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A study of vigilance, memory processing speed, cognitive ability, and the prediction of academic achievement in children 6–14 years old

Evans, Cheryl Anita, Ph.D.
The Ohio State University, 1988
A STUDY OF VIGILANCE, MEMORY PROCESSING SPEED, 
COGNITIVE ABILITY, AND THE PREDICTION OF ACADEMIC 
ACHIEVEMENT IN CHILDREN 6-14 YEARS OLD 

DISSERTATION 
Presented in Partial Fulfillment of the Requirements for 
the Degree Doctor of Philosophy in the Graduate 
School of the Ohio State University 

By 

Cheryl Anita Evans, B.A., M.A. 

* * * * * 

The Ohio State University 

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To My Parents
ACKNOWLEDGEMENTS

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CHAPTER I
INTRODUCTION

With the application of information processing approaches to the study of cognitive development and the study of learning disabilities (LD) increased consideration has been given to how "sensory input is transformed, reduced, elaborated, stored, retrieved, and used" (Swanson, 1987b, p.3). Within the information processing framework, which uses a computer analog to explain how the human mind works (Samuels, 1987), individuals are perceived as learning through various intervening stages of cognition including encoding, organizing, storing, retrieving, comparing, and generating information (Swanson, 1987a). One of the mechanisms involved in these processes is attention. As stated in Samuels and Edwall (1981) attention is the mechanism through which information is made available to the system at the higher processing stages.

Attention has been defined as "the effort or energy required to perform cognitive tasks" (Samuels, 1987). Gibson and Rader (1979) stated that "attending refers to perceiving in relation to a task or goal, internally or externally motivated." Davies and Parasuraman (1982) reiterated Posner's position that "attention" is not a single concept, but a complex construct or field of study.
Samuels (1987), sharing this position, further stated that attention has a number of different aspects or behaviors, all of which are referred to as "attention." He (Samuels, 1987; Samuels & Edwall, 1981) argues that these aspects of attention include arousal, alertness, vigilance, capacity, and selectivity. Other taxonomies or theories of attention have included all or some of these components.

The role of attention plays a central part in current conceptualizations of learning. For example, the LaBerge and Samuels (1974) information processing model of reading includes attention as one of its four key elements. The other elements are visual memory, phonological memory, and semantic memory. Samuels (1987) identified failure to maintain overt attention during instruction and defects in aspects of attention (i.e., arousal, alertness, vigilance, and selective attention) as several of the factors that can account for poor reading. Moreover, attention has been regarded as the sine qua non for learning (Samuels & Edwall, 1981).

One aspect of attention which has been the focus of research is vigilance or sustained attention. This aspect of attention would seem to be particularly important for school age children who, in a school setting are required to maintain their attention over a prolonged period of time in order to learn the information presented to them. Previous research (Margolis, 1973; Noland & Schuldt, 1971) has found a significant relationship between vigilance and reading achievement. Brown (1982) further stated that Margolis found the ability to sustain attention as important a factor in school achievement as intelligence.
Other studies (Kirchner & Knopf, 1974; Simon, 1982) confirm the positive relationship between performance on vigilance tasks and academic achievement.

The fact that many children with learning disabilities or hyperactivity exhibit attentional problems and concomitantly experience academic failure is suggestive of the role of attention in school learning or achievement. There is confusion in the literature over the role of attentional processes in individuals with learning disabilities (Eliason & Richman, 1987), but the problem is not limited only to those with learning disabilities. As they pointed out, the construct of attention is "not well defined and there are few widely accepted, objective methods of measuring attentional processes."

One of the objective methods of assessing vigilance in children has been the Continuous Performance Test (CPT). This task, first described by Rosvold, Mirsky, Sarason, Bronsome, and Beck (1956), was developed for the study of brain damage in human subjects. The original task required the subject to view a revolving drum through the visor of a boxlike case. The subject pressed a response key each time the designated target letter appeared. Subjects were instructed to respond to a single letter or letter combination (i.e., "X" following an "A"). Adult subjects were tested for 10 minutes on each of the two tasks, while children were tested for only 5 minutes on each task. Results indicated that the task discriminated well between children with and without brain damage and also between adults with and without brain damage.
The CPT vigilance paradigm has been widely used (e.g., Anderson, Halcomb, & Doyle, 1973; Eliason & Richman, 1987; Klee & Garfinkel, 1983; Klorman, Salzman, Pass, Borgstedt, & Dainer, 1979; O'Dougherty, Nuechterlein, & Drew, 1984; Sykes, Douglas, & Morgenstern, 1973; Swanson, 1981; 1983), but as pointed out by O'Dougherty, Evans, and Hayes (1988) the purpose of most of these studies has been either to assess attentional deficits in children with learning disabilities and/or hyperactivity or to assess the effectiveness of stimulant medication on attentional performance. There is a relative lack of research using the CPT paradigm to investigate age-related changes in sustained attention among normal children (O'Dougherty et. al., 1988).

One exception to this was a study by Levy (1980) which found that development of vigilance was clearly related to age in a group of 4-6 year olds. This study, however, did not include older children. As a secondary aim of his study on vigilance in LD and non-LD children, Swanson (1983) assessed age effects among three groups of these children (8, 10, 14-15 year olds). His finding was that children's performance in stimulus detection increased primarily between ages 8 and 10 years, with minimal capacity differences between ages 10 and 15 years. This finding is consistent with Gale and Lynn (1972) who, using a measure other than the CPT, found that the capacity for sustained attention (i.e., number of correctly detected signals) increased with age, with the greatest improvement occurring between the ages of 8 and 9 years. What is needed is a study that provides data on age-related changes in the development of vigilance among school-age children over a wider age range. In the present study,
developmental changes in the CPT vigilance performance of normal children, ages 6-14 years, are examined.

Sex differences in the development of vigilance have received very little consideration by researchers using the CPT paradigm. One such study that did examine sex effects (Levy & Hobbes, 1979) reported no differences in the 4-6 year olds studied. Murphy-Berman, Rosell, and Wright (1986), using the CPT paradigm with children in grades K-9, found that boys had a significantly higher overall false alarm rate than girls. The difference in the Levy and Hobbes (1979) and Murphy-Berman et al. (1986) studies may be attributed to the difference in the age of the subjects.

Most studies using other vigilance task paradigms (Herman, Kirchner, Streissguth, & Little, 1980; Kirchner & Knopf, 1974; Margolis, 1973; van Hoover, 1974) have found no differences in performance between boys and girls. Gale and Lynn (1972) however, found significant sex differences favoring girls only at ages 7, 8, and 12 years. They explained this as a reflection of "general sex differences in developmental rate." There is a need to clarify the issue of vigilance performance on the CPT and sex differences in school-age children's vigilance performance.

Studies have also found that in addition to age and sex, other individual differences, e.g., in socioeconomic status (SES) of the child's family, are positively related to vigilance performance (Herman et al., 1980) and the development of vigilance (Levy, 1980). Both of these studies were limited to preschool age children so the nature of this relationship at the later school years still has to be
explored. The present study examines children's vigilance performance in relation to parental SES.

No one version of the CPT exists. Several studies (Levy, 1980; Levy & Hobbes, 1979; Swanson, 1983) used laboratory equipment similar to that developed by Rosvold et al. (1956) while more recent studies (Eliason & Richman, 1987; Klee & Garfinkel, 1983; Murphy-Berman et al., 1986; O'Dougherty et al., 1988) replaced the laboratory equipment with microcomputers. Different versions of the CPT task vary in important dimensions of the task including task stimulus (e.g., letters only, letter and color pairs, light pairs), modality of presentation (auditory and/or visual presentation), length of the task (e.g., variable rate, 4.75, 9.5., 15, or 30 minutes), total number of stimuli presented, total number of targets, the interstimulus interval, and stimulus duration (Eliason & Richman, 1987). Thus, versions of the CPT vary in complexity and it is unclear how comparable they are (Eliason & Richman, 1987). For example, there is a need to determine whether children's performance on the CPT varies as a function of task variables. In the present study, the effect of (1) increasing stimulus encoding demands, (2) providing response feedback, and (3) requiring the ability to inhibit a well-learned response were examined in the CPT vigilance performance of school-age children.

Another important aspect of cognitive processing is the development of memory and memory processing skills. The emergence of information processing models of cognition has given increased emphasis to the role of memory functions in a variety of thinking and
problem-solving activities. For example, many recently developed models of reading specify an important role for a variety of memory functions (Torgersen, 1978-1979). Researchers and theorists seem to agree that memory deficits or impairments are prevalent in poor readers or children with learning disabilities (e.g., Brady, 1986; Lorsbach, 1982; Stanovich, 1982; Torgensen, 1978-1979) and may account for some of the variation in which these children learn to read or experience school achievement problems (Torgensen, 1981).

Learning and memory are so inextricably linked that the distinction between them is an "arbitrary one" (Maccoby & Jacklin, 1974). Information that is remembered must first have been learned. What has been learned can only be assessed by asking the individual to recall or recognize the learned information.

A major point to be considered in a discussion of memory is that it is not a single process or a unitary skill (Kail & Hagen, 1982; Torgensen, 1978-1979). Rather, it is a "convenient shorthand" for a complex set of cognitive activities or processes. These processes include encoding, retrieval, rehearsal, searching or scanning, clustering, elaboration, and schemas (Kail & Hagen, 1982).

Of particular interest in the present study is the rate of the memory scan or speed of information processing, also referred to as reaction time (RT). The recognition memory paradigm developed by Sternberg (1969) was designed to determine how information in short-term memory (STM) might be retrieved and provides a quantitative evaluation of the temporal dimensions of information processing. Sternberg's paradigm consists of a recognition memory/RT task in which
the subject is presented a memory set, consisting of a variable number of stimulus items, followed by a target item which may or may not have been included in the memory set. The subject's task is to make a given response, as quickly as possible, if the target item was in the memory set (i.e., "yes") and to make a different response (i.e., "no") if the item was not in the memory set. Subjects perform this task with few errors, so the measured (dependent) variable is the RT taken to decide whether the target was or was not a member of the memory set; that is, the time taken to recognize the target as the one being stored in short-term memory.

Reaction time typically increases linearly with the number of items contained in the memory set (Sternberg, 1969). The slope of the RT function is assumed to represent the rate at which memory is searched, i.e., the mean time required to compare the target item to the items in the memory set. Therefore, subjects with lower value slopes are assumed to be able to access items more quickly than those with higher value slopes. The zero-intercept of the RT function is interpreted as representing the sum of times taken to encode the stimulus and to execute the motor response.

Sternberg (1966; 1969) described the retrieval of information from short-term memory as exhaustive (i.e., it always includes the entire list of alternatives even though the target item may have appeared early in the search), serial (i.e., it proceeds through only one item in the memory set at a time), and high speed (i.e., about 38 comparisons are made in a second).
The Sternberg paradigm has been used in studies with children in an attempt to evaluate age-related changes in the rate of memory search. Several studies (e.g., Harris & Fleer, 1974; Hoving, Morin, & Konick, 1970; Keating & Bobbit, 1978) have not found age-related differences in search rate. Contrary to this, Maisto and Baumeister (1975) reported slightly faster (though non-significant) rates for younger children, while Naus and Ornstein (1977) found that older children (6th graders) had significantly faster search rates than younger children (3rd graders). Herrmann and Landis (1977) also found that search rates became markedly faster with age in the three groups of children they studied, but the search rates for their subjects were much larger than those reported by the other researchers.

Reasons for these discrepant findings are not immediately evident. It has been suggested (Dempster, 1981; Herrmann and Landis, 1977) that the most plausible explanation for these inconsistent results was the amount of practice the subjects received. The number of practice trials ranged from 16 in the Herrmann and Landis (1977) study to 48 in the Maisto and Baumeister (1975) study. Other differences in the studies discussed here and possible sources of conflicting results include task stimulus (e.g., pictures, letters, digits), modality of presentation (auditory or visual), and number of test trials.

The inconsistency of these results from studies of children's speed of information processing warrants further research. Previous investigations have typically compared two or three different age groups (or grades) of children. While this approach may be helpful in
delineating developmental differences, it does not afford the opportunity to examine yearly changes in memory scanning rate among school-age children. The present study examines speed of information processing among groups of normal children, ages 6-14 years inclusive.

Since most of the studies described here used subjects of the same sex, not much is known about sex differences in the development of children's rate of memory scanning as measured by the Sternberg. Only the study by Hoving et al. (1970) examined sex effects and they reported no differences in memory scanning rate as a function of sex in the three age groups studied. In their review of sex differences in memory (though not restricted to the Sternberg paradigm), Maccoby and Jacklin (1974) concluded, "...it clearly cannot be said that either sex has a superior memory capacity, or a superior set of skills in the storage and retrieval of information..." (p. 59). There is a need to further assess the existence of sex differences in children's memory processing speed as assessed by the Sternberg. The present study examines children's performance on the Sternberg as a function of sex.

As stated, within an information processing framework individuals are regarded as learning through various intervening stages or processes of cognition. The CPT and Sternberg paradigms as discussed here and used in the present study evaluate some of these processes. For example, encoding, the process by which input information is initially analyzed, is assessed through the four task variations of the CPT used in the study (See description in Chapter II, Methods.) In particular, when task stimuli are modified through image
degradation, increased demands are made on processing resources by burdening early stimulus encoding and analysis processes (Nuechterlein, 1983; Sternberg, 1969).

As previously described and used in the present study, the Sternberg paradigm involves storage (the process by which input information is added to the existing information within the mental system forming a memory trace), retrieval (the process by which previously stored information can be made available), searching (the process by which information is accessed), and comparing (the process by which information is judged or recognized to be either the same or different from previously stored information). In order for an individual to determine if the target item was a member of the previously displayed memory set, the individual must store and subsequently retrieve the memory set items from short-term memory. The target item must then be compared and searched against the items in the memory set if the individual is to determine whether it (the target item) was contained in the memory set. Sternberg's (1969) work involved stimulus encoding processes through the use of stimulus degradation. However, in the present study, encoding processes are tapped through stimulus degradation of the CPT instead of the Sternberg. (Additional encoding demands were placed on the individual during the Sternberg Test by increasing the number of items in the memory set. However, the data from this Sternberg variation is not reported here since all children did not receive this additional version of the Sternberg.)
Vigilance and short-term memory retrieval have been discussed as specific mechanisms involved in the processes through which individuals learn. Cognitive ability is another important area that has been the focus of a considerable amount of research in relation to learning.

The most common method or approach to assessing cognitive ability or functioning is by administering a standardized (individual or group) intelligence test. The Cognitive Abilities Test (Thorndike & Hagen, 1979a; 1979b), which evolved from its predecessor, the Lorge-Thorndike Intelligence Tests, is a frequently used group administered test that has good psychometric properties.

The construction and development of the Cognitive Abilities Test (CAT) incorporated research on "cognitive development, information processing, and lateralization and specialization of functions in the two hemispheres of the brain" (Thorndike & Hagen, 1979a). The CAT was designed to assess cognitive functioning by providing the individual with the opportunity to demonstrate his or her proficiency in using verbal, quantitative (numerical), and nonverbal (spatial or geometric) symbols. Theories of cognitive development and research on children's and adult's thinking have shown that these are three major types of symbols in cognitive reasoning (Thorndike & Hagen, 1979a).

Grade appropriate versions of the CAT exist for children in grades K-12 in order that their level of development of general cognitive skills might be assessed. These general cognitive skills, sometimes referred to as general skills of "learning how to learn", are important in both school learning and in the successful mastery of
important academic tasks such as reading. If children do not develop adequate learning skills, they are likely to have difficulty meeting success with school tasks throughout the school years.

Standardized measures of cognitive ability such as the CAT are constructed, developed, and normed by (or control for) age, so age differences in test performance would not be expected. Also during test development questions which discriminated or showed atypical patterns of difficulty between males and females or socio-economic groups were eliminated from the test (Thorndike & Hagen, 1979a).

Denno (1982) stated that tests of general intellectual ability are standardized to minimize sex biases and consequently consistent sex differences have not been found in general (or composite) measures of ability. However, some specific abilities "do show consistent sex differences which vary in degree according to the types of tests and samples examined" (Denno, 1982). For example, it has been consistently documented that (1) girls score higher on tests of verbal ability than boys beginning about age 11; (2) boys score higher than girls on visual-spatial tasks during adolescence, but not in childhood; and (3) boys' mathematical skills increase faster than girls beginning about the age of 12-13 years (Maccoby & Jacklin, 1974).

Differences in cognitive ability as a function of socioeconomic status (SES) have been one of the most frequently examined areas of research in the social sciences literature. The positive association between parental SES and children's performance on tests of cognitive ability has been well documented (e.g., Deutsch, 1973; Sameroff &
Chandler, 1975; St. James-Roberts, 1979; Werner & Smith, 1977). This voluminous body of literature has consistently shown that in studies of cognitive ability, children from middle class families score higher than children from poor or working-class families.

In spite of the importance of vigilance, short-term memory, and cognitive ability in learning, very little research available to date has examined the interrelationships among these constructs as operationalized by the Continuous Performance Test, the Sternberg Test, and the Cognitive Abilities Test. Investigations of the interrelationship of these constructs using other research paradigms have also been scarce.

Research by Kupietz and Richardson (1978) found that vigilance (assessed by a task similar to the CPT) was not correlated with cognitive ability (assessed by the Wechsler Intelligence Scale for Children-Revised). Similarly, other studies (e.g., Gale & Lynn, 1972; Margolis, 1973), employing different research paradigms found no significant relationship between cognitive ability and vigilance. Studies (Kirchner & Knopf, 1974; Kupietz & Richardson, 1978; Margolis, 1973; Noland & Schuldt, 1971; Simon, 1982), using vigilance paradigms other than the CPT have found a positive relationship with achievement.

Data on the relationship between cognitive ability and speed of memory processing (using the Sternberg paradigm) have largely come from studies comparing mentally retarded children and adults with those of normal intelligence. These studies (Dugas & Kellas, 1974; Harris & Fleer, 1974; Maisto & Jerome, 1977; Mosley, 1985) have
generally found that mentally retarded subjects process or scan information at significantly lower rates than comparison subjects of normal intelligence. This research indicated that the mentally retarded subjects employed the same search strategies (serial and exhaustive) as the normal comparison groups, but simply at a slower rate. Mosley (1985) suggested that the memory scanning rate of the retarded individuals may in part be related to the type of stimuli employed in the study (e.g., verbal vs. nonverbal) or the subjects' familiarity with the stimuli. In general, the encoding and/or response initiation stage of the reaction time (RT) process, as indicated by the RT intercept, has also been shown to be inversely related to cognitive ability (e.g., Dugas & Kellas, 1974, Harris & Fleer, 1974; Maisto & Jerome 1977; Mosley, 1985). Recent research (Cohn, Carlson, & Jensen, 1985) also found that speed of information processing tasks discriminated between a group of "bright - average" and "academically gifted" students.

No research was found studying the relationship between the CPT and Sternberg. Given the nature of the cognitive processes involved in these two tasks, it is important to investigate and document their relationship.

The growing body of research on cognitive information processing suggests the need to examine the relationship between vigilance, speed of memory processing, and cognitive ability. The relatedness of these aspects of cognitive processing seems to have been largely ignored in the literature. The present study addresses this issue by
investigating the interrelationship of these three processes as operationalized by the paradigms discussed here.

One of the goals, whether implied or stated, of educational programming is to understand the cognitive skills or processes which contribute to academic success. Many times children are referred to psychologists for testing in an effort to address questions regarding the child's expected level of academic achievement. To this end, researchers in psychology and education have worked to develop methods of predicting children's academic achievement.

The research on the prediction of academic achievement has consistently demonstrated that scores on tests of cognitive ability (i.e., IQ test scores) are significant predictors of children's academic achievement (e.g., Gose, Wooden, & Muller, 1980; Hale, 1978; McDermott, 1984; Wikoff, 1979). As reiterated by McDermott (1984), intelligence test scores have long been recognized as the best independent predictor of a child's future academic achievement. During the past decade efforts have centered on the development of a combination or battery of tests to better predict academic achievement. Stevenson, Parker, Wilkinson, Hegion, and Fish (1976) pointed out that the effects of such efforts would not only be the development of better predictive batteries, but also the identification of cognitive skills and processes that are important for learning. A better understanding of the factor involved in successful school performance could lead to more effective general programming or better remediation effort aimed at those children requiring such help.
The present study will investigate the contributions of cognitive ability, vigilance, and speed of memory processing as operationalized by the CAT, CPT, and Sternberg tests respectively to the prediction of academic achievement.

STATEMENT OF THE PROBLEM

The available literature on vigilance and speed of memory processing in children indicates a need for clarification of individual differences in these cognitive processes. As discussed, areas that warrant further study are age-related changes, sex differences, and relationships with socioeconomic status. Studies of this nature will provide important information about these processes in normal children. Additionally, such data from normal children will provide a baseline against which performance of children from clinical groups (e.g., attention deficit disorder with or without hyperactivity) can be compared.

There is also a need to investigate the interrelationships among vigilance, speed of information processing, and cognitive ability. Given the role of each of these processes in learning, their contribution to the prediction of academic success (i.e., achievement) should also be studied.

The purpose of the present study then was to investigate age-related changes and sex differences in vigilance and speed of information processing, as operationalized by the Continuous Performance Test and the Sternberg Test of Short-Term Memory, respectively, among normal children ages 6-14. Cognitive ability was
also assessed using the Cognitive Abilities Test and the
interrelationships among these three measures were studied.
Children's performance on these measures was also examined in relation
to parental SES. Finally, the prediction of the children's academic
achievement was undertaken using cognitive ability, vigilance, speed
of memory processing, age, and parental SES as components of the
model.

The hypotheses tested are given below.

HYPOTHESES

Age Related Changes

1. Children's performance on attention as measured by the Continuous
   Performance Test of Sustained Attention (CPT) will improve with
   increasing age across the four conditions of this task—i.e.,
   conventional numeral, degraded stimulus, hits feedback, and
   response reversal. Specifically, the reaction time and false
   alarm rate will decrease while the hit rate will increase across
   the age ranges.

2. Children's performance on speed of memory processing as measured
   by the Sternberg Test of Short-Term Memory and Concentration will
   improve with increasing age. Specifically, the mean reaction
time will decrease across the age range.

Sex Differences

3. Scores on the experimental measures of attention (CPT variables)
   and speed of memory processing (Sternberg mean reaction time)
   will not differ as a function of sex.
Socioeconomic Status (SES) Relationships

4. Children's performance on the tests of cognitive ability, achievement, attention, and memory, as measured by the Cognitive Abilities Test (CAT), Iowa Tests of Basic Skills (ITBS), CPT, and Sternberg Test respectively, will be positively though weakly related to their parents' socioeconomic status.

Predictive Relationships

5. Children's performance on cognitive ability as measured by the Cognitive Abilities Test will be the best predictor of language, mathematics, and composite (overall) achievement as measured by the Iowa Tests of Basic Skills.

6. Children's performance on the experimental measures of attention (CPT variables) and speed of memory processing (Sternberg) will be significant predictors of language, mathematics, and composite (overall) achievement as measured by the Iowa Tests of Basic Skills.

Interrelationships Among Measures

7. Attentional performance on the CPT will be positively associated with memory processing speed on the Sternberg.

8. Language scores as assessed by the Iowa Tests of Basic Skills will be correlated with perceptual encoding speed (RT) and accuracy (hit rate) on the CPT.

9. Mathematics achievement scores as assessed by the Iowa Tests of Basic Skills will be negatively associated with CPT false alarm rate (impulsivity).
10. Children's performance on language, mathematics, and composite achievement as assessed by the Iowa Tests of Basic Skills will be positively correlated with their speed of memory processing as measured by the Sternberg.

11. Children's performance on the tests of attention (CPT) and memory processing (Sternberg) will be positively though weakly related to their scores of cognitive ability as measured by the Cognitive Abilities Test.
CHAPTER II

METHOD

Subjects

The subjects in the study were 180 students attending a predominantly white parochial elementary school in a large midwestern city. They had no known sensory, neurological, or severe learning disabilities according to school records and reports from the school principal and classroom teachers. Approximately twenty children from each grade level, first through eighth grades (6-14 years old), half of whom were boys and half girls, participated in the study. See Table 1 for a complete description of the subjects by age and sex.

Information on the socioeconomic status (SES) of the families of these children including educational and occupational level of the parents was recorded from each child's student record. The Amherst modification (Watt, 1976) of Hollingshead and Redlich's (1959) Two Factor Index of socioeconomic status was used to determine a global SES index for each family. The mean SES index for the total sample was 47.21, with a standard deviation of 24.04. This value corresponds to a person having completed some college employed in occupational level 2 or 3. Means and standard deviations for each age group are
Table 1

Distribution of Subjects by Age and Sex

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Sex</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
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<tr>
<td>7</td>
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<td>13</td>
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<td>6</td>
</tr>
<tr>
<td>14</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td><strong>89</strong></td>
<td><strong>91</strong></td>
</tr>
</tbody>
</table>
given in Table 2. A complete copy of the Two-Factor Index is contained in Appendix A.

In order to recruit subjects, a letter describing the study and an enclosed consent form was sent to the parents of each child attending the school. Of the 256 consent forms distributed, 204 (79.7%) were returned indicating parental permission to participate in the study. No follow-up was made to parents who did not respond. (See Appendix B for a copy of the letter and consent form.)

Of the 204 affirmative responses, 184 children were tested. The remaining children (n=20) were not tested due to scheduling conflicts or identification by school personnel as manifesting a specific learning disability. (Data for four (4) of the 184 children tested were not coded or analyzed because of the extremely deviant performance on the experimental measures by these children).

A second letter with another consent form was sent to the parents if they agreed to have their child participate in the study. An affirmative response to this letter gave permission to obtain additional data (cognitive functioning, academic achievement, parental education and occupation) from the child's student record. Affirmative responses were received for 147 children. (Copies of this letter and consent form are also contained in Appendix B.)

A follow-up letter was sent to parents who did not respond to the initial request to obtain the additional information from their child's record. This resulted in the receipt of 22 additional consent forms. Overall, fifteen (8.15%) of the 184 parents who agreed to have
Table 2
Means and Standard Deviations of SES Ratings

<table>
<thead>
<tr>
<th>Age</th>
<th>N</th>
<th>SES Index</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>49.33</td>
<td>25.98</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>22</td>
<td>43.82</td>
<td>21.74</td>
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<tr>
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<td>45.44</td>
<td>19.63</td>
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<td>16</td>
<td>54.06</td>
<td>24.68</td>
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<td>17</td>
<td>43.06</td>
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<td>15</td>
<td>49.13</td>
<td>23.74</td>
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<tr>
<td>Total</td>
<td>164*</td>
<td>47.21</td>
<td>24.04</td>
<td></td>
</tr>
</tbody>
</table>

*The remaining parents did not consent to a review of their child's records. Therefore, this information was not obtainable for all subjects.
their child participate in the study did not give consent to obtain the additional information from their child's file.

General Testing Conditions/Administration of the Instruments

The experimental tasks were individually administered to the children over the course of a 30-40 minute session. All testing was conducted at the school during regular school hours in a well-lit room separated from the main portion of the school. Testing was scheduled so as to avoid conflicts with school examinations or special events.

Each child was met at his or her classroom and accompanied to a testing room by the researcher. While on the way to the testing room, introductions were made and the general nature of the project was explained to each child. (Appendix C contains the "script" for this dialogue as well as the instructions used during test administration.) Each child was first administered the Continuous Performance Test of Sustained Attention (CPT) followed by the Sternberg Test of Short-Term Memory and Concentration.

INSTRUMENTS

Experimental Measures

The Continuous Performance Test of Sustained Attention (CPT). The Continuous Performance Test (CPT) was administered under several of the test conditions developed by Nuechterlein (1983). This task involved the presentation of numerals (2-9) in a balanced constrained random sequence. The stimuli were computer-generated and presented every 1.4 seconds with an exposure time to 50 msec. Visual stimuli were presented on a video monitor (21' visual angle). The subject was
instructed to press with the preferred-hand a hand-held button when a predesignated target number appeared. Responses and reaction times were determined separately for: (1) hits—correct detection of a target stimulus and (2) false alarms—incorrect response to a nontarget. All stimuli and timing sequences were controlled, and reaction times measured, by an Apple IIe microcomputer.

Before each of the conditions was administered, the subjects were instructed in the task, and 30 practice trials were given for each condition except hits feedback. No practice was given on this condition as it only differed from the previous condition by the addition of an auditory signal. In order to test assumptions regarding the processing demands required, the four conditions of the CPT were administered in the following order to all subjects.

1. Conventional Numeral CPT (CN). The subject was instructed to press a button every time the number "5" was presented. A total of 240 trials was administered (60 targets and 180 nontargets), over a period of 5 minutes, 40 seconds. This condition makes little or no demands on processing.

2. Degraded-stimulus CPT (DS). Previous research has shown that the conventional numeral condition used with hyperactive and learning disabled children yields very low error rates, thus, limiting its sensitivity to subtle processing deficits. In order to improve sensitivity to subtle deficits of attentional and perceptual processes, a modified version of the conventional numeral CPT was used in which task difficulty was increased by introducing stimulus degradation (Nuechterlein, 1983; Nuechterlein, Parasuraman, & Qiyuan,
1983; O'Dougherty et al., 1984). Stimulus degradation was achieved through randomly displacing 25% of the dots comprising the numeral. This modification increased the demand on processing resources by burdening early stimulus encoding and analysis processes (Nuechterlein, 1983; Sternberg, 1969). This adaptation produces the weak signal situation recommended by Swets and Kristofferson (1970) for a more sensitive analysis of vigilance performance. Task duration was 5 minutes, 40 seconds as with the CN.

3. Hits Feedback CPT (HF). During this condition, auditory feedback was provided to each subject. Each time the child pressed correctly to a degraded stimulus "5" a tone generated by the computer sounded. This auditory feedback allowed the subjects an opportunity to improve their performance on this more difficult condition. No practice trial was given on this condition as the visual stimuli were identical to that of the previous DS condition. Immediately after the first instance of auditory feedback occurred, the experimenter informed the subject that the sound heard meant that the response was correct. Subjects were further instructed to "keep going until the computer stopped." The task duration was identical to the other two versions.

4. Response Reversal CPT (RR). The final condition of the CPT was equivalent to the initial conventional numeral CPT task, except that it required a reversal of the well-learned response to the number "5". The subjects were instructed to press the button to every number except the number "5". Stimulus degradation was not used with this condition. The response reversal CPT condition increased task
difficulty by burdening the response selection and response organization components of information processing (Massaro, 1975; Sternberg, 1969). By reversal of the task demands, inhibition of competing responses to the previously relevant stimulus was now required. Under this condition there were 240 trials administered with 180 of the trials being targets and 60 being nontargets. Task duration was identical to the other three CPT conditions.

**Scoring.** All scoring for the CPT was done by the Apple IIe microcomputer which controlled the stimuli and timing sequences. Scores used in the data analyses for the conventional numeral, degraded stimulus, and hits feedback conditions of this test were:

1. Total hits - total number of correct button presses to the target number "5" (n=60). This score was then converted to hit rate by dividing the total number of hits by "60". (Hit rate = total number of hits/60.)

2. Total false alarms - total number of button presses to a nontarget number (i.e., number other than "5") (n=180). This score was then converted to false alarm rate by dividing the total number of false alarms by "180". (False alarm rate = Total # of false alarms/180).

3. Reaction time - mean reaction time for the total number of hits.
Scores for the response reversal condition were:

1. Total hits - total number of button presses to a number other than "5" (n=180). This score was then converted to hit rate by dividing the total number of hits by "180" (Hit rate = Total # of hits/180).

2. Total false alarms - total number of button presses to the number "5" (n=60). This score was then converted to false alarm rate by dividing the total number of false alarms by "60". (False alarm rate = Total # of false alarms/60.)

3. Reaction time - mean reaction time for the total number of hits.

The Sternberg Test of Short-Term Memory and Concentration. In the Sternberg, each subject viewed on a video monitor a list of memory set numbers followed by a target number. The subject was required to make one of two button-press responses, based on whether the target number was or was not a member of the memory set. Half of the subjects responded "yes" with their preferred hand and half of the subjects responded "yes" with their nonpreferred hand.

All subjects in the study were administered a version of the Sternberg that contained either one or two digits in the memory set. All items in the memory set were presented simultaneously and consisted of single digit monosyllabic numbers from 1-9. After
presentation of the memory set, the single digit target number appeared. The memory set and target number were separated by a "special mark" resembling an asterisk.

Each subject was administered an average of 48 trials distributed over the following conditions: 1-item memory set with a positive target (requiring a "yes" response); 1-item memory set with a negative target (requiring a "no" response); 2-item memory set with a positive target; and 2-item memory set with a negative target. Subjects were required to successfully complete 10 trials on each of the above conditions before the criterion was reached and the test discontinued. Response reaction times and the number of correct responses were measured on each trial. The total number of errors and omissions was also recorded. Stimulus and timing sequences were controlled, and reaction times measured by an Apple IIe microcomputer data system.

Subjects 8 years of age and older were administered an additional version of the Sternberg test that differed only in the number of memory set items. The second version of the test contained either two or four digits in the memory set. All other aspects of the two versions of the test were identical. Since all children did not receive the second version of the Sternberg, that data was not used in the present analysis.

Before the first version of the Sternberg was administered, the researcher demonstrated five trials. The subjects were then given 15 practice trials before beginning each version of the test.
Scoring. All scoring for the Sternberg was also done by the Apple IIe microcomputer which controlled the stimuli and timing sequences. As previously discussed, all subjects, regardless of age, were administered the Sternberg 1-2 condition. For purposes of data analysis in the present study, the child's mean reaction time on this task (i.e., Sternberg 1-2) was used as an indicator of overall speed of memory processing or memory scanning rate.

Non-Experimental Measures

Cognitive Abilities Test (CAT). Each child's cognitive functioning or ability was assessed using the Cognitive Abilities Test (CAT). This group administered test, a revision and extension of the Lorge-Thorndike Intelligence Tests, was given to the children during the academic year as a part of the school's regular testing program.

Children who received this test while they were in the first, second, or third grades were administered the Primary Battery of the CAT. This battery is composed of the following subtests: (1) relational concepts, (2) multimental or object classification, (3) quantitative, and (4) vocabulary. Subtest items on the Primary Battery test specific aspects of cognitive development and scores on the test reflect the extent to which the child has developed the following skills and competencies: ability to comprehend oral English; ability to follow directions; ability to hold material in short-term memory; possession of effective strategies for scanning pictorial and figural stimuli to obtain either specific or general information; possession of a store or general information and verbal concepts; ability to compare stimuli and detect similarities and differences in
relative size, position, quantity, shape, and time; ability to clarify, categorize, or order familiar objects; and ability to use quantitative and spatial relationships and concepts (Thorndike & Hagen, 1979b). Given the interdependence of these eight skills, the most meaningful and reliable score to report is a "single overall score that indicates the overall level of these general cognitive skills" (Thorndike & Hagen, 1979b). Scores of this test are therefore reported in terms of the composite or standard age score (SAS).

Students who were administered the CAT in grades 4 through 8 were given the multilevel edition of the test. This edition of the CAT is composed of three batteries: (1) verbal, (2) quantitative, and (3) spatial or nonverbal. These areas reflect the three major types of symbols involved in cognitive reasoning (Thordike & Hagen, 1979a). Subtest items require the individual to abstract and use relationships among presented symbols.

The Verbal Battery assesses an individual's word knowledge, ability to develop verbal concepts or process verbal material, knowledge of the structure of the English language, comprehension, and verbal abstract reasoning ability. The Quantitative Battery provides a measure of one's general level of abstract reasoning. The items of this subtest assess abilities important to the development of quantitative concepts, quantitative reasoning, equation building, and problem solving. The Nonverbal Battery consists entirely of geometric shapes/figures or spatial symbols and "provides an opportunity for individuals who prefer to process information in a holistic way to show how well they can reason" (Thorndike & Hagen, 1979a, p.6).
Concurrent validity correlations of the CAT batteries with the Iowa Tests of Basic Skills (ITBS) subtests for grades 3-8 are high. Similarly, correlations between the CAT and Tests of Achievement Proficiency (TAP) subtests for grades 9-12 are also high (Ansorge, 1985). The highest correlations are between the CAT Verbal Battery and the achievement tests (.80 to .85). Correlations with the achievement tests range from .70 to .80 for the Quantitative Battery and .65 to .70 for the Nonverbal Battery (Nichols, 1978).

The Kuder-Richardson Formula 20 (KR-20), an index of internal consistency, yielded reliabilities ranging from .91 to .96 for the different batteries and levels in the multilevel edition (Ansorge, 1985; Nichols, 1978). The reliabilities for the primary edition (grades K-3) are slightly lower and go down to .89 (Nichols, 1978). Test-retest reliabilities of the CAT, following a 6 month interval, ranged from .76 to .94 (Ansorge, 1985).

Ansorge's (1985) review of the statistical properties of the CAT concluded that it has "high reliability and its criterion-related validity is also very high."

Scoring. Composite scores for all children were used as a measure of cognitive ability or functioning. The test battery yields a composite score for children in grade 1-3. The composite scores for children in grades 4-8 were derived by obtaining the mean of the subtest scores. Subscale and composite score inter-correlations (for grades 4-8) are given in Table 3.

Iowa Tests of Basic Skills (ITBS). Each child's academic achievement was assessed using the Iowa Tests of Basic Skills (ITBS),
Table 3

Inter-correlations of the Cognitive Abilities Test Batteries and Composite Scores for Grades 4-8

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
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<tr>
<td>1. Verbal Battery</td>
<td>.70*</td>
<td>.57*</td>
<td>.85*</td>
</tr>
<tr>
<td>2. Quantitative Battery</td>
<td>—</td>
<td>.74*</td>
<td>.92*</td>
</tr>
<tr>
<td>3. Nonverbal Battery</td>
<td>—</td>
<td>—</td>
<td>.87*</td>
</tr>
<tr>
<td>4. Composite</td>
<td>—</td>
<td>—</td>
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</table>

*p = .0001
Forms 7 and 8. This group administered test was also given to the children during the academic year as a part of the school's regular testing program.

The ITBS provide "for comprehensive and continuous measurement of growth in the fundamental skills: vocabulary, reading, the mechanics of writing, methods of study, and mathematics" (Hiernonymus, Lindquist, & Hoover, 1979, p.3).

The ITBS, multilevel edition, contain 11 subtests and yield the following scores: vocabulary, reading, language total (spelling, capitalization, punctuation, language usage), work study total (visual materials, reference materials), mathematics total (math concepts, math problems, math computation) and a composite.

Regarding the content validity of the scale, Airasian (1985) stated that "there is little question that the ITBS contain content that is generally representative of school curricula in grades 3 to 9." Intercorrelations among subtests and total scores between subtests range from the mid .50s to the mid .70s with the most around .65. Correlations between total scores are higher, ranging from .70 to .85. As previously discussed, the ITBS correlate highly with ability as measured by the Cognitive Abilities Test. The correlations range from .60 to .80 (Airasian, 1985; Ansorge, 1985). The K-R 20 reliabilities for the 11 subtests and total scores are generally greater than .85 with many exceeding .90. The K-R 20 reliability of the composite score for each level of the test is .98 (Airasian, 1985).
The review of the ITBS by Airasian (1985) concluded that they are well constructed, well documented, and one of the best standardized achievement test batteries available. Similarly, Nitko (1985) concluded that it is "an excellent basic skills battery measuring global skills that are likely to be highly related to the long-term goals of elementary schools."

Scoring. This test battery was machine scored and the following scores were used in the data analyses: language total, mathematics total, and composite.

Method of Data Analysis

The data were analyzed using the Statistical Analysis System (SAS Institute, 1986) computer program, Version 5, at the Instruction and Research Computer Center of The Ohio State University. Repeated measures analysis of variance (ANOVA), factor analytic procedures, multiple regression analyses, and partial correlational analyses were used to investigate the aims and hypotheses of the study.

Transformations. Total hits for the conventional numeral, degraded stimulus, and hits feedback conditions were converted to hit rate by dividing the total number of button presses to the target ("5") by "60". False alarm rate for these three conditions was obtained by dividing the total number of false alarms (presses to a nontarget number) by "180". For the response reversal condition, a hit was defined as pressing to every number except "5". To obtain the hit rate for this condition, the total number of hits was divided by "180". A false alarm was defined as pressing to the number "5". The
false alarm rate was obtained by dividing the total number of false alarms by "60".

Transformations for hit rate and false alarm rate were carried out by computing the Arcsine of the values. The means and standard deviations are reported on the original scale.

**Testing the Hypotheses.** In order to test the hypothesis regarding age-related changes and sex differences in children's vigilance performance, a repeated measures analysis of variance (ANOVA, with test condition as the repeated measure) was performed on reaction time, hit rate, and false alarm rate. Post hoc Newman-Keuls tests were used for testing the difference between test conditions. Since assumptions of homogeneity of covariance were not met, conservative $F$ tests (Geisser-Greenhouse) and $p$ values were used to test the null hypothesis of the within subject effects.

A separate ANOVA was performed to test the hypothesis regarding age-related changes and sex differences in children's speed of memory processing. Post hoc mean comparisons were made using Newman-Keuls tests.

Prior to testing subsequent hypotheses, a factor analysis was performed on the CPT data to determine if it could be reduced to a smaller number of factors. The resulting CPT factors were used for the multiple regression and correlational analyses.

To test the hypothesis regarding the relationship between children's test performance and their parents' socioeconomic status, Pearson product moment correlational analyses were computed for each age level.
In order to test hypotheses regarding the prediction of language, mathematics, and composite achievement, separate multiple regression analyses were performed for each achievement area.

To assess the interrelationships among the measures as set forth in hypotheses 6-10, Pearson product moment correlational analyses were performed for each age level.

Table 4 contains a list of the measures and variables in the study.
Table 4

List of Measures and Variables in the Study

<table>
<thead>
<tr>
<th>Measure</th>
<th>Variable</th>
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<tr>
<td>Continuous Performance Test (CPT)</td>
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<tr>
<td></td>
<td>False Alarm Rate</td>
</tr>
<tr>
<td></td>
<td>Reaction Time</td>
</tr>
<tr>
<td>Sternberg Test</td>
<td>Mean Reaction Time</td>
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<td>Cognitive Abilities Test (CAT)</td>
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<td>Composite Score</td>
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<tr>
<td></td>
<td>Relational Concepts</td>
</tr>
<tr>
<td></td>
<td>Multimental or Object</td>
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<tr>
<td></td>
<td>Classification</td>
</tr>
<tr>
<td></td>
<td>Quantitative</td>
</tr>
<tr>
<td></td>
<td>Vocabulary</td>
</tr>
<tr>
<td>Iowa Test of Basic Skills (ITBS)</td>
<td>Grades 4-8:</td>
</tr>
<tr>
<td></td>
<td>Composite Score</td>
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<tr>
<td></td>
<td>Verbal</td>
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<tr>
<td></td>
<td>Quantitative</td>
</tr>
<tr>
<td></td>
<td>Nonverbal</td>
</tr>
<tr>
<td></td>
<td>Language Achievement Score</td>
</tr>
<tr>
<td></td>
<td>Mathematics Achievement Score</td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER III

RESULTS

As previously discussed, 14 of the children's protocols contained missing achievement, IQ, and socioeconomic (SES) data as their parents did not give consent for this information to be obtained from school records. Seven (7) other protocols were missing some portion of the achievement or IQ data. The SAS procedures automatically exclude observations with missing data values from the analysis.

Means, standard deviations, minimum values, and maximum values for each of the variables studied are presented by age group (6-14 years) in Appendix D. Means and standard deviations on the four Continuous Performance Test conditions by age and sex are given in Appendix E. All data given in Appendix D and Appendix E are reported on the original scale.

Analysis of Variance (ANOVA)

In order to test for age and sex effects on the three performance measures of the Continuous Performance Test (i.e., reaction time, hit rate, and false alarm rate) a mixed design (two between - one within-subjects) ANOVA was computed. This repeated measures ANOVA was performed using the General Linear Model (GLM) Procedure of SAS. Separate ANOVAs were computed for each CPT dependent variable:
reaction time, total hit rate, and total false alarm rate. For each analysis, age and sex (and age x sex) were the independent variables. Test condition (conventional numeral, degraded stimulus, hits feedback, and response reversal) was entered as the repeated measure and was also an independent variable.

Age - Related Changes in Vigilance

$H_0$: Children's performance on attention as measured by the Continuous Performance Test of Sustained Attention (CPT) will improve with increasing age across the four conditions of this task - i.e., conventional numeral, degraded stimulus, hits feedback, and response reversal. Specifically, the reaction time and false alarm rate will decrease while the hit rate will increase across the age ranges.

**Reaction Time.** Results indicated a significant age x test interaction effect for reaction time, $F(24,471) = 2.61, p = .0004$. The interaction was apparently due to the older children's increase in reaction times on the response reversal test condition. This was confirmed by demonstrating lack of significant interaction between age and test when response reversal times were removed from the analysis, $F(16,314) = .74, p = .75$. Post hoc Tukey comparisons ($p < .05$) on response reversal indicated that the mean reaction time of the 6 year olds was significantly slower than those of the 9, 10, 11, 12, 13, and 14 year olds. Mean reaction time of the 7 year olds was also found to be slower than that of the 9, 10, 11, and 12 year olds. The 8 year olds were significantly slower than the 11 year olds. Comparisons indicated that there were no significant differences among the means of the 6-8 year olds and among the means of the 9-14 year olds on
response reversal. Overall, response reversal reaction times decreased from ages 6-11 with a slight (though non-significant) increase at age 10. Reaction times then increased at ages 12, 13, and 14. However, the differences in the means at these ages were not significant. Means and standard deviations for reaction time are given in Table 5.

The analysis with response reversal removed indicated a significant age main effect, $F(8, 157) = 22.48, p = .0001$.

The age x sex and age x sex x test interactions were not significant. ANOVA data for reaction time are given in Table 6.

**Hit Rate.** The age x test interaction for hit rate was significant, $F(24,471) = 1.66, p = .0340$. This was apparently due to the performance of the 6 year olds. Removing this age group from the analysis eliminated the statistical significance of the interaction, $F(21,441) = 1.09, p = .36$. When hit rate data for the 6 year olds were analyzed separately, there was a significant test effect, $F(3, 30) = 9.82, p = .0007$. Follow-up analyses indicated that of the four test conditions, 6 year olds had significantly lower hit rates than the other age groups on the hits feedback condition. However, the 6 year olds obtained fewest hits on the degraded stimulus condition. Transformed means for hit rate are given in Table 7.

The analysis without 6 year olds demonstrated a significant age main effect, $F(7,147) = 19.91, p = .0001$.

No significant age x sex nor age x sex x test interactions were found. Table 8 presents ANOVA data for hit rate.
Table 5
Means and Standard Deviations by Age and CPT
Test Condition for Reaction Time

<table>
<thead>
<tr>
<th>Age</th>
<th>Conventional Numeral</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>524.6</td>
<td>63.50</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>484.4</td>
<td>64.08</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>453.1</td>
<td>49.64</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>413.4</td>
<td>51.54</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>410.2</td>
<td>58.39</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>369.7</td>
<td>50.48</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>383.9</td>
<td>62.38</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>361.5</td>
<td>48.68</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>369.2</td>
<td>84.58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degraded Stimulus</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>6</td>
<td>595.0</td>
<td>48.66</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>559.6</td>
<td>55.14</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>531.5</td>
<td>57.39</td>
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<td>9</td>
<td>488.4</td>
<td>61.88</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>475.3</td>
<td>62.44</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>444.7</td>
<td>42.54</td>
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<tr>
<td>12</td>
<td>444.3</td>
<td>51.02</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>413.3</td>
<td>52.74</td>
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<tr>
<td>14</td>
<td>434.0</td>
<td>85.56</td>
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</tr>
<tr>
<td></td>
<td>Hits Feedback</td>
<td>Mean</td>
<td>SD</td>
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<td>6</td>
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<td>47.60</td>
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<td>7</td>
<td>527.5</td>
<td>47.60</td>
<td></td>
</tr>
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<td>8</td>
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<td>53.62</td>
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<td>9</td>
<td>447.4</td>
<td>57.96</td>
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<td>10</td>
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<td>53.80</td>
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<td>11</td>
<td>402.1</td>
<td>44.01</td>
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<tr>
<td>12</td>
<td>369.1</td>
<td>36.17</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>381.8</td>
<td>43.52</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>395.2</td>
<td>80.17</td>
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<tr>
<td></td>
<td>Response Reversal</td>
<td>Mean</td>
<td>SD</td>
</tr>
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<td>6</td>
<td>485.0</td>
<td>48.83</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>457.4</td>
<td>43.74</td>
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<td>8</td>
<td>438.8</td>
<td>64.75</td>
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</tr>
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<td>9</td>
<td>385.9</td>
<td>53.84</td>
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</tr>
<tr>
<td>10</td>
<td>388.3</td>
<td>58.05</td>
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</tr>
<tr>
<td>11</td>
<td>365.6</td>
<td>48.14</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>383.4</td>
<td>55.74</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>394.0</td>
<td>82.73</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>406.5</td>
<td>100.39</td>
<td></td>
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</table>
Table 6
Repeated Measures Analysis of Variance of
CPT Reaction Time by Age, Sex, and
Test Condition

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Ss</td>
<td>174</td>
<td>3004962.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>8</td>
<td>1502518.98</td>
<td>187814.87</td>
<td>20.47*</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>416.99</td>
<td>416.99</td>
<td>0.05</td>
</tr>
<tr>
<td>Age x Sex</td>
<td>8</td>
<td>61315.35</td>
<td>7664.42</td>
<td>0.84</td>
</tr>
<tr>
<td>Error</td>
<td>157</td>
<td>1440711.08</td>
<td>9176.50</td>
<td></td>
</tr>
<tr>
<td>Within Ss</td>
<td>525</td>
<td>1444141.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td>3</td>
<td>578252.50</td>
<td>192750.83</td>
<td>125.17*</td>
</tr>
<tr>
<td>Test x Age</td>
<td>24</td>
<td>96508.95</td>
<td>4021.21</td>
<td>2.61*</td>
</tr>
<tr>
<td>Test x Sex</td>
<td>3</td>
<td>2301.40</td>
<td>767.13</td>
<td>0.50</td>
</tr>
<tr>
<td>Test x Sex x Age</td>
<td>24</td>
<td>41771.49</td>
<td>1740.48</td>
<td>1.13</td>
</tr>
<tr>
<td>Error</td>
<td>471</td>
<td>725307.59</td>
<td>1539.93</td>
<td></td>
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<td>Total</td>
<td>699</td>
<td>4449104.33</td>
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</table>

*p < .001
## Table 7
Transformed Means by Age and CPT Test

Condition for Hit Rate

<table>
<thead>
<tr>
<th>Age</th>
<th>Conventional Numeral Mean</th>
<th>Degraded Stimulus Mean</th>
<th>Hits Feedback Mean</th>
<th>Response Reversal Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1.241</td>
<td>0.833</td>
<td>0.957</td>
<td>1.016</td>
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<td>7</td>
<td>1.238</td>
<td>0.980</td>
<td>1.241</td>
<td>1.116</td>
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<tr>
<td>8</td>
<td>1.359</td>
<td>1.118</td>
<td>1.259</td>
<td>1.202</td>
</tr>
<tr>
<td>9</td>
<td>1.463</td>
<td>1.279</td>
<td>1.351</td>
<td>1.354</td>
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<td>10</td>
<td>1.491</td>
<td>1.300</td>
<td>1.468</td>
<td>1.365</td>
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<tr>
<td>11</td>
<td>1.517</td>
<td>1.375</td>
<td>1.493</td>
<td>1.418</td>
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<tr>
<td>12</td>
<td>1.515</td>
<td>1.321</td>
<td>1.486</td>
<td>1.403</td>
</tr>
<tr>
<td>13</td>
<td>1.540</td>
<td>1.458</td>
<td>1.522</td>
<td>1.429</td>
</tr>
<tr>
<td>14</td>
<td>1.525</td>
<td>1.388</td>
<td>1.537</td>
<td>1.389</td>
</tr>
</tbody>
</table>
Table 8
Repeated Measures Analysis of Variance of CPT Total Hit Rate by Age, Sex, and Test Condition

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Ss</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>8</td>
<td>13.38</td>
<td>1.67</td>
<td>28.89*</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>0.08</td>
<td>0.08</td>
<td>1.39</td>
</tr>
<tr>
<td>Age x Sex</td>
<td>8</td>
<td>0.67</td>
<td>0.08</td>
<td>1.44</td>
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<tr>
<td>Error</td>
<td>157</td>
<td>9.09</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td><strong>Within Ss</strong></td>
<td>525</td>
<td>16.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td>3</td>
<td>3.87</td>
<td>1.29</td>
<td>57.93**</td>
</tr>
<tr>
<td>Test x Age</td>
<td>24</td>
<td>0.89</td>
<td>0.04</td>
<td>1.66*</td>
</tr>
<tr>
<td>Test x Sex</td>
<td>3</td>
<td>0.05</td>
<td>0.02</td>
<td>0.79</td>
</tr>
<tr>
<td>Test x Sex x Age</td>
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<td>0.76</td>
<td>0.03</td>
<td>1.43</td>
</tr>
<tr>
<td>Error</td>
<td>471</td>
<td>10.49</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>699</td>
<td>39.28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<.05.  **p<.001.
False Alarm Rate. There was a significant two way interaction between age and test condition for false alarm rate, $F(24,471) = 5.09$, $p = .0001$. This interaction was due to an increase in the number of false alarms made during response reversal. Removing the response reversal test condition from the analysis eliminated the statistical significance of the interaction, $F(16,314) = 1.14$, $p = .3340$. When response reversal false alarms were analyzed separately, there was a significant age effect, $F(8,174) = 6.45$, $p = .0001$. Post hoc Tukey comparisons ($p < .05$) indicated that the 6, 7, 8, 9, and 10 year olds made significantly more false alarms on response reversal than either the 13 or 14 year olds. Overall, mean comparisons (on response reversal) indicated that the performance of the 6-12 year olds was not significantly different nor was the performance of the 11-14 year olds. There was a large drop in the number of false alarms between the ages of 12 and 13 years. Transformed means for false alarm rate are given in Table 9.

The analysis with response reversal removed indicated a significant age main effect, $F(8,157) = 3.18$, $p = .0023$.

The three way interaction, age x sex x test, was also significant, $F(24, 471) = 2.27$, $p = .0169$.

No significant interaction was found between age and sex. See Table 10 for ANOVA data on false alarm rate.

Sex Differences in Vigilance

$H_3$: Scores on the experimental measures of attention (CPT variables) will not differ as a function of sex.
<table>
<thead>
<tr>
<th>Age</th>
<th>Conventional Numeral Mean</th>
<th>Degraded Stimulus Mean</th>
<th>Hits Feedback Mean</th>
<th>Response Reversal Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.013</td>
<td>0.050</td>
<td>0.012</td>
<td>0.327</td>
</tr>
<tr>
<td>7</td>
<td>0.020</td>
<td>0.037</td>
<td>0.023</td>
<td>0.320</td>
</tr>
<tr>
<td>8</td>
<td>0.022</td>
<td>0.060</td>
<td>0.025</td>
<td>0.323</td>
</tr>
<tr>
<td>9</td>
<td>0.015</td>
<td>0.040</td>
<td>0.021</td>
<td>0.338</td>
</tr>
<tr>
<td>10</td>
<td>0.008</td>
<td>0.029</td>
<td>0.017</td>
<td>0.303</td>
</tr>
<tr>
<td>11</td>
<td>0.012</td>
<td>0.010</td>
<td>0.011</td>
<td>0.244</td>
</tr>
<tr>
<td>12</td>
<td>0.002</td>
<td>0.027</td>
<td>0.014</td>
<td>0.196</td>
</tr>
<tr>
<td>13</td>
<td>0.005</td>
<td>0.014</td>
<td>0.006</td>
<td>0.133</td>
</tr>
<tr>
<td>14</td>
<td>0.002</td>
<td>0.019</td>
<td>0.006</td>
<td>0.135</td>
</tr>
</tbody>
</table>
Table 10
Repeated Measures Analysis of Variance of CPT Total False Alarm Rate by Age, Sex, and Test Condition

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Ss</td>
<td>174</td>
<td>1.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>8</td>
<td>0.44</td>
<td>0.06</td>
<td>7.63**</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>0.01</td>
<td>0.01</td>
<td>1.84</td>
</tr>
<tr>
<td>Age x Sex</td>
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<td>0.10</td>
<td>0.01</td>
<td>1.81</td>
</tr>
<tr>
<td>Error</td>
<td>157</td>
<td>1.14</td>
<td>0.01</td>
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</tr>
<tr>
<td>Within Ss</td>
<td>525</td>
<td>10.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td>3</td>
<td>6.74</td>
<td>2.25</td>
<td>418.59**</td>
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<tr>
<td>Test x Age</td>
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<td>0.66</td>
<td>0.03</td>
<td>5.09**</td>
</tr>
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<td>Test x Sex</td>
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<td>0.01</td>
<td>1.80</td>
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<tr>
<td>Test x Sex x Age</td>
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<td>0.29</td>
<td>0.01</td>
<td>2.27*</td>
</tr>
<tr>
<td>Error</td>
<td>471</td>
<td>2.53</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td>11.94</td>
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</table>

*p < .05.  **p < .001.
Reaction Time. The ANOVA with repeated measures (test condition) on reaction time indicated no significant sex effect. There was no significant interaction between sex and test condition. ANOVA data are given in Table 6.

Hit Rate. There were no significant effects on hit rate as a function of sex. Neither was there a significant sex x test interaction. Table 8 contains ANOVA data.

False Alarm Rate. There were no significant main effects for sex on false alarm rate. The sex x test interaction was not significant. ANOVA data are given in Table 10.

The three way interaction, age x sex x test, was significant, \( F(24,471) = 2.27, p = .0169 \).

Task Variations in Vigilance

Reaction Time. The repeated measures (test condition) ANOVA on reaction time was significant for test condition, \( F(3,471) = 125.17, p = .0001 \). ANOVA data are presented in Table 6. As indicated earlier, the age x test interaction was significant because of increases in response reversal reaction times (i.e., slower times) by the older children. Post hoc Newman-Keuls comparison analyses led to the conclusion that all of the test conditions were significantly different from each other \( (p \leq .05) \). In terms of speed of reaction time, the most difficult test was degraded stimulus, followed by hits feedback, conventional numeral, and response reversal. Transformed means for reaction time on each test condition are given in Table 11.
Table 11
Transformed Means by CPT Test Condition for Reaction Time

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Mean</th>
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<tbody>
<tr>
<td>Conventional Numeral</td>
<td>418.002</td>
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<tr>
<td>Degraded Stimulus</td>
<td>487.326</td>
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<tr>
<td>Hits Feedback</td>
<td>448.484</td>
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<tr>
<td>Response Reversal</td>
<td>409.526</td>
</tr>
</tbody>
</table>
**Hit Rate.** The repeated measures ANOVA on hit rate was significant for test condition, $F(3, 471) = 57.93, p = .0001$. ANOVA data are presented in Table 8. As indicated, the age x test interaction was significant due to the lower hit rate of the 6 year olds. Post hoc Newman-Keuls comparisons led to the conclusion that all of the test conditions were significantly different ($p < .05$). The most difficult condition was degraded stimulus, followed by response reversal, hits feedback, and conventional numeral. Transformed means for hit rate on each test condition are given in Table 12.

**False Alarm Rate.** The results of the repeated measures ANOVA indicated a significant test condition effect on false alarm rate, $F(3, 471) = 418.59, p = .0001$. ANOVA data are presented in Table 10. As previously discussed, the age x test interaction was significant because of the increase in false alarms made during the response reversal condition. Subsequent follow-up analyses (Newman-Keuls) indicated that response reversal was more difficult than the other test conditions ($p < .05$). This was followed by degraded stimulus, hits feedback, and conventional numeral. Only the conventional numeral and hits feedback test conditions were not significantly different from each other. Transformed means for false alarm rate on each test condition are given in Table 13. The age x sex x test condition interaction was significant.
Table 12
Transformed Means by CPT Test Condition for Hit Rate

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Numeral</td>
<td>1.433</td>
</tr>
<tr>
<td>Degraded Stimulus</td>
<td>1.234</td>
</tr>
<tr>
<td>Hits Feedback</td>
<td>1.373</td>
</tr>
<tr>
<td>Response Reversal</td>
<td>1.304</td>
</tr>
</tbody>
</table>
Table 13
Transformed Means by CPT Test Condition
for False Alarm Rate

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Numeral</td>
<td>0.012</td>
</tr>
<tr>
<td>Degraded Stimulus</td>
<td>0.033</td>
</tr>
<tr>
<td>Hits Feedback</td>
<td>0.016</td>
</tr>
<tr>
<td>Response Reversal</td>
<td>0.265</td>
</tr>
</tbody>
</table>
Age-Related Changes in Speed of Memory Processing

H$_2$: Children's performance on speed of memory processing as measured by the Sternberg Test of Short-Term Memory and Concentration will improve with increasing age. Specifically, the mean reaction time will decrease across the age range.

Results of the ANOVA on the Sternberg (1-2 item memory set) mean reaction time indicated a significant effect for age, $F(8,170) = 14.95, p = .0001$. Post hoc Tukey comparisons ($p < .05$) indicated that the mean reaction time of the 6 year olds was significantly slower than those of the 10, 11, 12, 13, and 14 year olds. Mean reaction times for the 7 and 8 year olds were also found to be slower than those of the 9-14 year olds. Means and standard deviations are given in Table 14. Comparisons indicated then that the performance of the 6-8 year olds differed from (i.e., was slower than) that of the 9-14 year olds, but there was no significant difference among the 6-8 year olds and no difference among the 9-14 year olds.

There was no age x sex interaction effects on the Sternberg mean reaction time. ANOVA data are presented in Table 15.

Sex Differences in Speed of Memory Processing

H$_3$: Scores on the experimental measure of speed of memory processing (Sternberg mean reaction time) will not differ as a function of sex.

Results of the ANOVA indicated no significant differences in children's speed of memory processing as a function of sex. Table 15 gives the ANOVA data for Sternberg mean reaction time.
Table 14

Means by Age for Sternberg Mean Reaction Time

<table>
<thead>
<tr>
<th>Age</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1202.44</td>
</tr>
<tr>
<td>7</td>
<td>1382.95</td>
</tr>
<tr>
<td>8</td>
<td>1245.75</td>
</tr>
<tr>
<td>9</td>
<td>995.00</td>
</tr>
<tr>
<td>10</td>
<td>923.24</td>
</tr>
<tr>
<td>11</td>
<td>813.33</td>
</tr>
<tr>
<td>12</td>
<td>883.16</td>
</tr>
<tr>
<td>13</td>
<td>847.56</td>
</tr>
<tr>
<td>14</td>
<td>791.38</td>
</tr>
</tbody>
</table>
Table 15

Analysis of Variance of Sternberg Test

Mean Reaction Time by Age and Sex

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>8</td>
<td>6387236.31</td>
<td>14.95*</td>
</tr>
<tr>
<td>Sex</td>
<td>1</td>
<td>15379.09</td>
<td>.29</td>
</tr>
<tr>
<td>Age x Sex</td>
<td>8</td>
<td>537236.19</td>
<td>1.26</td>
</tr>
<tr>
<td>Error</td>
<td>153</td>
<td>8173188.01</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>170</td>
<td>15113039.60</td>
<td></td>
</tr>
</tbody>
</table>

*p<.001
Prior to testing subsequent hypotheses, a factor analysis was done to examine the interrelationships among the CPT variables and to determine if these multiple variables could be reduced to a smaller, functionally interpretable number of factors to be employed in the regression analyses and to examine interrelationships among the measures.

The Factor Procedure of the Statistical Analysis System (SAS: "Proc Factor") computer program package was used to complete the factor analysis. The "Proc Score" option of the same statistical package was used to obtain the factor scores.

The factor model used in the analysis was the principal factor model. Squared multiple correlations were used to estimate communalities. In order to determine the number of factors to retain, the scree plot of the eigenvalues was evaluated. The promax technique was used in the analysis. Each of the resulting factor loadings was plotted and interpreted for psychological significance.

Eigenvalues were 5.59 and 1.41 for factors 1 and 2 respectively. All eigenvalues for subsequent factors were less than 1.0. These two combined factors account for 58.3% of the variance. The complete factor loading matrix is given in Table 16. The pattern matrix and interfactor correlations for the promax oblique rotation are given in Table 17.

As stated above, results of the factor analysis yielded two factors that appeared to be psychologically interpretable and meaningful. The first factor, entitled "Efficiency of Processing"
Table 16
Complete Factor Loadings Derived from
the Continuous Performance Test
(Two-Factor Model)

<table>
<thead>
<tr>
<th>Factor 1: Efficiency of Processing</th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits Feedback Reaction Time</td>
<td>.912</td>
</tr>
<tr>
<td>Degraded Stimulus Reaction Time</td>
<td>.909</td>
</tr>
<tr>
<td>Conventional Numeral Reaction Time</td>
<td>.848</td>
</tr>
<tr>
<td>Response Reversal Hit Rate</td>
<td>-.832</td>
</tr>
<tr>
<td>Response Reversal Reaction Time</td>
<td>.754</td>
</tr>
<tr>
<td>Degraded Stimulus Hit Rate</td>
<td>-.733</td>
</tr>
<tr>
<td>Hits Feedback Hit Rate</td>
<td>-.723</td>
</tr>
<tr>
<td>Conventional Numeral Hit Rate</td>
<td>-.712</td>
</tr>
<tr>
<td>Conventional Numeral False Alarm Rate</td>
<td>.289</td>
</tr>
<tr>
<td>Response Reversal False Alarm Rate</td>
<td>.233</td>
</tr>
<tr>
<td>Degraded Stimulus False Alarm Rate</td>
<td>.232</td>
</tr>
<tr>
<td>Hits Feedback False Alarm Rate</td>
<td>.191</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factor 2: Accuracy of Processing</th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degraded Stimulus False Alarm Rate</td>
<td>.710</td>
</tr>
<tr>
<td>Hits Feedback False Alarm Rate</td>
<td>.704</td>
</tr>
<tr>
<td>Response Reversal False Alarm Rate</td>
<td>.589</td>
</tr>
<tr>
<td>Degraded Stimulus Hit Rate</td>
<td>-.521</td>
</tr>
<tr>
<td>Hits Feedback Hit Rate</td>
<td>-.510</td>
</tr>
</tbody>
</table>
Table 16 (Cont'd)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Numeral False Alarm Rate</td>
<td>.453</td>
</tr>
<tr>
<td>Hits Feedback Reaction Time</td>
<td>.369</td>
</tr>
<tr>
<td>Degraded Stimulus Reaction Time</td>
<td>.361</td>
</tr>
<tr>
<td>Conventional Numeral Reaction Time</td>
<td>.307</td>
</tr>
<tr>
<td>Conventional Numeral Hit Rate</td>
<td>-.300</td>
</tr>
<tr>
<td>Response Reversal Hit Rate</td>
<td>-.282</td>
</tr>
<tr>
<td>Response Reversal Reaction Time</td>
<td>.034</td>
</tr>
</tbody>
</table>
Table 17
Inter-Factor Correlation Matrix for the Continuous Performance Test Factors (Two-Factor Model)

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1</td>
<td>1.000</td>
<td>0.365</td>
</tr>
<tr>
<td>Factor 2</td>
<td></td>
<td>1.000</td>
</tr>
</tbody>
</table>
(RT), contained variables with high positive loadings for (1) hits feedback reaction time, (2) degraded stimulus reaction time, (3) conventional numeral reaction time, and (4) response reversal reaction time. High but negative loadings on this factor were obtained for four variables. They were: (1) conventional numeral hit rate, (2) hits feedback hit rate, (3) degraded stimulus hit rate, and (4) response reversal hit rate. This cluster of variables suggests that children high on this factor had faster reaction times (i.e., their reaction time decreased) and also more hits.

"Accuracy of Processing" was the name given to the second factor. Variables having high positive loadings on this factor were: (1) degraded stimulus false alarm rate, (2) hits feedback false alarms rate, (3) response reversal false alarm rate, and (4) conventional numeral false alarm rate. The four variables that loaded negatively on this factor were: (1) response reversal hit rate, (2) conventional numeral hit rate, (3) hits feedback hit rate, and (4) degraded stimulus hit rate. This clustering of variables seems to represent an inaccuracy/accuracy (or false alarm) dimension. Children who were high on this factor made more false alarms (i.e., responses to non-target numbers) and had fewer hits.

In the initial factor analytic procedure, three factors emerged, which when combined, accounted for 64.96% of the variance. The first factor of the three-factor model was quite similar to the first factor of the two-factor model. Because of its high positive reaction time loadings and high negative hit rate loadings, it too was entitled "Efficiency of Processing." The magnitude of the variable loadings
for factor 2 differed for each model. In the three-factor model, the highest positive loadings for factor 2 were found for degraded stimulus false alarm rate and hits feedback false alarm rate. The highest negative loadings were found for degraded stimulus hit rate and hits feedback hit rate. Both of these tasks burden early stimulus encoding demands through stimulus degradation. Because of the factor loadings and the nature of the tasks, the second factor of the three-factor model was given the name "Perceptual Encoding Accuracy."

Variables having high positive loadings on the third factor were: (1) response reversal false alarm rate, (2) conventional numeral false alarm rate, (3) hits feedback reaction time, and (4) degraded stimulus reaction time. Negative loadings on this factor were obtained for: (1) response reversal hit rate, (2) response reversal reaction time, (3) degraded stimulus hit rate, (4) hits feedback hit rate, and (5) conventional numeral hit rate. This clustering of variables represents an "inhibitory control and organization" dimension.

Because the eigenvalue of the third factor was small (i.e., .80) the decision was made not to retain it or include it in subsequent analyses (e.g., partial correlational analyses, regression analyses). (See Tables 18 and 19 for the factor loading matrix and interfactor correlations respectively.)

**Socioeconomic Status (SES) Relationships**

$H_4$: Children's performance on the tests of cognitive ability, achievement, attention, and memory as measured by the Cognitive Abilities Test, Iowa Tests of Basic Skills, CPT, and Sternberg respectively will be positively though weakly related to their parents' socioeconomic status.
### Table 18
Complete Factor Loadings Derived From the Continuous Performance Test
(Three-Factor Model)

<table>
<thead>
<tr>
<th>Factor 1: Efficiency of Processing</th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits Feedback Reaction Time</td>
<td>.909</td>
</tr>
<tr>
<td>Degraded Stimulus Reaction Time</td>
<td>.907</td>
</tr>
<tr>
<td>Conventional Numeral Reaction Time</td>
<td>.847</td>
</tr>
<tr>
<td>Response Reversal Hit Rate</td>
<td>-.833</td>
</tr>
<tr>
<td>Response Reversal Reaction Time</td>
<td>.762</td>
</tr>
<tr>
<td>Degraded Stimulus Hit Rate</td>
<td>-.737</td>
</tr>
<tr>
<td>Hits Feedback Hit Rate</td>
<td>-.726</td>
</tr>
<tr>
<td>Conventional Numeral Hit Rate</td>
<td>-.706</td>
</tr>
<tr>
<td>Conventional Numeral False Alarm Rate</td>
<td>.285</td>
</tr>
<tr>
<td>Degraded Stimulus False Alarm Rate</td>
<td>.247</td>
</tr>
<tr>
<td>Response Reversal False Alarm Rate</td>
<td>.224</td>
</tr>
<tr>
<td>Hits Feedback False Alarm Rate</td>
<td>.205</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factor 2: Perceptual Encoding Accuracy</th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degraded Stimulus False Alarm Rate</td>
<td>.798</td>
</tr>
<tr>
<td>Hits Feedback False Alarm Rate</td>
<td>.775</td>
</tr>
<tr>
<td>Degraded Stimulus Hit Rate</td>
<td>-.469</td>
</tr>
<tr>
<td>Hits Feedback Hit Rate</td>
<td>-.441</td>
</tr>
<tr>
<td>Conventional Numeral False Alarm Rate</td>
<td>.268</td>
</tr>
</tbody>
</table>
### Table 18 (Cont'd)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Reversal False Alarm Rate</td>
<td>.264</td>
</tr>
<tr>
<td>Hits Feedback Reaction Time</td>
<td>.243</td>
</tr>
<tr>
<td>Response Reversal Hit Rate</td>
<td>-.241</td>
</tr>
<tr>
<td>Degraded Stimulus Reaction Time</td>
<td>.237</td>
</tr>
<tr>
<td>Conventional Numeral Reaction Time</td>
<td>.216</td>
</tr>
<tr>
<td>Response Reversal Reaction Time</td>
<td>.175</td>
</tr>
<tr>
<td>Conventional Numeral Hit Rate</td>
<td>-.130</td>
</tr>
</tbody>
</table>

**Factor 3: Inhibitory Control and Organization**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Reversal False Alarm Rate</td>
<td>.789</td>
</tr>
<tr>
<td>Conventional Numeral False Alarm Rate</td>
<td>.505</td>
</tr>
<tr>
<td>Conventional Numeral Hit Rate</td>
<td>-.373</td>
</tr>
<tr>
<td>Hits Feedback Hit Rate</td>
<td>-.342</td>
</tr>
<tr>
<td>Hits Feedback Reaction Time</td>
<td>.337</td>
</tr>
<tr>
<td>Degraded Stimulus Reaction Time</td>
<td>.328</td>
</tr>
<tr>
<td>Degraded Stimulus Hit Rate</td>
<td>-.323</td>
</tr>
<tr>
<td>Hits Feedback False Alarm Rate</td>
<td>.277</td>
</tr>
<tr>
<td>Conventional Numeral Reaction Time</td>
<td>.255</td>
</tr>
<tr>
<td>Degraded Stimulus False Alarm Rate</td>
<td>.252</td>
</tr>
<tr>
<td>Response Reversal Reaction Time</td>
<td>-.231</td>
</tr>
<tr>
<td>Response Reversal Hit Rate</td>
<td>-.169</td>
</tr>
</tbody>
</table>
Table 19

Inter-Factor Correlation Matrix for The Continuous Performance Test Factors
(Three-Factor Model)

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1</td>
<td>1.000</td>
<td>0.299</td>
<td>0.255</td>
</tr>
<tr>
<td>Factor 2</td>
<td></td>
<td>1.000</td>
<td>0.289</td>
</tr>
<tr>
<td>Factor 3</td>
<td></td>
<td></td>
<td>1.000</td>
</tr>
</tbody>
</table>
In considering the results of these correlational analyses, it should be noted that on the measure of SES used in the present study (Amherst modification of Hollingshead and Redlich's Two Factor Index), the negative sign reflects the way that parental SES is coded such that low parental SES values represent high parental status (i.e., high financial resources). All correlations are partial correlations controlling for age and are reported for the total sample in Table 20.

Children's cognitive ability was found to be significantly though weakly related to parental socioeconomic status ($r = -0.39, p = 0.0001$). This indicates that children's high cognitive ability was associated with high parental SES.

Children's language achievement on the ITBS was significantly though weakly related to parental SES ($r = -0.24, p = 0.0026$). As with cognitive ability, high language scores were associated with high parental financial resources.

High parental SES was significantly, but weakly associated with children's high mathematics achievement on the ITBS ($r = -0.28, p = 0.0006$).

Children's high overall achievement on the ITBS was also significantly related to parental SES ($r = -0.31, p = 0.0001$). High composite achievement was associated with high parental SES.

There were no significant correlations between parental SES and children's performance on either CPT factor 1, CPT factor 2, or Sternberg speed of memory processing. Though non-significant, only the correlation between parental SES and Sternberg mean reaction time was in the expected direction.
Table 20
Partial Correlations Among Variables
Controlling for Age (Total Sample)

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>4a</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ITBS Language</td>
<td>.68***</td>
<td>.87***</td>
<td>-.24**</td>
<td>.61***</td>
<td>-.25**</td>
<td>-.15</td>
</tr>
<tr>
<td>2.</td>
<td>ITBS Mathematics</td>
<td>___</td>
<td>.85***</td>
<td>-.28***</td>
<td>.66***</td>
<td>-.17*</td>
<td>-.12</td>
</tr>
<tr>
<td>3.</td>
<td>ITBS Composite</td>
<td>___</td>
<td>-.31***</td>
<td>.71***</td>
<td>-.24**</td>
<td>-.11</td>
<td>-.11</td>
</tr>
<tr>
<td>4.</td>
<td>SES</td>
<td>___</td>
<td>-.39***</td>
<td>-.04</td>
<td>.08</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>CAT Composite</td>
<td>___</td>
<td>-.22**</td>
<td>-.15</td>
<td>-.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Sternberg Mean RT</td>
<td>___</td>
<td>.45***</td>
<td>.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>CPT Factor 1</td>
<td>___</td>
<td>.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>CPT Factor 2</td>
<td>___</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note.  n = 150.
*Negative sign reflects the way that parental SES is coded such that low parental SES values represent high parental status.
*p < .05.  **p < .01.  ***p < .001.
**Predictive Relationships**

H$_5$: Children's performance on cognitive ability as measured by the Cognitive Abilities Test (CAT) will be the best predictor of language, mathematics, and composite (overall) achievement as measured by the Iowa Tests of Basic Skills.

H$_6$: Children's performance on the experimental measures of attention (CPT) and speed of memory processing (Sternberg) will be significant predictors of language, mathematics, and composite (overall) achievement as measured by the Iowa Tests of Basic Skills.

**Regression Analyses**

Regression analyses were completed to test the hypotheses regarding the prediction of academic achievement. Separate regression analyses were performed for the dependent variables of language, mathematics, and composite (overall) achievement on the Iowa Tests of Basic Skills. Each of these analyses evaluated the contribution of the following independent variables to the achievement areas given above: (1) composite score on the Cognitive Abilities Test (CAT), (2) SES, (3) Sternberg mean reaction time, (4) factor 1 (of the CPT), (5) factor 2 (of the CPT), (6) age, (7) age x Sternberg mean reaction time, (8) age x factor 1, and (9) age x factor 2. The correlation matrix for the regression analysis is given in Table 21.

**Language Achievement.** Results of the regression analysis confirmed the hypothesis and indicated that composite score on the CAT was the largest predictor of language achievement, accounting for 24.6% of the variance. The CPT factors and the Sternberg did not contribute significantly to the prediction of language achievement. All variables other than the CAT score contributed less than 1% each
<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>4a</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ITBS Language</td>
<td>.68***</td>
<td>.86***</td>
<td>-.25**</td>
<td>.00</td>
<td>.56***</td>
<td>-.18*</td>
<td>-.11</td>
<td>-.11</td>
</tr>
<tr>
<td>2. ITBS Mathematics</td>
<td>_</td>
<td>.85***</td>
<td>-.30***</td>
<td>.02</td>
<td>.66***</td>
<td>-.13</td>
<td>-.09</td>
<td>-.04</td>
</tr>
<tr>
<td>3. ITBS Composite</td>
<td>_</td>
<td>_</td>
<td>-.30***</td>
<td>.09</td>
<td>.64***</td>
<td>-.23**</td>
<td>-.14</td>
<td>-.13</td>
</tr>
<tr>
<td>4. SES</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>.08</td>
<td>-.40***</td>
<td>-.08</td>
<td>-.05</td>
<td>-.01</td>
</tr>
<tr>
<td>5. Age</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>-.11</td>
<td>-.59***</td>
<td>-.71***</td>
</tr>
<tr>
<td>6. CAT Composite</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>-.12</td>
<td>.00</td>
</tr>
<tr>
<td>7. Sternberg Mean RT</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>.68***</td>
</tr>
<tr>
<td>8. CPT Factor 1</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>9. CPT Factor 2</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
</tr>
</tbody>
</table>

⁎ P < .05.  ⁎⁎ P < .01.  ⁎⁎⁎ P < .001.

Negative sign reflects the way that parental SES is coded such that low parental SES values represent high parental status.
to the variance. Overall, the nine variables in the model accounted for 39% of the variance in language achievement. (See Table 22.)

**Mathematics Achievement.** Results of the regression analysis for mathematics achievement resembled those found for language achievement. Composite score on the CAT again was the largest contributor of variance and accounted for 32.0% of the variance in the model. No significant contributions were made by the CPT factors or Sternberg mean reaction time. (1) SES, (2) age, (3) age x Sternberg mean reaction time, (4) age x factor 1, (5) age x factor 2 also provided negligible (<1% each) contributions, none of which were significant. (Table 23 summarizes the results for mathematics achievement.) Overall, 45% of the variance in mathematics achievement was accounted for by the model. Slightly more of the variance was accounted for in mathematics than in language due in part to the increased contribution of the CAT composite scores.

**Composite Achievement.** Table 24 presents the results for composite or overall achievement on the Iowa Tests of Basic Skills. Here, consistent with results of the regression analyses for language and mathematics achievement, composite score on the CAT was the single largest contributor accounting for 34.4% of the variance. The CPT factors and Sternberg mean reaction time did not significantly predict composite achievement. All other variables in the model were again negligible and nonsignificant in their contribution accounting for less than 1% each of the total variance. Overall, the nine variables when considered together accounted for 52.2% of the variance.
Table 22
Regression Analysis for Achievement on the ITBS Language Subtests

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>F</th>
<th>p</th>
<th>Regression Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT Composite</td>
<td>1</td>
<td>12446.55</td>
<td>56.62</td>
<td>.0001</td>
<td>.92</td>
</tr>
<tr>
<td>SES</td>
<td>1</td>
<td>24.86</td>
<td>.11</td>
<td>.74</td>
<td>-.02</td>
</tr>
<tr>
<td>Sternberg Reaction Time</td>
<td>1</td>
<td>101.41</td>
<td>.46</td>
<td>.50</td>
<td>-.01</td>
</tr>
<tr>
<td>CPT Factor 1</td>
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<td>36.79</td>
<td>.17</td>
<td>.68</td>
<td>2.66</td>
</tr>
<tr>
<td>CPT Factor 2</td>
<td>1</td>
<td>113.97</td>
<td>.52</td>
<td>.47</td>
<td>-5.23</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>81.87</td>
<td>.37</td>
<td>.54</td>
<td>-1.41</td>
</tr>
<tr>
<td>Age x Sternberg RT</td>
<td>1</td>
<td>17.20</td>
<td>.08</td>
<td>.78</td>
<td>.00</td>
</tr>
<tr>
<td>Age x Factor 1</td>
<td>1</td>
<td>42.93</td>
<td>.20</td>
<td>.66</td>
<td>-.29</td>
</tr>
<tr>
<td>Age x Factor 2</td>
<td>1</td>
<td>68.34</td>
<td>.31</td>
<td>.58</td>
<td>.42</td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-6.00</td>
</tr>
</tbody>
</table>
Table 23
Regression Analysis for Achievement on the ITBS Mathematics Subtests

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>F</th>
<th>P</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT Composite</td>
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<td>18063.32</td>
<td>81.28</td>
<td>.0001</td>
<td>1.11</td>
</tr>
<tr>
<td>SES</td>
<td>1</td>
<td>31.74</td>
<td>.14</td>
<td>.71</td>
<td>-.02</td>
</tr>
<tr>
<td>Sternberg Reaction Time</td>
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<td>75.17</td>
<td>.34</td>
<td>.56</td>
<td>-.01</td>
</tr>
<tr>
<td>CPT Factor 1</td>
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<td>103.60</td>
<td>.47</td>
<td>.50</td>
<td>-4.47</td>
</tr>
<tr>
<td>CPT Factor 2</td>
<td>1</td>
<td>30.17</td>
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<td>.71</td>
<td>2.69</td>
</tr>
<tr>
<td>Age</td>
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<td>-.96</td>
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<tr>
<td>Age x Sternberg RT</td>
<td>1</td>
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<td>.61</td>
<td>.00</td>
</tr>
<tr>
<td>Age x Factor 1</td>
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<td>113.06</td>
<td>.51</td>
<td>.48</td>
<td>.47</td>
</tr>
<tr>
<td>Age x Factor 2</td>
<td>1</td>
<td>22.62</td>
<td>.10</td>
<td>.75</td>
<td>-.24</td>
</tr>
<tr>
<td>Intercept</td>
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<td></td>
<td></td>
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<td>-39.76</td>
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</table>
Table 24
Regression Analysis for Composite Achievement
on the ITBS

<table>
<thead>
<tr>
<th>Source</th>
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<th>SS</th>
<th>F</th>
<th>P</th>
<th>Regression Coefficient</th>
</tr>
</thead>
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<tr>
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<td>100.69</td>
<td>.0001</td>
<td>1.07</td>
</tr>
<tr>
<td>SES</td>
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<td>.70</td>
<td>.41</td>
<td>-.04</td>
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<tr>
<td>Sternberg Reaction Time</td>
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<td>163.79</td>
<td>.98</td>
<td>.32</td>
<td>-.02</td>
</tr>
<tr>
<td>CPT Factor 1</td>
<td>1</td>
<td>37.23</td>
<td>.22</td>
<td>.64</td>
<td>2.68</td>
</tr>
<tr>
<td>CPT Factor 2</td>
<td>1</td>
<td>7.77</td>
<td>.05</td>
<td>.83</td>
<td>-1.36</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>15.93</td>
<td>.10</td>
<td>.76</td>
<td>-.62</td>
</tr>
<tr>
<td>Age x Sternberg RT</td>
<td>1</td>
<td>58.28</td>
<td>.35</td>
<td>.56</td>
<td>.00</td>
</tr>
<tr>
<td>Age x Factor 1</td>
<td>1</td>
<td>10.40</td>
<td>.06</td>
<td>.80</td>
<td>-.14</td>
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<tr>
<td>Age x Factor 2</td>
<td>1</td>
<td>2.72</td>
<td>.02</td>
<td>.90</td>
<td>.08</td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td>-29.46</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Interrelationships Among Measures

$H_7$: Attentional performance on the CPT will be positively associated with memory processing speed on the Sternberg (i.e., mean reaction time).

Partial correlations controlling for age indicated a significant positive association between "efficiency of processing" (i.e., CPT factor 1) and memory processing speed ($r = .45, p = .0001$).

The partial correlation between accuracy of processing (CPT factor 2) and memory processing speed on the Sternberg was not significant.

$H_8$: Language scores as assessed by the Iowa Tests of Basic Skills will be correlated with perceptual encoding speed (RT) and accuracy (hit rate) on the CPT.

The partial correlation controlling for age between language achievement as assessed by the ITBS and perceptual encoding speed was not significant. Neither was there a significant relationship between language achievement and accuracy of processing (on the CPT). Though non-significant, these relationships were always negative.

$H_9$: Mathematics achievement scores as assessed by the Iowa Tests of Basic Skills will be negatively associated with CPT false alarm rate (i.e., impulsivity).

The partial correlation between mathematics achievement and false alarm rate (CPT factor 2) was not significant, but was in the expected direction.

$H_{10}$: Children's performance on language, mathematics, and composite achievement as assessed by the Iowa Tests of Basic Skills will be positively correlated with their speed of memory processing as measured by the Sternberg.
The partial correlation controlling for age indicated that children's language achievement on the ITBS was significantly related to speed of memory processing ($r = -.25, p = .0019$). Because smaller values for speed of memory processing indicate faster performance, this correlation is interpreted as meaning that higher language achievement scores are associated with faster speed of processing. (Conversely, lower language achievement scores are associated with slower speed of processing.)

The partial correlation (controlling for age) between children's mathematics achievement and memory processing speed on the Sternberg was significant ($r = -.17, p = .0349$). This correlation indicates that higher mathematics achievement scores are associated with faster speed of processing.

The partial correlation between composite achievement on the ITBS and memory processing speed was also significant ($r = -.24, p = .0039$). As with language and mathematics achievement, children who had higher composite achievement scores also had faster memory processing speeds.

$H_{11}$: Children's performance on the tests of attention (CPT) and memory processing (Sternberg) will be positively though weakly related to their scores of cognitive ability as measured by the Cognitive Abilities Test (CAT).

Partial correlations (controlling for age) indicated that children's scores on the CAT were not significantly related to efficiency of processing (CPT factor 1).
No significant partial correlations were found between the CAT composite scores and accuracy of processing (CPT factor 2). Though non-significant, this relationship was negative suggesting that children who had a high number of false alarms had low composite achievement scores.

Children's overall cognitive ability was significantly related to Sternberg speed of memory processing \((r = -0.22, p = 0.0072)\). This negative relationship is interpreted as indicating that high cognitive ability is associated with faster memory processing speed.

**Summary of Results**

Results of the repeated measures ANOVA performed on reaction time, hit rate, and false alarm rate indicated significant effects for age, test condition, and the age x test condition interaction. There were no sex or test x sex interaction effects. A significant age x sex x test condition interaction was found only for false alarm rate.

The ANOVA for children's speed of memory processing indicated a significant age effect, but no sex or age x sex interaction.

Regression analyses performed separately for language, mathematics, and composite achievement indicated that cognitive ability was the best predictor of achievement in each area. Attention and memory as operationalized in the present study did not contribute significantly to the prediction of achievement in either of the three areas.

Partial correlational analyses controlling for age indicated several significant interrelationships between the measures. Parental SES was found to be significantly correlated with children's
performance on tests of achievement (language, mathematics, composite) and cognitive ability. Speed of memory processing was significantly correlated with achievement in the three areas and also with cognitive ability. Efficiency of processing (CPT factor 1) was significantly correlated with speed of memory processing, but not with language achievement, composite ability, or parental SES. Accuracy of processing (CPT factor 2) was not significantly related to language achievement, mathematics achievement, cognitive ability, parental SES, or speed of memory processing.
CHAPTER IV

DISCUSSION

The present study investigated age-related changes and sex differences in children's vigilance performance (i.e., reaction time, hit rate, and false alarm rate) on four different task conditions of the Continuous Performance Test of Sustained Attention. The investigation also examined age-related changes and sex differences in children's speed of memory processing as measured by mean reaction time on the Sternberg Test of Short-Term Memory and Concentration. Overall, the results from both analyses indicated significant age-related changes, but no differences in performance due to sex. Additionally, CPT performance was found to vary on reaction time, hit rate, and false alarm rate as a function of the age x test condition interaction.

After reduction of the CPT variables by factor analysis, regression analyses were performed to assess the contribution of cognitive ability, attention, and speed of memory processing to academic achievement. Partial correlational analyses were used to investigate the interrelationships among measures.

The following discussion will focus on the hypotheses and issues addressed in the study.
Age-Related Changes in Vigilance

**Reaction Time.** The interaction of age and test condition was significant because of an increase in response reversal reaction times at the older ages. Overall, for the response reversal condition, reaction times decreased from ages 6-11 years. But, at age 12 years, reaction time increased (i.e., responding became slower) and continued to do so though not significantly with each of the remaining age groups. This test condition requires the reversal of a previously learned response to be successful. Task difficulty on the response reversal condition is increased by burdening the response selection and response organization components of the task (Massaro, 1975; Sternberg, 1969). Reversal of the task demands requires increased inhibitory control and response organization in order to avoid responding to the competing previously relevant stimuli. The shift in speed of responding by older subjects is therefore adaptive and reflects increased inhibitory control at the older ages. Increased inhibitory control as a function of age has also been reported by Brown (1983).

The shift in reaction time at 11-12 years old parallels concomitant cognitive developments in these children as they move from the period of concrete operational to formal operational thought in Piagetian theory terms. It may also represent a heightened meta-awareness of the cognitive strategies necessary to complete the task. For example, the older children may say to themselves, "Go slow. Press to every number except the 5."
No other age interactions were significant (i.e., age x sex and age x sex x test) for reaction time.

**Hit Rate.** The interaction of age and test condition was significant. This was due to the significantly lowered performance of the youngest age group (6 year olds). On all test conditions except the conventional numeral condition, the 6 year olds consistently obtained the lowest number of correct detections to the target stimulus. However, 6 year olds were only significantly lower than the other age groups on the hits feedback condition. The most difficult test for this age group, as reflected in their poor performance was the degraded stimulus condition. This condition increases the demand on processing resources by burdening early stimulus encoding and analysis aspects of processing (Nuechterlein, 1983; Sternberg, 1969). This finding of lowered hit rate for the youngest children is indicative of their difficulty with accurate perceptual encoding and rapid signal discrimination.

Analysis of the age x test interaction also indicated that there was a shift toward increased hit rate between the ages of 8 and 9 for the conventional numeral, degraded stimulus, and response reversal conditions. For these conditions, the performance of the 9-14 year olds did not differ significantly. (For the hits feedback condition, the shift in attentional performance came between ages 9 and 10.) Reasons for this shift toward improved performance are not immediately obvious. It may represent a developmental change.

No other age interactions (i.e., age x sex; age x sex x test) were significant.
False Alarm Rate. The interaction of age and test was significant because of the very large increase in false alarms made by all age groups during the response reversal condition. However, the response reversal false alarm rate showed a large drop (improvement) between the ages of 12 and 13 years. It remained at the same level for 14 year olds. This age-related decrease in false alarm rate occurred at approximately the same age as did the slowing down of the speed of responding (i.e., increase in reaction time). As previously discussed, the response reversal condition consists of a reversal of the task demands thereby requiring inhibition of competing responses to the previously relevant stimulus. Older children (i.e., 13 and 14 year olds) were significantly better at inhibiting the well-learned response and making fewer impulsive errors as evidenced by the false alarm rate. Meta-cognitive processes most likely contributed to their improved performance.

Sex Differences in Vigilance

There were no significant effects of sex for any of the CPT dependent variables in the study—i.e., reaction time, hit rate, and false alarm rate—thereby confirming the stated hypothesis regarding sex differences. This finding corroborates research with younger children using the CPT paradigm (Levy & Hobbes, 1979) as well as studies using other vigilance task paradigms (Herman et al., 1980; Kirchner & Knopf, 1974; Margolis, 1973; van Hover, 1974). One study (Gale & Lynn, 1972) found sex differences favoring girls, but only at ages 7, 8, and 12 years. They interpreted this finding as a reflection
of "general sex differences in developmental rate," but given the other evidence, it may have been a sample effect. Murphy-Berman et al. (1986) found that boys had significantly higher overall false alarm rates than girls on the vigilance task. These differences were consistent across all of the grade levels studied (K-9). The Murphy-Berman et al. study appears to be a more representative sample than the one of the Gale and Lynn.

As previously discussed, there does not appear to be a clear sex difference in attentional performance between normal learning boys and girls. However, there is some evidence from the Murphy-Berman et al. (1986) study to suggest that boys and girls in the general population vary in attentional style with boys being somewhat more impulsive. The tendency for normal boys to exhibit an impulsive response style mirrors the data from clinical populations which have consistently documented a higher incidence of attention deficit disorder and learning disabilities among boys. Possible explanations for this include the developmental immaturity of boys, sex-linked genetic factors influencing the disorder, or the impact of socialization upon development and functioning.

It is of interest to note that most of the students deleted from the study, either due to school personnel suspected attentional problems or deviant test performance, were boys. Apparently, though not considered "normal" with regard to attention, very few of these children had problems severe enough to warrant referral for a psychological assessment.
Task Variations in Vigilance

Reaction Time. Although no hypotheses were made about the four different test conditions of CPT, a significant test condition effect was found for reaction time. Follow-up analysis indicated that the four test conditions were significantly different from each other. In terms of speed of reaction time, the most difficult test condition was degraded stimulus followed by hits feedback, conventional numeral, and response reversal.

The conventional numeral CPT was made more difficult by introducing degradation of the target stimulus through random displacement of the dots comprising the numeral. The degraded stimulus condition requires difficult stimulus discrimination while the pace of stimulus presentation remains fast. A substantial amount of attentional capacity is demanded as the task burdens early stimulus encoding and analysis processes (Nuechterlein, 1983; Nuechterlein et al., 1983; O'Dougherty et al., 1984).

The effect of the increased encoding and processing demands was an increase in reaction time, i.e., reaction time became slower than for the other conditions. Children required more time to process and respond to this task than they did the others.

Introducing auditory feedback for correct detection of degraded stimuli (i.e., hits feedback condition) gave the children an opportunity to improve their performance over the degraded stimulus condition. The decrease in the amount of time required to complete this condition indicates the effectiveness of the feedback. So, even
when task processing demands are made difficult, improved performance can result when informational feedback is given.

Children were fastest to respond to the response reversal condition. During this condition, task difficulty is increased by taxing the response selection and response organization components of information processing (Massaro, 1975; Sternberg, 1969). By reversing the task demands, the children were required to inhibit competing responses to the previously relevant stimulus. The proportion of targets was significantly higher than for the other test conditions. Even though the pace of the presentation of the stimuli remained constant across all of the test conditions, it is likely that reaction time decreased because of the increased proportion of target stimuli requiring responses. Children were forced to organize their responses to become efficient at correct detections.

As the response reversal condition makes more demands on processing than the conventional numeral condition (which required little or no demands on processing; cf. Nuechterlein, 1983) it is interesting to note that reaction times for the latter conditions were significantly slower. This significant difference may have been the result of the increased number of targets in the response reversal condition and/or the order of the task presentation. It is most likely that during the response reversal condition, children developed and maintained a faster rate of responding in order to keep pace with the task and respond to the now more frequently occurring target stimuli.
Hit Rate. No hypothesis was made about the effect of test condition on hit rate. However, a significant test condition effect was found on this variable. Subsequent post hoc tests indicated that each of the four test conditions differed significantly from the other. With regard to accuracy of performance, the most difficult test condition was degraded stimulus followed by response reversal, hits feedback, and conventional numeral.

Given the nature of the test conditions and the resulting processing demands made on the child's attentional capacity, this ordering of most difficult to least difficult test condition is not surprising. The increased encoding burdens placed on the attentional system by the degraded stimuli made it more difficult to correctly identify target numbers. The difficulty of this task condition was also reflected in increased reaction time as previously discussed.

Hit rate for response reversal was higher than that for degraded stimulus. This indicates that the vigilance task was less difficult when response selection and response organization components of information processing were being taxed than when stimulus-encoding and analysis aspects were tested.

As with reaction time, the data for hit rate suggest an improvement in performance when auditory feedback is given (after the correct detection of a degraded stimulus). Consistent with what would be expected, the highest hit rate was found for the conventional numeral condition. This condition makes little or no demands on processing abilities, therefore, the correct detection of target stimuli is relatively easy.
False Alarm Rate. As previously noted, no hypotheses were made about the effect of test condition on false alarm rate. However, a significant test condition effect was found for false alarm rate. With regard to impulsivity or inhibitory control, response reversal was the most difficult task condition. This was followed by degraded stimulus, hits feedback, and conventional numeral. All test conditions were significantly different from each other except hits feedback and conventional numeral.

Considering the nature of the task conditions, it is not surprising that the response reversal condition would be the most difficult one in terms of inhibitory control. This was the last test administered and it required reversal of the responses that children made during the three preceding conditions (lasting approximately 15 minutes). Problems with inhibitory control and response organization were clearly evident in the high false alarm rate for this test condition.

The effect of auditory feedback on false alarm rate was to effectively increase the level of performance on this test condition (reduce the level of difficulty) to that of the conventional numeral. Even though hits feedback involved stimulus degradation which has been shown to increase information processing demands, auditory feedback improved performance (or reduced impulsivity) to a level comparable to that of a task that makes fewer demands on attentional capacity.

Age-Related Changes in Speed of Memory Processing

As the results of the ANOVA indicated, a significant effect was found for age on speed of memory processing as measured by mean
reaction time on the Sternberg Test. Post hoc mean comparisons indicated that the performance of the 6-8 year olds was significantly slower than that of the 9-14 year olds, but there was no difference among the 6-8 year olds and no difference among the 9-14 year olds. Essentially then, the performance of the 9 age groups was reduced to two separate groups; a younger (6-8 years old) and an older group (9-14 years). These results partially confirm the hypothesis predicting speed of memory processing to improve (i.e., reaction time to decrease) across the age range. The hypothesis is only partially supported as the 6-8 year olds performed in a similar manner and the 9-14 year olds also performed in a similar manner. These two groups differed in their performance with the younger children searching their short-term memory at significantly slower rates. (A review of the data for each age group indicates an overall downward trend with the exception of non-significant increases at ages 7 and 12).

It appears that the younger children in the study executed the operations of retrieval and comparison of items in the memory set at a slower rate than did the older children. The younger children in the present study may not have had significant organizational processes to perform the tasks as efficiently as the older children. A possible nonprocessing explanation is that a difference existed between the age groups in the amount of time required to execute the motor response. The data used in the present study did not allow for the separation of processing and nonprocessing components of this task.

Results of the present study corroborate those of Naus and Ornstein (1977) and Herrmann and Landis (1977) which found that the
search rates of older children were faster than those of younger subjects. These three studies are in disagreement with other studies (Harris & Fleer, 1970; Hoving, Morin, & Konick, 1970; Keating & Bobbit, 1978) that have not found age-related changes in search rate and the study by Maisto and Baumeister (1975) which found slightly faster, though non-significant, search rates in younger children.

As previously discussed, Dempster (1981) and Herrmann and Landis (1977) have suggested that the most plausible explanation for these inconsistent findings is the amount of practice given to the subjects. Subjects in studies that found age group differences favoring older children generally received less practice than the subjects in studies that reported no age-related changes in search rate. Children in the present study were allowed 15 practice trials. Similarly, children in the Herrmann and Landis (1977) study, the results of which are consistent with present findings, received 16 trials. Children in studies finding faster research rates for younger subjects (e.g., Maisto and Baumeister, 1975) received as many as 48 practice trials.

The issue of age-related changes in search rate appears to be unresolved and further research is warranted.

Sex Differences in Speed of Memory Processing

Results of the study indicated no difference in children's speed of memory processing speed as function of sex. This finding supports the hypothesis predicting no sex effects on this variable. It also corroborates research by Hoving et al. (1970) which also found no differences in memory scanning rate as a function of sex among the kindergarten, fourth grade, and college students they studied. The
present study further substantiates Maccoby and Jacklin's conclusion (1974) that neither sex has a "superior" set of skills in the storage and retrieval of information.

Socioeconomic Status (SES) Relationships

As predicted, parental socioeconomic status (SES) was significantly though weakly associated with the child's performance on the tests of cognitive ability and achievement. This is in agreement with a large body of literature (e.g., Deutsch, 1973; Sameroff & Chandler, 1975; St. James-Roberts, 1979) that has consistently documented the positive association between parental SES and children's ability.

Parental SES was not found to be related to children's performance on either CPT factor 1 (efficiency of processing) or CPT factor 2 (accuracy of processing) in this sample of school-age children. The results related to parental SES and children's CPT performance were contrary to the hypothesis. The data of the present study do not replicate previous findings of significant relationships between CPT performance (errors of omission and commission) and social class among pre-school age children (Levy, 1980; Levy & Hobbes, 1979).

Failure to find consistent results in these two studies may be due to measurement and cultural differences as the Levy study (Levy, 1980; Levy & Hobbes, 1979) took place in Australia. The index of social class in their study, the Congalton classification, was used to rate the Sydney suburbs in which the schools were located. Even though the particular measure has been shown to have a "clear relationship to occupational classification" (Levy & Hobbes, 1979), this broad measure would very likely yield results contrary to an
index that rates education and occupation at an individual level. The noncomparability of the samples (i.e., cultural and age differences) and the SES indexes used in the Levy and Hobbes study and the present study make it difficult to generalize across the studies.

The correlation between parental SES and speed of memory processing was not significant. The lack of a significant relationship between these two variables is counter to the stated hypothesis. Even though speed of memory processing is a cognitive process, it may be that it is reflective of an "individual capacity" and therefore less influenced by SES than are other cognitive processes. Further research is needed to investigate the role of parental SES in children's memory processing and vigilance.

Predictive Relationships

Results of the three separate regression analyses were similar and confirm the hypothesis that the cognitive ability score was the best predictor of language, mathematics, and composite achievement. This is also consistent with previous literature (e.g., Gose, Wooden, & Muller, 1980; Hale, 1978; McDermott, 1984; Wikoff, 1979) reporting that intelligence is the best predictor of children's academic achievement. In the present study, cognitive ability accounted for 24.6% of the variance in language achievement, 32.0% of the variance in mathematics achievement, and 34.4% of the variance in composite achievement.

The hypothesis that attention and memory would be significant predictors of achievement was not supported. The two CPT factors and
Sternberg mean reaction time contributed less than 1% each to the variance in the three regression achievement models. All other variables (SES, age x Sternberg mean reaction time, age x CPT factor 1, and age x CPT factor 2) also provided negligible contributions, none of which were significant.

The results related to CPT performance contrast with studies (Margolis, 1973; Noland & Schuldt, 1971) that found a significant relationship between vigilance and reading achievement. Brown (1982) further reported that in the study by Margolis, the ability to sustain attention was found to be as important a factor in school achievement as intelligence. The vigilance task employed by Margolis was not based on the CPT paradigm.

In the present study, several reasons for the non-contributory role of attention and memory in the prediction of achievement can be posited. The first reason concerns the outcome measure of achievement. It may be that the measure of academic achievement used in the present study was "too global" to be sensitive to the effects of attention and memory as operationalized in the study. Perhaps other measures of achievement such as school grades (which are more closely related to daily classroom performance and behavior) would better reflect the role of attention and memory in overall school performance and success.

A related issue is the measurement of attention and memory as operationalized in the study. It may be that the CPT vigilance task does not measure sustained attention in a way that is meaningful or
valid for school tasks. Even though during school, attention must be sustained, the input to the student is varied as well as continuous.

Additionally, and perhaps more importantly, the study implies that given a normal threshold of attention and memory (as with the present children), these two variables are not especially important in academic achievement. Viewed in this way, if a child's attention span and memory processing abilities are within normal limits, then attention and memory are "necessary, but not sufficient" conditions for learning and achievement.

Interrelationships Among Measures

Partial correlational analyses controlling for age were performed upon the total sample to determine the interrelationships among measures used in the study. The discussion focuses on these partial correlations.

Correlational analyses between the CPT and the Sternberg mean reaction time confirmed the hypothesis regarding positive associations between the two measures. Specifically, the CPT efficiency of processing factor (on which reaction time had high positive loadings and false alarm rate had high negative loadings) was significantly related to Sternberg memory processing speed (i.e., mean reaction time). These significant correlations indicate the interrelatedness of the CPT (particularly reaction time) and the Sternberg. Children who processed information efficiently on the CPT were also able to respond to the Sternberg with faster reaction times. It is not surprising that children who are able to organize their responses on the CPT also have better retrieval strategies or make more efficient
use of retrieval strategies on the Sternberg and are therefore able to respond with faster reaction times on this task.

The correlation between CPT factor 2 (accuracy of processing) and memory processing speed on the Sternberg was not significant, indicating no association between these variables. As factor 2 had high positive loadings on false alarm rate, suggesting a poorer or less accurate performance, it is not surprising that the factor would have no relationship to a variable which requires efficient and organized strategies for success.

The hypothesis regarding the correlation between language scores on the Iowa Tests of Basic Skills (ITBS) and CPT performance was not supported. It is likely that a more significant association would have been found with reading scores (had they been available) rather than with language scores. The efficiency and accuracy with which an individual processes information are likely more salient aspects of learning to read than acquiring language skills as assessed by the ITBS. The ITBS language subtests evaluate skills in the "mechanics" of language and include items related to spelling, capitalization, punctuation, and usage. As such, the ITBS language score does not reflect skills and abilities related to reading per se. Reading, for example, requires good decoding skills. Efficient and accurate processing of information are assumed to be important in the development of good decoding skills.

The partial correlation between mathematics achievement on the ITBS and false alarm rate (CPT factor 2) was not significant although the correlation was in the hypothesized direction. As pointed out
previously, this was a "normal" sample and no severe achievement deficits were expected from any of the children included in the study. Failure to achieve significance may have been related to lack of variation in the mathematics scores of children.

As predicted, the relationship between children's speed of memory processing and their achievement scores (language, mathematics, and composite) was significant. Because smaller values for speed of memory processing indicate faster performance, the negative correlations are interpreted as meaning that higher achievement scores (in each of the three areas) are associated with faster speed of processing. It suggests then that children's speed of memory processing is a significant factor in their academic achievement. Further, it would seem that children who are able to process information faster (make more successful use of their memory) are able to attain higher levels of achievement. Children who process information faster are better able to access information available to them and therefore meet success with regard to school achievement.

As hypothesized, and similar to the achievement results previously presented, the partial correlation (controlling for age) between speed of memory processing and children's overall cognitive ability was significant though weak. Even though these two measures vary in content and complexity, it has been suggested by Vernon (1983) that they are "tapping a subset of the same cognitive operations involved in all tests that measure intellectual behavior." The efficient accessibility of information through storage, retrieval, search, and comparing processes appears to be important in overall cognitive
ability as well as achievement. If faster speeds or processing continues for long periods of time, an individual has the opportunity to process more information or acquire more knowledge. The result of this may be that more knowledge is available to the individual. This may be indicated by higher scores on measures of cognitive ability and achievement.

Contrary to the hypothesis, no significant correlations were found between children's cognitive ability and their performance on CPT factor 1 and CPT factor 2. Though non-significant, the correlations were in the expected direction.

Limitations of Study

Limitations of the present study are as follows:

1. The order of presentation of the experimental measures (CPT and Sternberg) was not counter-balanced. The effects of this are not known, especially as it may have affected reaction time.

2. Detailed analysis of the Sternberg data (e.g., slope, intercept) was not done in the present study as mean reaction time was taken as the best single indicator of memory processing speed. This made it difficult to determine if differences in reaction time were related to cognitive processing or motor readiness aspects of the tasks.

3. The school that participated in the study was rather homogenous with respect to family socioeconomic status, race, and level of intelligence. This homogeneity makes it difficult to generalize to other populations.
4. When age x sex x test condition analyses were performed, the
n's of the cells ranged from 5 to 14. Certainly, a more equal
distribution of subjects would have been desirable.

Implications of the Study

With these limitations in mind, the present study has the
following implications. Perhaps the major implication of the study
concerns the use of the CPT to examine aspects of cognitive
information processing within a vigilance task. The data here, as
well as the study by O'Dougherty et al. (1988) show that there are
age-related changes in normal children in cognitive processes such as
stimulus encoding, response selection, and response organization.
Availability of normal developmental data will allow for more accurate
comparisons to be made with children who may be evaluated for
suspected attention and learning problems.

The very strong test condition effect points to the usefulness of
the CPT task conditions (used in the present study) to assess
vigilance in children. Even though conventional versions of the CPT
can discriminate children with attentional problems, the addition of
other task conditions gives a more complete picture of children's
attention and cognitive processing.

It would also appear that given a normal threshold of attention
and memory processing ability, these two processes may not be as
related to academic achievement as presumed. This is not to imply
that they have no importance at all. Obviously, this is not the case.
What this suggests is that they are both required for learning. But,
if the child has a normal attention span and memory, other factors may be more important to school achievement.

Suggestions for Future Research

Based on the present study, the following suggestions for future research are made:

1. The study should be replicated with a clinical group such as children with attention deficit disorder or learning disability. This would allow the assessment of similarities and differences in cognitive processing between these children as compared with normals. Impressions garnered from previous clinical use of the CPT suggest that the version used in the present study can discriminate children with some behavioral disorders. Systematic study of children with certain clinical diagnoses may provide information that will be diagnostically valuable.

2. Replication of the study using other measures of attention would allow the examination of the relationship of these measures to the CPT and also provide more information regarding the clinical screening of children with suspected problems.

3. Use of other measures of achievement would clarify the role of attention and memory (as operationalized here) in achievement among normal children. As previously suggested, the measures of achievement used in the present study may represent a lack of sensitivity of the measures to attention and memory as operationalized in the study. It has been observed clinically that many students have normal cognitive ability and achievement (as measured by standardized tests) but do not function normally or perform well on a daily basis. More sensitive
outcome measures of achievement or ability, such as study skills, tasks requiring organization and effort, timed tests requiring rote memory (e.g., math facts, spelling), or paired associate type learning tasks could be used to clarify the role of attention and memory in the prediction of achievement.

4. Further study with the Sternberg appears warranted to directly address the affect of practice on children's performance.
APPENDIX A

AMHERST MODIFICATION OF HOLLINGSHEAD'S TWO-FACTOR INDEX OF SOCIAL POSITION
AMHERST MODIFICATION OF HOLLINGSHEAD'S
TWO FACTOR INDEX OF SOCIAL POSITION

Alphabetical List of Occupations by Level

1. Professional and Large Business Owner and Official

Certified Social Service
College Educator and Scientist
Engineer
High Government Official
Legal
Lesser Medical
Medical
Official
Owner
Religious

Advertiser
Archeologist
Area representative
Astronomer
Auditor
Bacteriologist
Banker
Bank president
Bookmaker
Business executive
Chemist
Chiropractor
Civil engineer
Comptroller
Cottonbroker
CPA
Criminologist
Dentist
Department-store-owner
Diplomat
Doctor
Educational administrator
Auctioneer
Chiropodist

Electronics researcher
Financier
Geologist
Geo-physicist
Grain broker
High government official
Horticulturist
Hotel manager
Hotel owner
Hydrographer
Importer
Import-export broker
Judge
Judge advocate in army
Large business owner
Lawyer
Manufacturer
Mathematician
Meterologist
Minister
Missionary
Motel owner
Nun
Occupational therapist

Oceanographer
Optometrist
Osteopath
Pharmacist
Physician
Physicist
Producer
Property owner
(large)
Psychiatrist
Psychoanalyst
Psychologist
Psychotherapist
Rancher
Real-estate owner
Recreation director
Researcher
Restaurant owner
School psychologist
Social worker
Sociologist
Speech therapist (certified)
Stock owner
Veterinarian
2. Business Agent and Manager

Accounting
Insurance
Management
Real Estate
Sales Representative

Accountant  Accountant
Advertiser  Advertiser
Advertising manager  Advertising manager
Advertising space seller  Advertising space seller
Agent  Agent
Art director  Art director
Auctioneer  Auctioneer
Business agent  Business agent
Business manager  Business manager
Buyer  Buyer
Construction superintendent  Construction superintendent
Credit manager  Credit manager
Department head  Department head
Distributor  Distributor
Escrow officer  Escrow officer
Field superintendent  Field superintendent
Foreign trade for big company  Foreign trade for big company
Insurance claim investigator  Insurance claim investigator
Insurance collector  Insurance collector
Insurance sales  Insurance sales
Insurance underwriter agent  Insurance underwriter agent
Labor-union business agent  Labor-union business agent
Loan-company agent  Loan-company agent
Manufacturer's representative  Manufacturer's representative
Marketer  Marketer
Meat jobber  Meat jobber
Metal trader  Metal trader
Personnel manager  Personnel manager
Plant superintendent  Plant superintendent
Production manager  Production manager
Real-estate broker  Real-estate broker
Real-estate manager  Real-estate manager
Retail-furniture dealer  Retail-furniture dealer
Sales manager  Sales manager
Stockbroker  Stockbroker
Wholesaler  Wholesaler
3. **Semiprofessional and Public Administrator**

Art
Educator
Government Administration
Literature
Music and General Entertainment
Scientific and Medical Service

Actor  
Actuary  
Advertising copy writer  
Agricultural consultant  
Airplane pilot  
Architect  
Art designer  
Artist  
Cartoonist  
Ceramicist  
Chief of police  
Choreographer  
Church school teacher  
Coach  
Dental hygienist  
Dietician  
Dress designer  
Educator (primary and secondary)  
Embalmer  
Fashion consultant  
Fashion designer  
Fashion illustrator  
Film editor  
Foreign Service (consulate)  
Forester  
Forest ranger  
Funeral director  
Game warden  
Graduate student  
Home economist  
Industrial-relations counselor  
Interior designer  
Investment counselor  
Journalist  
Lab assistant  
Labor-relations counselor  
Lab technician  
Librarian  
Make-up artist  
Medical librarian  
Military officer  
Mortician  
Movie or stage director  
Musician  
Nurse  
Nutritionist  
Physical culturist  
Physical therapist  
Politician  
Postmaster  
Post-Office inspector  
Practical nurse  
Private music teacher  
Professional athlete  
Professional race-back driver  
Programmer  
Public official  
Public-relations man  
Recreational therapist  
Reporter  
Secret-service agent  
Securities analyst  
Singer  
Sound editor  
Sound technician  
State interviewer  
Statistician  
Substation head  
Tax assessor  
Tax collector  
Translator  
Tree surgeon  
T.V. or radio announcer  
Weatherman  
Writer  
X-ray technician
4. Lesser White-collar Worker and Small-Business Owner, Manager
And Salesman

Agriculture
Clerical
Commission Sales
Contractor, construction
Manager
Nonretail owner
Salesclerk
Small-business
White collar
Retail owner

Appliance salesman
Bank teller
Bookkeeper
Car salesman
Cashier
Claims investigator
Clerk
Contractor
Dental assistant
Dispatcher
Display man
Dry cleaner
Estimator
Farmer
Florist
Freight adjuster
Gas-station owner
Grocer
Haberdasher
IBM operator
Interior decorator
Junk dealer

Key punch operator
Landscaper
Laundry owner
Logger
Magazine photographer
Mailer
Manager of small business
Meter reader
Motel owner (small)
Movie cameraman
Nursery owner
Office or desk work
Order clerk
Owner of small business
Pawn-broker
Personnel interviewer
Photographer
Plastering business
Printing business
 Produce clerk
Rancher
Receiving clerk

Receptionist
Restaurant owner
Rubbish collector
Salesclerk
Secretary
Service-station manager
Sharecropper
Shipper
Shipping clerk
Tabulator
Telephone operator
Title searcher
Traffic man
Trailer-park owner
Trucking business
T.V. cameraman
Typist
Undergraduate student
Upholsterer
White collar
Window trimmer
5. **Skilled Laborer**

- Construction
- Draftsman
- Electrical
- Food and Personal Service
- Foreman
- Metal and Mechanical
- Printing
- Protective

<table>
<thead>
<tr>
<th>Industry/Profession</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Force (enlisted)</td>
<td>Electronics technician</td>
</tr>
<tr>
<td>Air Force</td>
<td>Finisher</td>
</tr>
<tr>
<td>Ground crew</td>
<td>Fireman</td>
</tr>
<tr>
<td>Airline hostess</td>
<td>Flight engineer</td>
</tr>
<tr>
<td>Army (enlisted)</td>
<td>Floor lady</td>
</tr>
<tr>
<td>Baker</td>
<td>Foreman</td>
</tr>
<tr>
<td>Barber</td>
<td>Form setter</td>
</tr>
<tr>
<td>Barge captain</td>
<td>Freight conductor</td>
</tr>
<tr>
<td>Bartender</td>
<td>Furrier</td>
</tr>
<tr>
<td>Beauty operator</td>
<td>Glazer</td>
</tr>
<tr>
<td>Blacksmith</td>
<td>Government meat inspector</td>
</tr>
<tr>
<td>Boiler &quot;engineer&quot;</td>
<td>Grinder</td>
</tr>
<tr>
<td>Boilermaker</td>
<td>Hand engraver on precious metals</td>
</tr>
<tr>
<td>Brewer</td>
<td>Horse trainer</td>
</tr>
<tr>
<td>Brick mason</td>
<td>Inspector</td>
</tr>
<tr>
<td>Cabinetmaker</td>
<td>Jig-maker</td>
</tr>
<tr>
<td>Caddymaster</td>
<td>Lifeguard</td>
</tr>
<tr>
<td>Carpenter</td>
<td>Linoleum layer</td>
</tr>
<tr>
<td>Carpet layer</td>
<td>Lithographer</td>
</tr>
<tr>
<td>Cement finisher</td>
<td>Machine maintenance</td>
</tr>
<tr>
<td>Chef</td>
<td>Machine operator</td>
</tr>
<tr>
<td>Coast Guard (enlisted)</td>
<td>(by education)</td>
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<tr>
<td>Compositor</td>
<td>Machinist</td>
</tr>
<tr>
<td>Cook</td>
<td>Marines (enlisted)</td>
</tr>
<tr>
<td>Cooper</td>
<td>Mechanic</td>
</tr>
<tr>
<td>Craftsman</td>
<td>Milliner</td>
</tr>
<tr>
<td>Crane operator</td>
<td>Millwright</td>
</tr>
<tr>
<td>Design checker</td>
<td>Mold-maker</td>
</tr>
<tr>
<td>Detective</td>
<td>Movie projectionist</td>
</tr>
<tr>
<td>Diamond setter</td>
<td>Navy (enlisted)</td>
</tr>
<tr>
<td>Diesel mechanic</td>
<td>Neon sign-maker</td>
</tr>
<tr>
<td>Draftsman</td>
<td>Painter</td>
</tr>
<tr>
<td>Diver</td>
<td>Paint mixer</td>
</tr>
<tr>
<td>Electrical leadman</td>
<td>Pattern maker</td>
</tr>
<tr>
<td>Electrician</td>
<td>Photo-engraver</td>
</tr>
<tr>
<td>Marine (enlisted)</td>
<td>Plumber</td>
</tr>
<tr>
<td>Millwright</td>
<td>Policeman</td>
</tr>
<tr>
<td>Millwright</td>
<td>Propman in movies</td>
</tr>
<tr>
<td>Millwright</td>
<td>Quality-control supervisor</td>
</tr>
<tr>
<td>Millwright</td>
<td>Radio repairman</td>
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<tr>
<td>Millwright</td>
<td>Riveter</td>
</tr>
<tr>
<td>Millwright</td>
<td>Roofer</td>
</tr>
<tr>
<td>Millwright</td>
<td>RR engineer</td>
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<tr>
<td>Millwright</td>
<td>Scaleman</td>
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<tr>
<td>Millwright</td>
<td>Seaman</td>
</tr>
<tr>
<td>Millwright</td>
<td>Ship fitter</td>
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<tr>
<td>Millwright</td>
<td>Shoemaker</td>
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<tr>
<td>Millwright</td>
<td>Steel finisher</td>
</tr>
<tr>
<td>Millwright</td>
<td>Structural iron worker</td>
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<tr>
<td>Millwright</td>
<td>Surveyor</td>
</tr>
<tr>
<td>Millwright</td>
<td>Tailor</td>
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<tr>
<td>Millwright</td>
<td>Telephone installer</td>
</tr>
<tr>
<td>Millwright</td>
<td>Telephone lineman</td>
</tr>
<tr>
<td>Millwright</td>
<td>Telephone switchman</td>
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<tr>
<td>Millwright</td>
<td>Template maker</td>
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<tr>
<td>Millwright</td>
<td>Tile setter</td>
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<tr>
<td>Millwright</td>
<td>Tool and die maker</td>
</tr>
<tr>
<td>Millwright</td>
<td>Upholsterer</td>
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<tr>
<td>Millwright</td>
<td>Watchmaker</td>
</tr>
<tr>
<td>Millwright</td>
<td>Weather stripper</td>
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<tr>
<td>Millwright</td>
<td>Welder</td>
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6. **Semiskilled Laborer**

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<thead>
<tr>
<th>Delivery</th>
<th>Food</th>
<th>Laundry</th>
<th>Operator</th>
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<tbody>
<tr>
<td>Assembler</td>
<td>Attendant</td>
<td>Auto attendant</td>
<td>Belt-maker</td>
</tr>
<tr>
<td>Blueprinter</td>
<td>Brakeman (RR)</td>
<td>Bus driver</td>
<td>Butcher</td>
</tr>
<tr>
<td>Buttermaker</td>
<td>Chauffer</td>
<td>Chemical operator</td>
<td>Chrome plater</td>
</tr>
<tr>
<td>Color matcher</td>
<td>Coremaker</td>
<td>Creamery man</td>
<td>Counterman</td>
</tr>
<tr>
<td>Die caster</td>
<td>Draw-bench operator</td>
<td>Distiller</td>
<td>Drill-maker</td>
</tr>
<tr>
<td>Exterminator</td>
<td>Film developer</td>
<td>Film technician</td>
<td>Finisher</td>
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<tr>
<td>Flour miller</td>
<td>Food checker</td>
<td>Foster mother</td>
<td>Foundry worker</td>
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<tr>
<td>Furnace operator</td>
<td>Galvanizer</td>
<td>Garment cutter</td>
<td>Gear cutter</td>
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<tr>
<td>Hydraulic operator in construction</td>
<td>Hydraulic-press operator</td>
<td>Labeler</td>
<td>Lathe operator</td>
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<tr>
<td>Lather in construction</td>
<td>Laundry worker</td>
<td>Lift-trunk operator</td>
<td>Mailman</td>
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<td>Meat packer</td>
<td>Meat weigher</td>
<td>Metal cutter</td>
<td>Metal polisher</td>
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<td>Millman</td>
<td>Mineral prospector</td>
<td>Molder</td>
<td>Oil driller</td>
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<td>Parcel post driver</td>
<td>Potter</td>
<td>Presser</td>
<td>Processor (rubber)</td>
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<td>Quality-control tester</td>
<td>RR carman</td>
<td>Renderer</td>
<td>Sand blaster</td>
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<td>Seamstress</td>
<td>Sheet-metal worker (by education)</td>
<td>Shirt-maker</td>
<td>Soapmaker</td>
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<td>Sorter (fruit, vegetables and nuts)</td>
<td>Steel pourer</td>
<td>Stickerman</td>
<td>Stitcher</td>
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<td>Tally man</td>
<td>Taxi driver</td>
<td>Tire builder</td>
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<td>Truck driver</td>
<td>Vending machine operator</td>
<td>Waiter</td>
<td>Weaver</td>
</tr>
<tr>
<td>Well digger</td>
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7. **Unskilled Laborer**

<table>
<thead>
<tr>
<th>Agriculture</th>
<th>Construction</th>
<th>Factory</th>
<th>Gardener</th>
<th>Laborer</th>
<th>Service</th>
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<tbody>
<tr>
<td>Asphalt maker</td>
<td>Fruit picker</td>
<td>Garden (urban)</td>
<td>Grip</td>
<td>House mover</td>
<td>Janitor</td>
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<tr>
<td>Bus boy</td>
<td>Hammer driver</td>
<td>Kitchen attendant</td>
<td>Janitor</td>
<td>Kitchen attendant</td>
<td>Janitor</td>
</tr>
<tr>
<td>Cattle herdsman</td>
<td>House mover</td>
<td>Laborer</td>
<td>House mover</td>
<td>Loader</td>
<td>Longshoreman</td>
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<tr>
<td>Cement mixer</td>
<td>Checker</td>
<td>Loader</td>
<td>Machine helper</td>
<td>Machine helper</td>
<td>Loader</td>
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<tr>
<td>Checker</td>
<td>Chipper</td>
<td>Steel loader</td>
<td>Stock girl</td>
<td>Woodworker</td>
<td>Watchman</td>
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<td>Stevedore</td>
<td>Warehouseman</td>
<td>Watchman</td>
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<td>Grip</td>
<td>Stock girl</td>
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<tr>
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<td>Grip</td>
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<td>Hammer driver</td>
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<td>Elevator operator</td>
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<td>Farmer (employed)</td>
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<td>Field irrigator</td>
<td>Kitchen attendant</td>
<td>Watchman</td>
<td>Watchman</td>
<td>Watchman</td>
<td>Watchman</td>
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<tr>
<td>Freight carrier</td>
<td>Longshoreman</td>
<td>Watchman</td>
<td>Watchman</td>
<td>Watchman</td>
<td>Watchman</td>
</tr>
<tr>
<td>------</td>
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**Education**

1. Graduate professional degree
2. Standard college graduation
3. Partial college (1 year or more)
4. High school graduation
5. Partial high school (10 or 11)
6. Junior high school (7-9)
7. Less than 7 years
Z. Data missing
APPENDIX B

LETTERS TO PARENTS AND CONSENT FORMS
Dear Parents:

Please read the attached letter carefully. We are asking you to let your child/children take part in a study being conducted at St. Timothy's School by faculty members of The Ohio State University and the Columbus Children's Hospital. This project has been approved by the Children's Hospital Research Foundation and I believe has great importance in furthering our understanding of children with learning disabilities.

I have worked with Dr. Margaret O'Dougherty during the past year and have great confidence in her. She is well known for her research and clinical work with children who have learning disabilities or hyperactivity.

I support this project, and hope you will give permission for your child/children to participate. If you have any questions about the study at St. Timothy's, please feel free to call me at 451-0739.

Sincerely,

Margaret E. Mooney
Principal
Dear Parents:

We are writing to you with the approval of Mrs. Margaret Mooney, Principal of St. Timothy's School. By way of introduction, we are members of the Department of Pediatrics at The Ohio State University and the Columbus Children's Hospital where we are currently examining and treating many children. Some of the children we see in our work have learning disabilities and hyperactivity. Other children are being treated for seizure disorders, brain infection, head trauma or other neurologic conditions.

We have begun to use two computer-adapted tests of attention and concentration to aid in our diagnosis. We believe that these tests can also provide information about how well the children pay attention and learn information presented in the classroom. A problem that we have in using this test is that we do not know how normal elementary school children perform on these tests. Without this knowledge, we have no way of comparing the children we see at the hospital with children their own age who are not disabled.

Will you help us by allowing your child to be one of the normal children whose performance we would like to study? We hope to be able to test a substantial number of boys and girls from each grade, first through eighth.

The testing will be done right in the school and requires only 30 minutes of the child's time. Both tests, which are administered individually on an Apple computer, simply require a child to look at a series of numbers which appear on a screen and to make an appropriate response by pressing a hand held button. The first test examines the children's ability to sustain their attention and the second test studies their speed of response and memory for numbers in a sequence.

There are no physical risks involved in taking the tests. In fact, children often find them enjoyable. Although the tests are simple, research shows that they are particularly useful in identifying children with attention or memory problems.

Since we are interested in how groups of children perform, your child's name will be kept completely confidential. However, if you wish to learn about our findings on the attentional functioning of normal children, we will willingly share this information with you.

We have enclosed a permission slip with this letter which we hope you will sign and have your child return to his or her classroom teacher as soon as possible. We are grateful to you for your willingness to help us better serve disabled children of Ohio. If you have any questions, please call either of us at 461-2343.

Sincerely,

Margaret O'Dougherty, Ph.D.
Clinical Psychologist

Francis S. Wright, M.D.
Pediatric Neurologist

Enclosure
CONSENT TO SPECIAL TREATMENT
OR PROCEDURES
CHILDREN'S HOSPITAL RESEARCH FOUNDATION
Columbus, Ohio

Date ____________________________ Time ____________________________

I consent to the performance upon ____________________________ of the following treatment or procedures: ____________________________

of which part the information processing and data analyses are ____________________________ (procedure).

This is done as part of an investigation entitled: ____________________________.

This treatment or procedure is to be done by, or under the direction of ____________________________ (investigator).

1. Nature and purpose of the procedure or treatment: ____________________________

2. Other possible methods of treatment: not a treatment

3. Known risks involved: Possible fatigue, boredom, or performance anxiety during test administration

4. Possible benefits to the patient: ____________________________

STATEMENT OF CONFIDENTIALITY: I understand that the confidentiality of my response will be observed in a manner consistent with the goals of the project and my individual right to privacy.

COMPENSATION STATEMENT: I understand that in the unlikely event of physical injury occurring during the course of this study, The Children's Hospital and The Children's Hospital Research Foundation are not in a position to provide either free medical care or financial compensation.

The above have been explained to me and I understand them. I understand that any further questions I may have concerning the procedure described will be fully answered. Finally, I understand that I am free to withdraw my consent and stop participation in the project at any time. My signature represents a free and voluntary act.

Witnesseth: ____________________________ Signed ____________________________

(Margaret O'Dougherty, Ph.D. (investigator)) (patient)
Dear Parents:

Thank you so much for allowing your child to participate in our study on attention and memory skills in children. We had an excellent response from the families and have been able to collect data on children of both sexes, in every class, from grade 1 through 6. We are now finishing our data collection at the school and are writing to ask for your permission to record your child's academic achievement data from his or her cumulative school record. We would like to examine how children's performance on these tests of attention and memory relate to their achievement in reading, math, and other standard assessments that are administered by the school. We hope that by gathering this information from many normal children, we will gain much needed information about the relationship between attentional skills and school learning.

All information that is obtained from the test procedures or your child's cumulative record will be kept strictly confidential within the project's staff and will not be made available to anyone unless you request this and give your written permission. Further, your child's name will not be mentioned in any report and all project test data will be kept in a locked file, coded with no name so that they cannot be identified in any way.

We have enclosed a consent form with this letter which we hope you will sign and return in the enclosed stamped envelope. Once again, we are very grateful for your willingness to allow your child to participate in our project. The help that you and your child have given us by participating in our study has been a great contribution to our understanding of the development of attention and memory skills in children. If you have any questions, please call one of us at (614) 461-2343.

Sincerely yours,

Margaret O'Dougherty, Ph.D.
Assistant Professor
Section of Psychology

Francis S. Wright, M.D.
Professor and Chief
Section of Pediatric Neurology

M.O'D/dr

Encl.
Children's Hospital

PERMISSION FORM

I give permission for my child (name of child)'s school record to be examined and compared to his or her performance on the computer tests of attention and memory. I understand that this information will be kept confidential, that the data will be coded by number not name, and will be used only for research purposes.

Name of parent of guardian

Date
Dear Parents:

We are writing to follow up the letter sent in April requesting permission to compare your child's cumulative record achievement data with his or her performance on the computer tests of attention and memory. We hope that this information will give us a better understanding of the relationship between attention and memory skills and school learning. Of the 186 children in the study, we have received permission from 137 parents to record their child's achievement data.

We have not yet heard whether we could have your permission to record this information. Since we are studying developmental changes in children's attention and memory skills and have only 10-12 children of each grade and sex in the study, each child's performance is very important. We hope to be able to study academic achievement in relation to these skills in as many of the children as possible. We have enclosed a revised permission form which we hope you will sign and return in the enclosed stamped envelope. If you do not wish to give your permission, just check the box at the bottom of the form and indicate your child's name.

As we indicated earlier, all information that is obtained from the test procedures or your child's cumulative record will be kept strictly confidential within the project's staff and will not be made available to anyone unless you request this and give your written permission. Further, your child's name will not be mentioned in any report and all project test data will be kept in a locked file, coded with no name so that they cannot be identified in any way.

Once again, thank you very much for your willingness to have your child participate in our study on the development of attention and memory skills. The help that you and your child have given

Sincerely yours,

Margaret O'Dougherty, Ph.D.
Assistant Professor, Section of Psychology

Francis S. Wright, M.D.
Professor and Chief, Section of Pediatric Neurology

Encl.
Children's Hospital

PERMISSION FORM

I give permission for my child (name of child)'s school record to be examined and compared to his or her performance on the computer tests of attention and memory. I understand that this information will be kept confidential, that the data will be coded by number, not name, and will be used only for research purposes.

(name of parent or guardian)

(date)

If you do not wish to give your permission, check the box below and fill in your child's name.

I do not want my child (name of child)'s cumulative record examined.
APPENDIX C

INSTRUCTIONS FOR TEST ADMINISTRATION
GENERAL TESTING INSTRUCTIONS

Introduction on the way to the conference room:

Hi! I'm __________ ___________. I'm from Children's Hospital. We're doing a study on the development of attention, memory, and concentration skills and you're one of the students we've chosen for our study. (If child is not wearing glasses, ask if he/she usually does and if so, ask the child to bring them to wear during the test session.) Do you remember this permission slip you brought from home for your teacher? (Show child the permission slip from parent.) Your mother/father, like most others, agreed to let you participate in this study. Our testing room is upstairs.

Once in conference room:

Check to see if the child has signed the consent form. If he/she has, continue with instructions. If the form has not been signed, begin the description of the general test session and have the child sign the form before beginning either the CPT or Sternberg.

General Introduction to Testing:

I have some things I'd like you to try for the next half hour or so. It will involve watching this small computer monitor as numbers appear very quickly, and pressing this button every time a certain number comes up.

I'll tell you more about that in a minute, but let me say first that none of your scores on these tasks will affect your school grades in any way. They are used only for our research. But I'd like you to do your best, so the research will make the most sense.
First, let me tell you a little about this Apple Computer. It has a
clock and other equipment that controls what appears on the monitor. The
disc drives and keyboard allow the computer to work automatically and keep
score automatically. Feel free to ask any questions that you want as we go
along. Do you have any questions now? (If so, answer child's questions.)
OK, you can have a seat right here in front of this screen.
CPT INSTRUCTIONS

Conventional Numerical Condition

Let me tell you about the first thing we're going to do. Some numbers are going to flash on and off the screen very quickly. They will always appear in the center of the screen, about here. Your job is to press this button each time you see the number "5". Because the numbers flash on the screen very briefly, just on and then off right away, you really have to pay attention to make sure you press for every "5" you see.

OK, let's practice a little to make sure you've got the idea and that you are used to how quickly the slides appear. Ready?

(Give 25 practice trials, watching to make sure that the student is pressing correctly to "5"s. If the presses are often absent, too late, or made to incorrect numbers, stop the program and clarify task. Tell subject that he should press as soon as he sees a "5", but can press anytime until the appearance of the following number and still be counted as correct.)

OK, you seem to have the right idea, so I'll bring it back to the beginning and get ready to start. Reset program to beginning, i.e., (Rtn), then (Exc).

I'm going to sit here, but you can just ignore me and concentrate on the screen. Also, I'd like you to wear these headphones to block out any noise and help you concentrate on the screen. (Adjust headphones on child's head and make sure he understands that they're not plugged into anything, that they are just meant to block out noise.)

Now try to pick out all of the "5"s that you possibly can and remember to press the button each time you see one. Are you ready? (Pause.) OK, here we go.

How did you find that?
Degraded Stimulus Condition

Well, you did very well on that. We've found that to make this research most meaningful, we have to make this task somewhat more difficult. So, I'm going to make the numbers harder to tell apart. I'm going to intentionally make the numbers rather blurry, so that they will be harder to see and to tell apart. Set Parameters to appropriate degraded condition:

1. Children 8 years and younger receive the 20% degraded condition (2).
2. Children 9 years and older receive the 25% degraded condition (3).

OK, now you're going to look for the "5"s just like before. Practice pressing to "5"s for a minute to get used to the way the numbers look now. (Show 25 practice numbers. If the student seems to be missing most of the "5"s or pressing too many of the other numbers, stop the program to make sure he/she understands the task and re-question for visual acuity problems. Encourage student to keep his/her head about three feet from the screen.

OK, you seem to be finding the "5"s alright, so let's get ready to start. (Return to (P)arameters and reset the degraded parameter.) Now, I want you to pick out all the "5"s that you can throughout this next series, despite the fact that they are more difficult to see. Are you ready? (Pause.) OK, here we go. (Press ready.)

Hits Feedback Condition

How did you find that last condition? You noticed that the last version was fairly difficult. Like most other students, you missed a few of the "5"s and pressed to a few numbers that weren't "5"s. We want to find out if students can do even better (be even more accurate) than they were on their first try if we help them by giving some feedback or information on how they're doing as they go along.
I'm going to turn on a switch so that every time you press correctly to a "5", a bell in the computer will ring right away. Set 2 (P)arameters for this condition - the appropriate level of stimulus degradation and "Y"es for feedback. Then (Ritm).

After the subject presses correctly to the first "5", say:

There. That's the signal that you're correct and that you are pushing to a "5". Keep going until the computer stops.

Also, take out Behavior Profile rating scales and be ready to rate the student's test session behavior unobtrusively during the last 2 sessions. At the end of the feedback condition - Fine. Did you find the bell helpful?
Response Reversal Condition

OK, now for this last thing I want you to try, I'm going to make the numbers normal again. They're not going to be blurry.

What I want you to try this last time is just the opposite of what we've been doing. Instead of pressing to "5"'s, I want you to press the button for every number except "5". That is, you press for every number, but when you see the number "5", try to hold back and not press. Do you understand?

OK, let's have you practice for a minute, because we've found that sometimes it is difficult to make this change. Allow 25 practice slides. Then reset the program.

OK, you seem to be catching on. Now as soon as you're ready, we'll start. Remember to press each time except to "5"s. Ready? (Pause.) OK, here we go. Finish behavior ratings.

Very good. That's all you have to do on this part of the test. Did you find this difficult?

Well, do you have any question about any of this? (Answer questions as well as possible to make sure that the student understands the general nature of the skills being measured.)
INSTRUCTIONS FOR THE STERNBERG

First, select the program to be entered: 1 = the 1, 2 Condition and 
2 = the 2, 4 Condition. All children receive 10 trials per condition.
This test involves memory as well as attention and concentration.

For this test, you'll have to use both of these buttons for your responses. 
(For one-half of the children at each grade level, arrange the paddles so that 
the "positive response" or "yes" paddle is in the child's preferred hand. 
For the other subjects, the "yes" paddle should be placed in their non-preferred hand. NOTE: The "positive response" paddle is NOT marked. The "negative response" paddle is designated by a silver tab on the bottom surface.)

On the screen first you'll see either one or two numbers (for children 
9 years and older say "two or four numbers") followed by a mark that looks like a star. Then you'll see another number. You are to decide if the number that appears after the star was one of the numbers that you saw on the screen before the star. If your answer is "yes", then press the button (point to the appropriate paddle). A "yes" answer would mean that the number which came after the star was one of the numbers that had just appeared before the star. 
If your answer is "no", then press this button (point to the appropriate paddle). A "no" answer would mean that the number which came after the star was not one of the numbers that had just appeared before the star.

So, again, you press this button (pointing) if your answer is "yes, 
the number after the star was one of the numbers just before the star." And you press this button (pointing) if your answer is "no, the number after the star was not one of the numbers before the star."

Let me show you how it works. (Demonstrate/vocalize the task to the child 
for 6 trials.) You can say the numbers silently, to yourself. I said them 
out loud so that I could show you how I was doing it. Do you have any questions? 
(Then, give the child the appropriate paddles and let the child practice for
15 trials. Say - "Now you try some for practice.) Give feedback about the accuracy of each response during the practice trials.) If the child's response is correct, say "that's right". If the child's response is incorrect, say "no". (If, after 15 practice trials, the child is still having difficulty, allow 15 more practice trials and give the necessary assistance. After the last 15 practice trials are completed, begin the task.)

(Note: if more than 15 practice trials are given, make a notation of the type of assistance provided while subject was performing the task.)
APPENDIX D

TABLES OF DESCRIPTIVE STATISTICS ON ALL VARIABLES BY AGE
Table 25
Descriptive Statistics on all Variables by Age — 6 Year Olds

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<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum Value</th>
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Table 25 (Cont'd)

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Table 26
Descriptive Statistics on all Variables by Age — 7 Year Olds

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CPT Variables:

Conventional Numeral Condition

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Degraded Stimulus Condition

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Hits Feedback Condition

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### Table 28
Descriptive Statistics on all Variables by Age -- 9 Year Olds

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**CPT Variables:**

**Conventional Numeral Condition**

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**Degraded Stimulus Condition**

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**Hits Feedback Condition**

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Descriptive Statistics on all Variables by Age -- 10 Year Olds

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CPT Variables:

Conventional Numerical Condition

| RT                         | 17 | 410.2| 58.39| 305.7         | 557.3         |
| Hit Rate                   | 17 | .99  | .036 | .85           | 1.00          |
| False Alarm Rate           | 17 | .01  | .012 | .00           | .04           |

Degraded Stimulus Condition

| RT                         | 17 | 475.3| 62.44| 409.3         | 632.3         |
| Hit Rate                   | 17 | .94  | .080 | .73           | 1.00          |
| False Alarm Rate           | 17 | .03  | .054 | .00           | .22           |

Hits Feedback Condition

| RT                         | 17 | 437.1| 53.88| 370.7         | 536.7         |
| Hit Rate                   | 17 | .99  | .015 | .95           | 1.00          |
| False Alarm Rate           | 17 | .02  | .023 | .00           | .09           |
Table 29  (Cont'd)

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Descriptive Statistics on all
Variables by Age --
11 Year Olds

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Descriptive Statistics on all  
Variables by Age --  
12 Year Olds

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Conventional Numeral Condition

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</table>

Degraded Stimulus Condition

<table>
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<tr>
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<th>52.02</th>
<th>364.0</th>
<th>570.7</th>
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<tr>
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<td>.114</td>
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Hits Feedback Condition

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<td>.88</td>
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Table 31 (Cont'd)

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<tr>
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Table 32
Descriptive Statistics on all Variables by Age -- 13 Year Olds

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<td>17.03</td>
<td>37.0</td>
<td>99.0</td>
</tr>
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CPT Variables:

Conventional Numeral Condition

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Degraded Stimulus Condition

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<th>SD</th>
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<th>Maximum Value</th>
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<td>510.3</td>
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Hits Feedback Condition

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Table 32 (Cont'd)

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<th>Value</th>
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Table 33
Descriptive Statistics on all
Variables by Age --
14 Year Olds

<table>
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<th>Variable</th>
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<th>Maximum Value</th>
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<td>80.0</td>
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<td>113.9</td>
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<tr>
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<td>84.58</td>
<td>266.3</td>
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</tr>
<tr>
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<td>80.2</td>
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<td>534.7</td>
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<td>.99</td>
<td>.007</td>
<td>.98</td>
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<td>.00</td>
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</table>
Table 33 (Cont'd)

<table>
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<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Reversal Condition</td>
<td></td>
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<td>RT</td>
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<td>618.7</td>
</tr>
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<td>.97</td>
<td>.051</td>
<td>.81</td>
<td>1.00</td>
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</table>
APPENDIX E

TABLE OF CPT MEANS AND STANDARD DEVIATIONS FOR BOYS, GIRLS, AND TOTAL GROUP
Table 34

Age Differences on the Four Continuous Performance Test (CPT) Conditions: Means and Standard Deviations for Boys, Girls, and Total Group

**Conventional Numeral CPT: Reaction Time**

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Total Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{X}$</td>
<td>$\bar{X}$</td>
<td>$\bar{X}$</td>
</tr>
<tr>
<td></td>
<td>$\pm$ SD</td>
<td>$\pm$ SD</td>
<td>$\pm$ SD</td>
</tr>
<tr>
<td>6</td>
<td>507.9 ± 77.77</td>
<td>541.2 ± 46.43</td>
<td>524.6 ± 63.50</td>
</tr>
<tr>
<td>7</td>
<td>483.9 ± 56.68</td>
<td>484.8 ± 73.56</td>
<td>484.4 ± 64.08</td>
</tr>
<tr>
<td>8</td>
<td>425.2 ± 46.60</td>
<td>469.9 ± 44.78</td>
<td>453.1 ± 49.64</td>
</tr>
<tr>
<td>9</td>
<td>413.3 ± 54.13</td>
<td>413.5 ± 50.66</td>
<td>413.4 ± 51.54</td>
</tr>
<tr>
<td>10</td>
<td>430.2 ± 69.86</td>
<td>392.5 ± 42.36</td>
<td>410.2 ± 58.39</td>
</tr>
<tr>
<td>11</td>
<td>364.9 ± 51.55</td>
<td>377.2 ± 51.79</td>
<td>369.7 ± 50.48</td>
</tr>
<tr>
<td>12</td>
<td>398.5 ± 57.62</td>
<td>378.7 ± 65.24</td>
<td>383.9 ± 62.38</td>
</tr>
<tr>
<td>13</td>
<td>361.0 ± 57.80</td>
<td>362.5 ± 26.56</td>
<td>361.5 ± 48.68</td>
</tr>
<tr>
<td>14</td>
<td>407.8 ± 90.05</td>
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<td>369.2 ± 84.58</td>
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</table>

**Conventional Numeral CPT: Hit Rate**

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Total Group</th>
</tr>
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<td>$\bar{X}$</td>
<td>$\bar{X}$</td>
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<td>$\pm$ SD</td>
<td>$\pm$ SD</td>
<td>$\pm$ SD</td>
</tr>
<tr>
<td>6</td>
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<td>0.92 ± .064</td>
<td>0.94 ± .050</td>
</tr>
<tr>
<td>7</td>
<td>0.93 ± .046</td>
<td>0.93 ± .092</td>
<td>0.93 ± .071</td>
</tr>
<tr>
<td>8</td>
<td>0.96 ± .036</td>
<td>0.97 ± .033</td>
<td>0.97 ± .034</td>
</tr>
<tr>
<td>9</td>
<td>0.99 ± .018</td>
<td>0.99 ± .015</td>
<td>0.99 ± .016</td>
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<tr>
<td>10</td>
<td>0.98 ± .052</td>
<td>0.99 ± .012</td>
<td>0.99 ± .036</td>
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<tr>
<td>11</td>
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<td>1.00 ± .006</td>
<td>0.99 ± .020</td>
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<td>0.99 ± .011</td>
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<tr>
<td>13</td>
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<td>1.00 ± .006</td>
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<tr>
<td>14</td>
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**Conventional Numeral CPT: False Alarm Rate**

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<td>$\bar{X}$</td>
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<td>$\pm$ SD</td>
</tr>
<tr>
<td>6</td>
<td>0.01 ± .003</td>
<td>0.01 ± .008</td>
<td>0.01 ± .006</td>
</tr>
<tr>
<td>7</td>
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<td>0.02 ± .014</td>
<td>0.02 ± .013</td>
</tr>
<tr>
<td>8</td>
<td>0.04 ± .024</td>
<td>0.01 ± .010</td>
<td>0.02 ± .020</td>
</tr>
<tr>
<td>9</td>
<td>0.02 ± .011</td>
<td>0.01 ± .012</td>
<td>0.01 ± .011</td>
</tr>
<tr>
<td>10</td>
<td>0.01 ± .016</td>
<td>0.01 ± .008</td>
<td>0.01 ± .012</td>
</tr>
<tr>
<td>11</td>
<td>0.02 ± .008</td>
<td>0.01 ± .006</td>
<td>0.01 ± .009</td>
</tr>
<tr>
<td>12</td>
<td>0.00 ± .000</td>
<td>0.00 ± .003</td>
<td>0.00 ± .003</td>
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<tr>
<td>13</td>
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<td>0.00 ± .005</td>
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</table>
Table 34 (Cont'd)

Degraded Stimulus CPT: Reaction Time

<table>
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<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Total Group</th>
</tr>
</thead>
<tbody>
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<td>$\bar{X} \pm SD$</td>
<td>$\bar{X} \pm SD$</td>
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<td>$595.0 \pm 48.66$</td>
</tr>
<tr>
<td>7</td>
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<td>$559.6 \pm 55.14$</td>
</tr>
<tr>
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<td>$531.5 \pm 57.39$</td>
</tr>
<tr>
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<td>$448.4 \pm 59.35$</td>
<td>$448.4 \pm 61.88$</td>
</tr>
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<td>$467.6 \pm 50.43$</td>
<td>$475.3 \pm 62.44$</td>
</tr>
<tr>
<td>11</td>
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<td>$461.8 \pm 36.11$</td>
<td>$444.7 \pm 42.54$</td>
</tr>
<tr>
<td>12</td>
<td>$449.9 \pm 83.94$</td>
<td>$442.4 \pm 39.53$</td>
<td>$444.3 \pm 52.02$</td>
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<tr>
<td>13</td>
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<td>$443.9 \pm 37.05$</td>
<td>$413.3 \pm 52.74$</td>
</tr>
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<td>$459.3 \pm 103.34$</td>
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</table>

Degraded Stimulus CPT: Hit Rate

<table>
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<th>Total Group</th>
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<td>$\bar{X} \pm SD$</td>
<td>$\bar{X} \pm SD$</td>
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<td>$0.95 \pm .042$</td>
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<tr>
<td>12</td>
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<td>$0.94 \pm .114$</td>
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<tr>
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<td>$0.99 \pm .009$</td>
<td>$0.96 \pm .056$</td>
<td>$0.98 \pm .035$</td>
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<tr>
<td>14</td>
<td>$0.94 \pm .076$</td>
<td>$0.98 \pm .052$</td>
<td>$0.96 \pm .065$</td>
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</tbody>
</table>

Degraded Stimulus CPT: False Alarm Rate

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Total Group</th>
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</thead>
<tbody>
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<td>$\bar{X} \pm SD$</td>
<td>$\bar{X} \pm SD$</td>
<td>$\bar{X} \pm SD$</td>
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<td>6</td>
<td>$0.03 \pm .022$</td>
<td>$0.07 \pm .052$</td>
<td>$0.05 \pm .046$</td>
</tr>
<tr>
<td>7</td>
<td>$0.02 \pm .021$</td>
<td>$0.05 \pm .058$</td>
<td>$0.04 \pm .046$</td>
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<td>$0.06 \pm .076$</td>
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<td>$0.04 \pm .053$</td>
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<tr>
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<td>$0.02 \pm .017$</td>
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<tr>
<td>13</td>
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<td>$0.01 \pm .032$</td>
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<tr>
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<td>$0.02 \pm .040$</td>
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</tr>
<tr>
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<td>-------</td>
<td>------</td>
<td>-------------</td>
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<tr>
<td>Hits Feedback CPT: Rise Rate</td>
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<td>0-90°</td>
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<td>1.00</td>
<td>0.50</td>
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<td>91-110°</td>
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<td>1.00</td>
<td>1.00</td>
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<tr>
<td>111-202°</td>
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<td>1.00</td>
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<tr>
<td>203-313°</td>
<td>0.50</td>
<td>0.50</td>
<td>1.00</td>
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<tr>
<td>314-415°</td>
<td>0.50</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td>416-517°</td>
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<tr>
<td>518-619°</td>
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<tr>
<td>620°</td>
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<td>0.50</td>
<td>1.00</td>
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</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Girls</th>
<th>Boys</th>
<th>Total Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits Feedback CPT: Hit Rate</td>
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<tr>
<td>10-20°</td>
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<tr>
<td>21-40°</td>
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<td>390.0</td>
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<tr>
<td>41-60°</td>
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<td>61-80°</td>
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<tr>
<td>81-100°</td>
<td>415.3</td>
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<tr>
<td>101-120°</td>
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<td>425.6</td>
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<tr>
<td>121-140°</td>
<td>435.9</td>
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</tr>
<tr>
<td>141-160°</td>
<td>446.2</td>
<td>446.2</td>
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<tr>
<td>161-180°</td>
<td>456.5</td>
<td>456.5</td>
<td>456.5</td>
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<tr>
<td>181-200°</td>
<td>466.8</td>
<td>466.8</td>
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Table 4 (cont'd)
Table 34 (Cont'd)

Response Reversal CPT: Reaction Time

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Total Group</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(\bar{X} \pm SD)</td>
<td>(\bar{X} \pm SD)</td>
<td>(\bar{X} \pm SD)</td>
</tr>
<tr>
<td>6</td>
<td>471.1 ± 59.55</td>
<td>498.9 ± 35.15</td>
<td>485.0 ± 48.83</td>
</tr>
<tr>
<td>7</td>
<td>458.6 ± 56.78</td>
<td>456.1 ± 28.10</td>
<td>457.4 ± 43.74</td>
</tr>
<tr>
<td>8</td>
<td>426.9 ± 86.29</td>
<td>446.0 ± 49.85</td>
<td>438.8 ± 64.75</td>
</tr>
<tr>
<td>9</td>
<td>393.4 ± 58.93</td>
<td>377.9 ± 48.68</td>
<td>385.9 ± 53.84</td>
</tr>
<tr>
<td>10</td>
<td>371.2 ± 50.82</td>
<td>403.5 ± 60.05</td>
<td>388.3 ± 56.65</td>
</tr>
<tr>
<td>11</td>
<td>355.5 ± 51.13</td>
<td>381.6 ± 41.53</td>
<td>365.6 ± 48.14</td>
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<tr>
<td>12</td>
<td>374.7 ± 65.19</td>
<td>386.4 ± 54.36</td>
<td>383.4 ± 55.74</td>
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<tr>
<td>13</td>
<td>409.8 ± 83.03</td>
<td>362.2 ± 79.32</td>
<td>394.0 ± 82.73</td>
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<tr>
<td>14</td>
<td>416.1 ± 98.45</td>
<td>396.8 ± 108.12</td>
<td>406.5 ± 100.39</td>
</tr>
</tbody>
</table>

Response Reversal CPT: Hit Rate

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Total Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\bar{X} \pm SD)</td>
<td>(\bar{X} \pm SD)</td>
<td>(\bar{X} \pm SD)</td>
</tr>
<tr>
<td>6</td>
<td>0.87 ± 0.108</td>
<td>0.79 ± 0.126</td>
<td>0.83 ± 0.119</td>
</tr>
<tr>
<td>7</td>
<td>0.87 ± 0.110</td>
<td>0.89 ± 0.049</td>
<td>0.88 ± 0.084</td>
</tr>
<tr>
<td>8</td>
<td>0.91 ± 0.118</td>
<td>0.92 ± 0.056</td>
<td>0.92 ± 0.082</td>
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<tr>
<td>9</td>
<td>0.97 ± 0.041</td>
<td>0.96 ± 0.037</td>
<td>0.97 ± 0.038</td>
</tr>
<tr>
<td>10</td>
<td>0.98 ± 0.015</td>
<td>0.96 ± 0.036</td>
<td>0.97 ± 0.030</td>
</tr>
<tr>
<td>11</td>
<td>0.98 ± 0.045</td>
<td>0.98 ± 0.029</td>
<td>0.98 ± 0.038</td>
</tr>
<tr>
<td>12</td>
<td>0.99 ± 0.014</td>
<td>0.98 ± 0.018</td>
<td>0.98 ± 0.017</td>
</tr>
<tr>
<td>13</td>
<td>0.97 ± 0.039</td>
<td>0.98 ± 0.061</td>
<td>0.97 ± 0.046</td>
</tr>
<tr>
<td>14</td>
<td>0.96 ± 0.063</td>
<td>0.98 ± 0.039</td>
<td>0.97 ± 0.051</td>
</tr>
</tbody>
</table>

Response Reversal CPT: False Alarm Rate

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
<th>Total Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\bar{X} \pm SD)</td>
<td>(\bar{X} \pm SD)</td>
<td>(\bar{X} \pm SD)</td>
</tr>
<tr>
<td>6</td>
<td>0.36 ± 0.100</td>
<td>0.28 ± 0.136</td>
<td>0.32 ± 0.120</td>
</tr>
<tr>
<td>7</td>
<td>0.32 ± 0.130</td>
<td>0.31 ± 0.136</td>
<td>0.31 ± 0.130</td>
</tr>
<tr>
<td>8</td>
<td>0.40 ± 0.130</td>
<td>0.26 ± 0.095</td>
<td>0.31 ± 0.126</td>
</tr>
<tr>
<td>9</td>
<td>0.32 ± 0.186</td>
<td>0.33 ± 0.111</td>
<td>0.33 ± 0.152</td>
</tr>
<tr>
<td>10</td>
<td>0.38 ± 0.227</td>
<td>0.21 ± 0.090</td>
<td>0.29 ± 0.183</td>
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<td>11</td>
<td>0.28 ± 0.106</td>
<td>0.18 ± 0.116</td>
<td>0.24 ± 0.118</td>
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<tr>
<td>12</td>
<td>0.16 ± 0.079</td>
<td>0.20 ± 0.120</td>
<td>0.19 ± 0.110</td>
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<tr>
<td>13</td>
<td>0.11 ± 0.085</td>
<td>0.18 ± 0.159</td>
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<tr>
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<td>0.18 ± 0.179</td>
<td>0.13 ± 0.142</td>
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</table>
REFERENCES


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