<.05). The computed variable, Number of Codes Below Average, yielded the most significant of the t-test comparisons (2.68; p<.01).
Discussion

The present study demonstrated the feasibility and practicality of a fully-computerized cognitive assessment battery to aid in the assessment process. While a number of psychological assessment instruments have been adapted for computerized administration (Brown, 1984), and a number of traditional tasks have been developed consistent with an empirically validated neuropsychological model of cognition (Das, et. al., 1979), there has been little attention given to applying current theory to the assessment process using computer technology.

There are a number of intervening variables that may have a detrimental effect on computerized test results. Knights et. al. (1973) indicate difficulty training MR children on computerized tasks. Obviously if children possess visual or motor impairments, computer use in the assessment process may not be appropriate. This study included a group of children with attention problems for two reasons. First, in order to determine the effects on performance on computerized tasks, and secondly, to evaluate the ability of the computer to evaluate this growing diagnostic category (Love and Thompson, 1988).

The present research indicates that the development and administration of cognitive measurement procedures are possible in a computerized format. The reliability and internal consistency of the computerized tasks demonstrates the profound potential of such methods
especially when combined with covert measures of response time and length variables. The reliability coefficients of the CSMT equalled or surpassed those obtained on similar tasks such as the Memory for Design subtest of the Binet:IV (Thorndike, et. al., 1986) and the Digit Span subtest of the WISC-R (Wechsler, 1974). This finding is not surprising given the precision of computerized presentation methods and considering that the CSMT was based on these two tasks.

Significant positive correlations were obtained for the majority of the sectional time and length variables of the CCAB. There were, however, a number of sectional variables of specific tasks that did not correlate with the other time and length variables. The low correlations occurred on the final time and length variables. There are two possible explanations for the phenomenon; one is that the final sections of the tests measured different constructs than the earlier sections of the test; and another explanation is that the third section of the test possessed design flaws. The evidence supporting the first explanation is stronger in accounting for the inconsistencies on the Computerized Trails Test. On this measure the last sectional variables (Length 3 and Time 3) lacked consistent positive relationships with the other sectional variables, but significant positive relationships were obtained between them (Length 3 and Time 3) and total length and time variables. In one case (Trails A), the correlation between Length 3 and Total Length was greater than the other length variables and Total Length. Increased complexity on the third section of this task is the likely reason for the obtained pattern on the Trails task.
Increased complexity of the task is unlikely to be the reason for a lack of concurrence between the final time section of the CSMT and the other CSMT scores. There was considerable difficulty encountered when attempting to standardize scoring procedures for these variables due to item variability and complexity. Because the item sequence on this test was contingent on performance on earlier tasks, all items were not administered to all subjects. The numbers of items administered to each subject varied with regard to number of items per level and number of levels per section. With this variable item format, an attempt was made to standardize the scoring method of the final covert measures. The method utilized was to take the amount of time from the initial mouse click until confirmation of choice was made, then divide this value by the number of designs presented and the number of items administered. As indicated by the statistical results, the information obtained using this method yielded no significance. This variable may contribute to the understanding of mental processes, but in the form utilized for this study, it was not found to be a valid measure of Sequential Processing.

An unexpected relationship was found between two of the CSMT covert measures. A correlation of .36 (p<.01) was obtained between Time 1 and Length 1. Time 1 was the duration of time the subject spent in the "start" area before moving the mouse to make a choice. Length 1 was the cursor line length after leaving the "start" area until the first choice was made. This correlation indicates that the longer the delay period before making a response, the more efficient was the following motor response
to confirm the choice. Whether this delay period is defined as reflection or a period of response visualization is only speculation at this time. Further analysis of this variable is necessary before conclusions can be made, but the obtained pattern of relationships indicate that these variables are related to the Planning Component.

Difficulties with scoring methods and complex intercorrelations were not encountered on the CCPT. On this test, individual sections were totally consistent with regard to complexity and task variation. Also, length variables were not utilized since only a click response was required. Presentation of materials was consistent throughout the three tasks of the test. The methods used on these tasks were basically the same as Rosvold et. al. (1956), who used an elaborate piece of mechanical equipment to present and record information. The major difference between the CCPT and previous measures of this type was that geometric designs were utilized for presentation instead of numerals or letters.

One assumption of this study was that the covert, or response style variables would be related to attention or other behavioral correlates assessed in a classroom or home setting. While covert measurement has not been utilized to a great extent in evaluating cognitive functioning, Buxton (1985) obtained a correlation of .57 (p<.01) between total response time and an abbreviated version of the Freedom from Distractibility factor of the WISC-R (Arithmetic and Coding subtests). Kaufman (1979) indicated that a low score on this factor may be the result of difficulties with attention and concentration. Given the strong, positive relationship
obtained by Buxton (1985), a prediction was made by this author that the covert measures would be related to behavioral functioning, particularly in the area of attention. Not taken into consideration was the fact that the Arithmetic and Coding subtests are, first and foremost, measures of IQ. The results of this evaluation found no relationship between any of the response style variables and behavioral ratings in the following areas: Conduct Problems, Hyperactivity, Inattentive-Passive, Learning Problems, Psychosomatic Indicators, Impulsivity and Anxiety. While attention problems are often pervasive across tasks in a classroom setting, the rejection of Hypothesis Two indicates that the covert measures of this assessment device are able to evaluate aspects of cognitive functioning apart from attention as measured by behavioral rating scales.

If, according to the above results, these new covert measures are not related to attention or behavioral functioning as first hypothesized, then to what, if anything, are they related? Analysis of the correlations among CCAB time and length variables provide some insight with regard to this question. A positive relationship was found between these variables and the Planning Component as measured by the Computerized Trails Test. On the Simultaneous Task (Raven) significant positive correlations were found between Raven Length Total and Trails Time A Total (.34; p<.01), and also Raven Time Total and Trails Time A Total (.33 p<.01). The covert measures of the Sequential Component were also found to be related to Planning. Correlation between Sequential Length Total and Trails Time A Total was found to be .55 (p< .01). Correlation between Sequential Length Total and Trails Time B Total was found to be .33 (p<
.01). However, none of the correlations between Sequential and Simultaneous (Raven) were found to reach significance. These results indicate a positive relationship between the coding strategy of Simultaneous Processing and Planning, and that there is a positive relationship between the coding strategy of Sequential Processing and the Planning component. No relationship was found between the two coding strategies (Simultaneous and Sequential Processing). The PASS Model would predict this pattern of relationships which demonstrated the influence of the Planning Component on coding strategies.

Planning has been referred to as the executive control process, the overseer of mental operations, metacognitive skills, and as self-regulatory skills. Sternberg (1984) and Glaser (1981) indicate that present methods of cognitive assessment are inadequate in their measurement of these skills, yet they are the basis of intelligent action. This computerized assessment battery not only provided a direct measure of Planning (Trails), but also found evidence that the covert measures partially assessed this same critical component.

While internal consistency and reliability of individual test scales are important, tests which do not demonstrate validity are of little use. The computerized test designed to measure attention (CCPT) was able to distinguish between children with attention problems and a random group of children with eighty-nine percent accuracy. This level of accuracy is commensurate with that of the Gordon Diagnostic System (eighty seven percent accuracy). Classification using the CCPT resulted in one false
positive identification while the GDS did not make any such errors. This fact may have been the result of a child in the random group with attention problems, a subtle difference in the two assessment methods, or a random occurrence. The focus of this study was not to determine the reasons for minor differences in scores, but the effectiveness of the total test battery. The CCPT comprises only a portion of the thousands of data points obtained through the entire test. These values were totaled, summarized, and analyzed to obtain as much information as possible about the subjects' mental processes. When the entire battery was included in the discriminant function, the CCAB was able to distinguish between the two groups with one hundred percent accuracy. The reason for this high classification outcome can only be speculated at the present time. The additional variables were able to account for the other eleven subjects which were the result of both false positive and false negative errors. These results indicate an interaction between the PASS Model factors. The indication of this interaction would be that if a child is low in Attention, he/she may be able to compensate for this deficit with high Planning, Simultaneous Processing or Successive Processing. While the notion of PASS factor interaction or compensatory mechanisms is not new, this study provides the groundwork for the assessment of a multitude of variables, the standardization of the scores in comparison to chronological peers, and their immediate analysis to provide a comprehensive evaluation of the learner.

Despite this evidence of the computer's potential to split up tasks, analyze results according to a specified cognitive model and make
predictions about behavior or learning, the computer will never replace psychologists. The complexities of emotions and social interaction are far beyond the computer's capability at the present time. Computers are effective decision makers if provided with the parameters of the decision-making process and adequate input. This fact was demonstrated as far back as 1963 when Kleinmuntz demonstrated that a computer program based on a highly accurate MMPI examiner's decision-making process was more successful in interpreting profiles than the examiner himself. This study showed the usefulness of the computer in performing routine activities despite their complex nature, but only when the variables were quantified. Rather than offering a more mechanistic alternative, computers can free school psychologists from the time-consuming, legally-mandated activities in order to concentrate on more direct services to children.

A very basic example of the computer's ability to analyze test information in novel ways was demonstrated in this study when the two groups were compared on the total CCAB scores. While the two groups differed on only three of the thirteen total CCPT scores at the .05 probability level, the utility of the computer to analyze patterns of scores proved most beneficial. This benefit was substantiated by the fact that the computed score, which reflected how many of the thirteen scores fell below average, yielded the most significant t-test result (2.68; p<.01). Refinement of the other CCAB scales through the application of such methods may prove useful for the diagnosis of other difficulties in addition to attention problems.
The above noted positive relationships between the test subsections are particularly encouraging given that approximately half of the sample had documented difficulty with attention. Kaufman (1979) indicates that the IQ test scores obtained from children with attention problems should be viewed with caution due to the possible negative influence of inattention on subtest scores. The results of this research indicate that the potential exists to evaluate cognitive functioning by a computer based assessment system. Not only could such a test provide an index of intellectual ability based on a well researched and extensively used IQ test (Raven), it could also yield a great deal of information related to meta-cognitive skills, self-regulatory behavior, processing styles and compensatory mechanisms.

Reschly and Wilson (1990) suggest that the PASS model of cognitive processing may be the most viable model on which to base new assessment procedures because of its consistency with Luria's neuropsychological model and extensive research base. They further indicate that novel measures should lead to appropriate intervention strategies if they are to be useful. This challenge to new assessment methods may be the computer's most viable contribution in the educational environment. A measure such as the CCAB could be tied to computerized instruction matching the child's cognitive strengths, weaknesses and styles with academic curriculum. Some present computerized instructional programs are able to match academic levels with the instructional level, but do not take into account cognitive
factors. A program that takes into account such information may provide extended drill and practice for a low IQ student while providing short instructional lessons in a variety of areas to a child demonstrating high overall ability, but experiencing difficulty with attention.

The measures developed for this study are not novel. The Continuous Performance Test, The Trail Making Test and The Raven's Progressive Matrices have all been in use for over thirty-five years and the GDS has been in use for almost ten years. Individual IQ tests generally do include a sequential memory task, but subtests assessing this skill are usually auditory in nature (digits). The novelty of the CCAB is two fold. One, it provides consistency in item presentation, response evaluation, scoring and potentially, test interpretation. Two, it provides additional information not previously available when using these measures in their traditional form.

In summary, the results of this evaluation indicate that the CCAB demonstrated reliability and internal consistency. It was also found to discriminate between a group of children with attention problems and a random group of children with one hundred percent accuracy. When the CCAB scores of the two groups were compared, the groups differed only on the attention component (CCPT). No relationship was established between the covert measures of the CCAB and behavioral measures of attention. This fact may be indicative of more discrete factors emerging on computerized tasks than previously thought. The pattern of interrelationships obtained between the CCAB tests lends support for the
Planning Component and its function as an executive control mechanism that is influential on a variety of cognitive tasks.

Implications for Further Research

On the basis of the results obtained in this study and a review of related literature, future research efforts should focus on the three following areas:

1. The results of this evaluation generated a large amount of data. Areas of further analysis should include factor analysis to evaluate the construct validity of the CCAB tests, and specifically to determine whether the covert measures of performance load on the Planning Factor. The results of the present study found that the CCAB scores were able to discriminate well between the two groups. A multiple regression analysis should be performed to determine which CCAB variables are able to best distinguish between the two groups.

2. At present, the component measures of the CCAB, with the exception of the CCPT, have only one test in each of the PASS Model areas. Additional measures should be developed, not only to vary the task structures, but also to include auditory stimuli to evaluate language functioning. A Digit Span Test could be developed in which the computer generates the numerals using voice synthesis. The digits one through nine would then appear on the screen. At that point the child would be required to click on the numbers in their correct order. Another improvement of
the test would be to develop branching techniques, so that when an area of functioning is found to be deficient, the program, using an expert system model, would further evaluate that particular problem area in greater detail.

3. This research provides preliminary indications that performance of children with attention problems on a computerized test is not invalidated by the attention problems. Future efforts toward validating the PASS four factor model of cognitive processing should be made. A version of the CCAB, modified according to the above noted suggestions, should be evaluated using factor analytic methods. These efforts should be performed to determine whether the four factor solution can account for within test variance. This would be the first such effort to evaluate the PASS four factor model using computerized measures of the components. Concurrent validity studies should also be performed to determine the relationship between the CCAB and traditional measures of cognitive assessment such as the WISC-R and Stanford Binet:IV.

4. The research of Das (1972), Das (1984) and Naglieri and Das (1988), among others have evaluated the PASS model on varying subgroups including reading disabled, delinquents and retarded children. Future research with the CCAB should be performed to evaluate the performance of varying subgroups and extended age ranges on the four components of the PASS Model.
Appendices
Appendix A

Teacher Forms
Dear teacher:

Your class has been randomly chosen as a part of a study I am conducting as part of my Doctoral Dissertation through the College of William & Mary. The study will examine the performance of children on computerized tests to evaluate the effects of inattention. You will be asked to provide information on six children who will be chosen to take part in the study. Three of the children will be randomly chosen from your class roster and three will be nominated by you.

Attached is a list of characteristics that should be used to nominate the three most inattentive students in your class. Once you have reviewed the list and decided which three children best meet the criterion, please complete the form for the students. Additional background information on all six children will also need to be provided.

Once the six children are determined, permission forms will be sent home to each parent. I will be available to discuss the research with each parent if necessary. Regarding inattentive children that are receiving medication, parents will be requested to withhold the medication for 48 hours before the testing, so in order to alleviate possible classroom difficulties, such children will be evaluated on a Monday morning.

Your cooperation in this project will be greatly appreciated.

Thank you,

C. Rick Ellis
School Psychologist
**Teacher Questionnaire**

Name: ______________________  Birthdate: __________  Tch. ____________

Below are a list of characteristics that are related to inattention as manifested in the school setting. Please check the characteristic (s) that apply to the above named child. Thank you for your cooperation.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Not at All</th>
<th>Sometimes</th>
<th>Often</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Often fidgets with hands or feet or squirms in seat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Has difficulty remaining seated when required to do so</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3. Is easily distracted by extraneous stimuli</td>
<td></td>
<td></td>
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<tr>
<td>4. Has difficulty awaiting turn in games or group situations</td>
<td></td>
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<tr>
<td>5. Often blurts out answers to questions before they have been completed</td>
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<tr>
<td>6. Has difficult following through on instructions from others</td>
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<td></td>
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<tr>
<td>7. Has difficulty sustaining attention in tasks or play activities</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>8. Often shifts from one uncompleted activity to another</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>9. Has difficulty playing quietly</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>10. Often talks excessively</td>
<td></td>
<td></td>
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<tr>
<td>11. Often interrupts or intrudes on others, e.g., butts into other children's games</td>
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<tr>
<td>12. Often does not seem to listen to what is being said to him or her</td>
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<tr>
<td>13. Often loses things necessary for tasks or activities</td>
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<tr>
<td>14. Often engages in physically dangerous activities without considering consequences</td>
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</tbody>
</table>
Background Information Form

Teacher- Could you please complete these forms as soon as possible. Please put them in my box in the office.

Student Name: _____________________ Teacher Name: _____________________
Gender: Male/ Female Age: ______ Birthdate: ____________ Grade: ____

Academics
Ever Retained: Yes/ No Meeting Promotion Standards: Yes/No
Special Education: LD__ ED:__ None:___
Most Recent Grades: Math:_____ Reading:_____ Language:____ Science:____

Family Characteristics
Socio-economic Status: Free Lunch__ Lower__ Working Class__ Military__ Professional__
Family: Intact__ Single parent__ Resides with other relative__ Foster __
Number of Siblings__ Child is: Youngest__ Oldest__ Middle Child__

In order for me to complete data gathering during the summer if necessary, please provide the following:

Home Address:______________________________ Home Phone:__________
Emergency Phone:______________ Work Phone: _______________
Parent(s) Name: _________________________

Norfolk Public School Building closest to the child's home (do not list schools that are under construction):

Thank you so much for your assistance on this project.

Rick Ellis
Teacher's Questionnaire

Name of Child

Date of Evaluation

Grade

Please answer all questions. Beside each item, indicate the degree of the problem by a check mark (✓)

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Just a little</th>
<th>Pretty much</th>
<th>Very much</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Restless in the &quot;squirm&quot; sense.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2. Makes inappropriate noises when he shouldn't.</td>
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<tr>
<td>3. Demands must be met immediately.</td>
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<tr>
<td>4. Acts &quot;smart&quot; (impudent or sassy).</td>
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<tr>
<td>5. Temper outbursts and unpredictable behavior.</td>
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<tr>
<td>6. Overly sensitive to criticism.</td>
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<tr>
<td>7. Distractibility or attention span a problem.</td>
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<td></td>
</tr>
<tr>
<td>8. Disturbs other children.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>11. Mood changes quickly and drastically.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>12. Quarrelsome.</td>
<td></td>
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<tr>
<td>13. Submissive attitude toward authority.</td>
<td></td>
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<tr>
<td>14. Restless, always &quot;up and on the go.&quot;</td>
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<tr>
<td>15. Excitable, impulsive.</td>
<td></td>
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<tr>
<td>16. Excessive demands for teacher's attention.</td>
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<tr>
<td>17. Appears to be unaccepted by group.</td>
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<tr>
<td>18. Appears to be easily led by other children.</td>
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<tr>
<td>19. No sense of fair play.</td>
<td></td>
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<tr>
<td>20. Appears to lack leadership.</td>
<td></td>
<td></td>
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<tr>
<td>21. Fails to finish things that he starts.</td>
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</tr>
<tr>
<td>22. Childish and immature.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. Denies mistakes or blames others.</td>
<td></td>
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<tr>
<td>24. Does not get along well with other children.</td>
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<tr>
<td>25. Uncooperative with classmates.</td>
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</tr>
<tr>
<td>27. Uncooperative with teacher.</td>
<td></td>
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</tbody>
</table>
Appendix B

Parent Forms
NORFOLK PUBLIC SCHOOLS
Student Research Consent Form

I would like for your child ______________________ to participate in a research study that is being conducted as a part of my doctoral studies at the college of William and Mary.

This study will evaluate the possible use of computerized tests to evaluate thinking skills and attention. The subjects will be administered a number of computerized / microprocessor - based tasks. This information will be utilized to determine the effectiveness of computerized tests to assist in the diagnostic evaluations of children.

The time involved in the assessment process will be from 60 to 75 minutes during the regular school day. The opportunity will be provided for the students to make up work missed during the assessment period. The children will be told that the evaluation is a part of an experiment and that his/her performance will not be released to others or affect his/ her grades, thus no foreseeable risks / discomforts are anticipated. Your child's teacher will also complete a rating form on your child.

The children's test results will be confidential, using only code numbers on personally identifiable information. Group analysis will be performed on the data. The student's participation will be completely voluntary and the parent or student may withdraw in part or whole at any time. Refusal to participate or withdraw will not result in penalty, bias, or loss of benefits.

This examiner, C. Rick Ellis, can be reached at the student's school, his office (441-2916) or at home (587-5199). The sponsoring faculty member at the College of William and Mary is Dr. John Lavach and he can be reached at (O)253-4434.

I hereby give permission for my child ______________________ to participate in the above described research project. Also, please complete the enclosed form with regard to your child behavior.

______________________________  ________________________________
Date  Parent / Guardian

It is important that your child understand the purpose of this study and that he or she understand that he or she can refuse to answer any or all of the questions, or stop at any time, without hurting their standing in their class or with their friends or teachers. Would you please explain this to your child and have your child sign below.

______________________________  ________________________________
Date  Child
## Parent's Questionnaire

**Name of Child**

**Date**

Please answer all questions. Beside each item below, indicate the degree of the problem by a check mark (✓)

<table>
<thead>
<tr>
<th>Item</th>
<th>Not at all</th>
<th>Just a little</th>
<th>Pretty much</th>
<th>Very much</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Picks at things (nails, fingers, hair, clothing).</td>
<td></td>
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</tr>
<tr>
<td>2. Sassy to grown-ups.</td>
<td></td>
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<tr>
<td>3. Problems with making or keeping friends.</td>
<td></td>
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<tr>
<td>4. Excitable, impulsive.</td>
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<tr>
<td>5. Wants to run things.</td>
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<tr>
<td>6. Sucks or chews (thumb; clothing; blankets).</td>
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<tr>
<td>7. Cries easily or often.</td>
<td></td>
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<tr>
<td>8. Carries a chip on his shoulder.</td>
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</tr>
<tr>
<td>11. Restless in the &quot;squirmy&quot; sense.</td>
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<tr>
<td>12. Fearful (of new situations; new people or places; going to school).</td>
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<tr>
<td>13. Restless, always up and on the go.</td>
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<td>15. Tells lies or stories that aren't true.</td>
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<tr>
<td>17. Gets into more trouble than others same age.</td>
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<tr>
<td>18. Speaks differently from others same age (baby talk; stuttering; hard to understand).</td>
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<tr>
<td>19. Denies mistakes or blames others.</td>
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<tr>
<td>20. Quarrelsome.</td>
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<tr>
<td>22. Steals.</td>
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<td>23. Disobedient or obeys but resentfully.</td>
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<td>24. Worries more than others (about being alone; illness or death).</td>
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<td>25. Fails to finish things.</td>
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<tr>
<td>26. Feelings easily hurt.</td>
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<td>27. Bullies others.</td>
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<td>28. Unable to stop a repetitive activity.</td>
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<td>29. Cruel.</td>
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<tr>
<td>30. Childish or immature (wants help he shouldn't need; clings; needs constant reassurance).</td>
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<tr>
<td>31. Distractibility or attention span a problem.</td>
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<tr>
<td>32. Headaches.</td>
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<tr>
<td>33. Mood changes quickly and drastically.</td>
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<td>34. Doesn't like or doesn't follow rules or restrictions.</td>
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<tr>
<td>35. Fights constantly.</td>
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<tr>
<td>36. Doesn't get along well with brothers or sisters.</td>
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<tr>
<td>37. Easily frustrated in efforts.</td>
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<tr>
<td>38. Disturbs other children.</td>
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<tr>
<td>39. Basically an unhappy child.</td>
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<tr>
<td>40. Problems with eating (poor appetite; up between bites).</td>
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<tr>
<td>41. Stomach aches.</td>
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<tr>
<td>42. Problems with sleep (can't fall asleep; up too early; up in the night).</td>
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<tr>
<td>43. Other aches and pains.</td>
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<tr>
<td>44. Vomiting or nausea.</td>
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<tr>
<td>45. Feels cheated in family circle.</td>
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<tr>
<td>46. Boasts and brags.</td>
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<tr>
<td>47. Lets self be pushed around.</td>
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<tr>
<td>48. Bowel problems (frequently loose; irregular habits; constipation).</td>
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</tbody>
</table>
Appendix C

Norfolk Public Schools
Permission Form
February 28, 1990

Mr. C. Rick Ellis
2748 E. Ocean View Avenue
Norfolk, VA 23518

Dear Mr. Ellis:

Your request to conduct a research study at Ghent Elementary School, Ocean View Elementary School, and Tarrallton Elementary School entitled "The Utility of a Computerized Assessment Battery to Evaluate Cognitive Functioning and Attention" is granted, contingent upon the final approval of the building principals.

You must solicit the cooperation of the teachers and students selected to participate in your study. Parental approval must be obtained prior to student involvement.

My best wishes to you in this endeavor. Please send a copy of your completed study to my office for my files.

Sincerely,

Anna G. Dodson
Director
Research, Testing and Statistics

jas

c: Dr. Shirley B. Wilson, Assistant Superintendent, Region I
Dr. Margaret B. Saunders, Assistant Superintendent, Region II
Dr. Julia S. Kidwell, Principal, Ghent Elementary School
Mrs. Mildred F. Uber, Principal, Ocean View Elementary School
Mr. Charles W. Clay, Principal, Tarrallton Elementary School
Appendix D

Raven Use Permission Form
Dear Mr Ellis,

Your letter of 20th November to Mr Summers was forwarded by him to Dr John Raven and by Dr Raven to me as agent to J.C. Raven Limited, the copyright owners of the Raven Progressive Matrices. You will be glad to hear that it is us rather than Psych. Corp., with whom you should deal for a licence to use the Matrices for research or other purposes.

It occurs to us, particularly since you are writing from Virginia Beach, to suggest that you contact Mr Michael J. Buxton of 4307F Lauderdale Avenue, who has been working for some time on automating the Matrices using a Macintosh computer. His telephone number is 444 1051.

We suppose that it may be that you will find Mr Buxton has already covered the ground you propose to explore but, if you want to proceed with research of your own, the copyright owners are agreeable to your using their tests for that purpose provided you do so on a strictly private and non-commercial basis. I should tell you, however, that they have formulated a standard set of requirements to be met by anyone wishing to market or distribute reproductions of the tests, which are as follows:

1. For the purposes of reproduction, the current versions of the tests must be used and not altered in any way.
2. Any licence to market the tests must be dependent upon absolute clarity being achieved in the presentation of the items and on the copyright owners' approval being obtained of the computerised versions in their final form. Failing such approval no licence could be granted.
3. The controllable display to indicate the answer chosen by the testee should be laid out as in the printed tests.
4. The person tested should not be moved on to the next item as soon as he or she has considered their choice; it should be possible for the person to delay so long as they wish and finally to move on to the next item by making a separate response to show that they are ready to move on.
5. During the delay period there should be a clear indication to the person tested to show which item has been selected.
6. A reliable counter should be incorporated into the test equipment so that an accurate record can be kept of the numbers tested for royalty purposes.
7. The grant of licences to market the tests will be dependent upon a sound commercial basis having been established and to the payment of an agreed royalty in respect of each presentation.
8. The licence would be incorporated into a formal document in which the copyright and all rights in the tests would be reserved to J.C. Raven Limited and nothing in the licence would be deemed to inhibit the copyright owners from preparing, distributing or marketing other computerised versions.
9. The versions marketed must incorporate acknowledgements to the permission of J.C. Raven Limited.
10. Any licence granted would be for a limited period of time only.
In view of the importance the copyright owners attach to the standard of reproduction, we generally suggest that would-be developers of the tests should as a first step send us copies of their versions so that the copyright owners may judge the quality achieved.

Yours sincerely, 

[Signature]
Appendix E

Description of
The Computerized Trails Test
Description of the Computerized Trails

Since this is the first of the CCAB scales to be administered to the child extended training and practice is provided.

Initially rapport is established and the child's level of computer literacy is determined. The child is then questioned as to familiarity with the use of a mouse. The assumption is made, however, that the child has no familiarity with the device. First, the examiner demonstrates how a vertical movement of the mouse is able to produce a vertical movement of the cursor on the screen and that a horizontal movement of the mouse results in a horizontal movement of the cursor. The cursor is in the shape of a hand with the index finger extended and the child is told that the tip of the finger is what should be used for pointing.

The sequence of events beginning with the sample item for Trails A is as follows:
- A set of circles numbered from one to eight appear on the computer screen. Circle one has the word Start above it and Circle eight has the word Finish above it.
- The child is instructed to click on the circles in numerical order. Assistance is provided if necessary.
- The subject is required to click on the initial item (1) which is indicated by the label, Start. If the child clicks on the correct
circle, the white circle with a black border reverses colors for one second. If the item is out of sequence, nothing happens.

- The child then clicks on the items one through eight.
- Once the item sequence is completed, the child is given the opportunity to take the sample task again.
- If the child decides to take the sample task again this sequence is repeated from the beginning.
- If the examiner feels that the child has determined the task characteristics, and the child agrees to take the actual test then the sequence proceeds.

- On Trails A, a set of circles appear on the computer screen numbered from one to twenty five. Circle one has the word Start above it and Circle twenty five has the word Finish above it.
- The procedures are the same as Sample for Trails A except the child is only give the opportunity to take the test once.
- Once Trails A is completed the child is then presented with Sample Item B.

- On Sample Item B a set of circles appear on the computer screen numbered from one to four and a set of circles lettered "A" through "D". Circle one has the word Start above it and Letter "D" has the word Finish above it.
- The child is required to click on the circles in the order of "1", "A", "2", "B", etc.
- The administration requirements of Sample Item B are the same as Sample Item A and once it is completed, Trails B is administered.

- On Trails B, a set of circles appear on the computer screen numbered from one to thirteen and a set of circles lettered "A" to "L". Circle one has the word Start above it and Circle thirteen has the word Finish above it. The child is required to click on the circles in the order of "1", "A", "2", "B", etc.

Output of the Computerized Trails Test

The numerical output of the Computerized Trails Test will consist of the following variables:

**Score variables:**
On this task all scoring variables are either in time or length.

**Time Variables**
The time variables are the amount of time it takes for the child to click on a number of circles on each of the two tests.
- For Trails A- Time1, Time2, Time3 and Total Time
- For Trails B- Time1, Time2, Time3 and Total Time

**Length Variables**
- For Trails A- Length1, Length2, Length3 and Total Length
- For Trails B- Length1, Length2, Length3 and Total Length
Computerized Trails A
Computerized Trails B

Finish

Start

1

2

3

4

5

6

7

8

9

10

11

12

13

J  K  L  B  C  D  I  A  E  F  G

G

H

I

10

11

12

13
Appendix F

Description of
The Computerized Raven
Progressive Matrices
Description of the Computerized Raven's Progressive Matrices

The sequence of events beginning with Sample Item 1 is as follows:
- In the upper right hand corner of the screen the text Start Here appears.
- The child is instructed to click on the text.
- After the child clicks on the text, the Raven item A1 appears on the screen and the child is told an adaptation of the directions contained in the directions 1985 manual of the Raven's Scale (Raven et al., 1985).
- The task appears on the screen for unlimited period.
- The child is asked to click on the correct design that will complete the pattern.
- Assistance is given if difficulties are encountered.

As with other tasks, the following choices appear in the upper right hand corner of the computer screen:

I am sure
I want to change it

- The child is instructed to make a choice.
- The item is repeated until the child responds correctly.
- Even if the child responds correctly, the opportunity is given to repeat the trial.
The same format as noted above is provided for the second sample item. Once the second sample item has been administered, the standard test is administered. The display and response format of the standard items are the same as the sample items except that once the child clicks on the response I am Sure, no further opportunity is provided to respond to the given item.

Attached is a sample of a Raven Design.

Output of the Computerized Raven's Progressive Matrices

Score Variables
- The total raw score of the Raven is obtained from the program. This score is later converted to percentile and IQ.

Time Variables
- Initial Response Time- the time it takes the subject to begin moving the cursor out of the Start Here, 2x2 inch box.
- Response Time 2- the time it takes for the subject to click on a design.
- Response Time 3- the amount of time from the initial choice until the choice is confirmed.
- Total response time- the time it takes from the beginning of the task until the choice is confirmed.

**Length Variables**

- Length 1- the length of the cursor trail until the subject clicks on a design.
- Length 2- the length from the initial choice until the choice is confirmed.
- Total Length- the length from the beginning of the task until the choice is confirmed.
Sample Raven Item
Appendix G

Description of The Computerized Sequential Memory Test
Description of the Computerized Sequential Memory Test

The sequence of events beginning with Sample Item 1 is as follows:
- A circle appears on the screen for 1 second.
- The screen is blank for 1 second.
- The words Start Here appear in the upper right hand corner of the screen.
- The child is instructed to click on Start Here.
- Three designs appear on the screen (circle-square-triangle).
- The child is instructed to click on the design that was shown.
- After a choice is made, the following options appear in the upper right hand corner of the screen.
  1. I am sure
  2. I want to change it
- The child is instructed to click on a choice.

If the child is correct then Sample Item 2 is administered. If not then Item 1 is administered again.

The sequence of events for Sample Item 2 is the same as Sample Item 1, but a square is used as the stimulus item instead of a circle.

The sequence of events for Sample Item 3 is the same as Sample Items 1 and 2, but a two item stimulus sequence is used (square-triangle).
The first section of this task is known as Sequential A. Sequential A uses from 2 to 5 items as the stimulus (tree, heart, moon, star and/or arrow) one at a time in a randomly assigned order. The child is to click on the correct items in the correct order to obtain full credit. The second section, or Sequential B uses from 3 to 9 items as the stimulus. These items are abstract designs as opposed to familiar icons.

The item sequence is:
- The subject is administered the first item of Section A (two designs).
- If that item is failed, the second item (two designs) at that level is administered.
- If the first item of Section A is passed then the first item at the next level is administered (three designs), and so on.
- If the subject fails both items in a given level on Section A, the testing at that section is discontinued. Section B begins with a three design sequence. If the subject misses two items at a level on Section B then the Sequential Test is discontinued.
**Item Order and Sequence for Sequential A and B**

**Section 1 - Sequential A**

<table>
<thead>
<tr>
<th>Level</th>
<th>Item/ order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>a - 23</td>
</tr>
<tr>
<td></td>
<td>b - 52</td>
</tr>
<tr>
<td>2.</td>
<td>a - 512</td>
</tr>
<tr>
<td></td>
<td>b - 423</td>
</tr>
<tr>
<td>3.</td>
<td>a - 3421</td>
</tr>
<tr>
<td></td>
<td>a - 1524</td>
</tr>
<tr>
<td>4.</td>
<td>a - 32541</td>
</tr>
<tr>
<td></td>
<td>b - 25431</td>
</tr>
</tbody>
</table>

**Section 2 - Sequential B**

<table>
<thead>
<tr>
<th>Level</th>
<th>Item/ order</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>a - 26</td>
</tr>
<tr>
<td></td>
<td>b - 52</td>
</tr>
<tr>
<td>2.</td>
<td>a - 865</td>
</tr>
<tr>
<td></td>
<td>b - 143</td>
</tr>
<tr>
<td>3.</td>
<td>a - 8523</td>
</tr>
<tr>
<td></td>
<td>b - 6921</td>
</tr>
<tr>
<td>4.</td>
<td>a - 25736</td>
</tr>
<tr>
<td></td>
<td>b - 84,10,91</td>
</tr>
<tr>
<td>5.</td>
<td>a - 315697</td>
</tr>
<tr>
<td></td>
<td>b - 8,10,6731</td>
</tr>
<tr>
<td>6.</td>
<td>a - 9167582</td>
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<tr>
<td></td>
<td>b - 7,10,39542</td>
</tr>
<tr>
<td>7.</td>
<td>a - 41397658</td>
</tr>
<tr>
<td></td>
<td>b - 241,10,5987</td>
</tr>
</tbody>
</table>

* The numerical order of the designs correspond to the designs attached.
Output of the Computerized Sequential Memory Test

The numerical output of the *Computerized Sequential Memory Test* will consist of the following variables:

**Score variables:**
- Number correct for each of the two scales
- The total raw score for both scales

**Time Variables:**
- Initial response time (when the mouse is moved from a 2x2 square) after the child clicks on **Start Here**
- Time until the first choice is made
- Time Three- this is the time from the first choice until the item is confirmed divided by the number of stimulus designs presented at that level.
- Total time- time from presentation of the choice screen until the choices are confirmed.

**Length Variables:**
- Length until the first choice is made
- Length Two- This is the length from the first choice until the item is confirmed divided by the number of stimulus designs presented at that level.
- Total Length - Length from presentation of the choice screen until the choices are confirmed.
Computerized Sequential Memory Test
Scale A Items

start here

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
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<td>🖤</td>
<td>🌕</td>
<td>★</td>
<td>↑</td>
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</table>
Computerized Sequential Memory Test
Scale B Items

start here
Appendix H

Description of
The Computerized Continuous Performance Test
Description of the Computerized Continuous Performance Test

This Test involves three separate sections, Delay, Vigilance and Distractibility. On this Test a computer ROM routine is utilized to disable, or "hide" the cursor. This is done since during beta testing of the instrument, some of the the subjects were moving the cursor around in a haphazard manner or using it to aid in focusing visual attention. Also the cursor is not required to perform any of the task requirements. Only a mouse click is required for the child to perform on this test.

*Delay* The Delay Task evaluates the child's ability to inhibit responding when presented with a task involving a visual stimulus. On this task the child gains "points" for correct responses. The sequence of events are as follows:
- The Delay Sample Task is presented first.
- The *counter*, or numeral "0", initially appears on the screen. The child is instructed that in order to get "points" it is necessary to wait a while and then "click" the mouse. In order for the child to increase the counter and obtain "points" it is necessary to wait at least six seconds. If a response, "click", is made before six seconds have elapsed since the last response, the timer is reset to zero and another six seconds are required before a response results in an increase in the number of points.
- The sample item is administered until the child is able to correctly respond to the stimulus for three consecutive times. Once this criterion is achieved the examiner manually resets the counter and the actual administration of the CCPT Delay Task is initiated.
- The duration of the CCPT Delay task is for 8 minutes.

**Vigilance**  
On the Vigilance Task the child is instructed that designs will be flashing on the screen and *every time a black circle appears with a white square right after it the mouse should be clicked.*

- No sample task is presented on this section of the CCPT.
- On this task nine different designs flash semi-randomly on the screen. There are 45 sets of the black circle/white square combinations divided equally over the three blocks, or sections, of this task.
- The duration of the CCPT Vigilance Task is 9 minutes.

**Distractibility**  
On the Distractibility Task of the CCPT the task requirements are identical to the Vigilance Task except that two other sets of designs flash as distractors. These designs flash on either side of the target designs.
Output of the Computerized Continuous Performance Test

Score Variables

Delay
- The scores obtained or computed on this task are as follows:
- Total Correct, Total Responses, total correct and total responses per block for four blocks of two minutes each
- Efficiency Ratio = correct/total responses
- Efficiency Block Variability for 4 blocks
- Slope of Correct Responses over the 4 blocks

Vigilance
- Number correct, omissions, and errors of commissions for 3 blocks, total commissions, commissions block variability, number correct block variability

Distractibility
- Number correct, omissions, and errors of commissions for 3 blocks, total commissions, commissions block variability, number correct block variability

- In order to evaluate the variability of the scores on this measure the cutoff scores developed by Gordon (1982) were utilized. The codes determine whether the derived scores for all 3 sections are
within the average, borderline or below average range. A total of thirteen codes are generated. Three additional values were computed: how many borderline scores, below average scores, or scores in either borderline or below average range.

**Time Variables**
- Not utilized - The test is divided into 3 and 4 minute blocks

**Length Variables**
- Not utilized - the cursor is disabled on this test
Computerized Continuous Performance Test Items
REFERENCES


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Clinical Psychology*, 40, 217-222.

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The Utility of a Computerized Assessment Battery to Evaluate Cognitive Functioning and Attention
Carl Richard Ellis

The College of William and Mary in Virginia, February 1991.
Chairperson: John Lavach, Ed.D.

In recent years much attention has been given to the application of computer technology to psychometric methods, but researchers have concentrated on adapting traditional methods of psychological testing to the new technology instead of utilizing it to develop innovative methods of assessment. The purpose of this study was to determine whether a computerized assessment battery designed to evaluate cognitive functioning and attention could demonstrate reliability and validity. The Computerized Cognitive Assessment Battery (CCAB) was developed according to the PASS Model of Cognitive Functioning and administered via a Macintosh computer and test results included response style variables (mouse movement and response time). Children having attention problems (N=25) in grades three through five were compared to a random group of children (N=29). On the newly developed CCAB, the majority of the sectional variables displayed significant intercorrelations (p<.01) indicating internal consistency of this measure. The reliability of the Sequential component of the CCPT was found to be .90 for Scale 1 and .83 for Scale 2. No relationship was found between the covert measures on the CCAB and Conners' parent and teacher rating scales. Evidence indicated that the covert measures are related to the Planning Factor. The attention measure of the CCPT was able to discriminate between the two groups as well as the Gordon Diagnostic System. The total CCAB was able to predict group membership with one hundred percent accuracy using the classification results of the discriminant function analysis. Consistent with the prediction of the PASS model, the Attention component (CCPT) was the only area in which the scores of the two groups differed. The present study demonstrated the feasibility and practicality of a fully-computerized cognitive assessment battery to aid in the assessment process. The results of this research indicate that the potential exists to evaluate cognitive functioning by a computer-based assessment system. Not only could such a test provide an index of intellectual ability based on a well researched and extensively used IQ test (Raven), it could also yield a great deal of information related to meta-cognitive skills, self-regulatory behavior, processing styles and compensatory mechanisms.