

**Continuous Processing Task (CPT) Performance in Children with  
Attention Deficit Disorder with and without Hyperactivity:  
Effects of Rate and Control of Pacing**

by  
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(ABSTRACT)

This study investigated the effects of task pacing on the cognitive performance of ADD/WO (n=8), ADD/H (n=10), and normal control (n=12) children on a continuous processing task (CPT). In the CPT, each child was exposed to fast (500ms), medium (1000ms), slow (2000ms), and self-paced conditions. Performance was measured as number of omission errors, number of commission errors, number of specific types of commission errors, reaction time, and rate of self-pacing. The ADD/H group had a significantly slower mean RT than the normal control group. However, groups did not differ on omission or commission errors, and there were no group by pacing condition or group by (non-target) sequence interactions. Reasons for the appearance of group differences on mean RT without group differences on accuracy are discussed in terms of subject and task characteristics.

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## Introduction

Childhood hyperactivity has been identified and studied under a variety of labels for decades. As a result, a vast literature exists describing these children's behavior/ performance on a multitude of tasks and responses to various treatments. In brief, research has found that the behavior and performance of these children differs from that of normal children across a variety of contexts and task parameters. Recognizing that attention deficits may play a crucial role in contributing to the problems of hyperactive children, researchers have shifted their emphasis away from hyperactivity and towards inattention. In the third edition of the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-III; APA, 1980), Attention Deficit Disorder (ADD) with Hyperactivity (ADD/H) replaced the previous DSM-II category of Hyperkinetic Reaction of childhood. Criteria for this new category required that a child display at least three developmentally inappropriate inattention symptoms, three impulsivity symptoms, and two hyperactivity symptoms. In addition to hyperactivity and problems of attention and impulsivity, these children frequently have various associated problems that are not required in the diagnostic criteria. Such problems may include poor academic performance, conduct disorders and peer relationship problems. The change in emphasis away from hyperactivity resulted in recognizing an additional population of children who have attentional problems in the absence of motor excess.

A diagnosis of ADD without Hyperactivity (ADD/WO) requires the presence of inattention and impulsivity in the absence of excessive motor activity.

In 1987 the DSM-III-R committee on childhood disorders reconceptualized and relabeled the ADD diagnostic category again. According to Barkley, Costello, and Spitzer (1988), the committee first decided to change the name of the disorder to Attention Deficit- Hyperactivity Disorder (ADHD), in order to, ". . . elevate the symptom of hyperactivity from that of a trailing clause to near equal status with the attentional deficits (p. 5)." The DSM- III-R committee also made a major diagnostic change by converting the ADHD category into an unidimensional category. Prior to the change, children diagnosed with ADD were required to exhibit particular symptoms or a combination of symptoms from each of three categories of behaviors: inattention, impulsivity, and hyperactivity. However, within the new framework, ADHD symptoms were combined into a single category of "maladaptive behavior." For example, in order to be classified as ADHD under the new definition, a child must demonstrate 8 symptoms out of a total of 14, regardless of how the symptoms might be categorized. This unidimensional category contrasts sharply with the DSM-III description which required that a child show symptoms in *each* of the three domains. In addition, it was decided that there was not enough empirical evidence to justify the categorization of ADD children based on the presence or absence of hyperactivity. While the committee reportedly recognized that children with attention problems but without hyperactivity are identified in clinical and research settings, it was argued that the identification of ADD/WO children does not necessarily suggest differences in etiology, developmental course, prognosis, or response to treatment. However, at the last minute, a decision was made to introduce a residual category, Undifferentiated ADD (UADD) to include, "Some of the disturbances that in the DSM-III would have been categorized as Attention Deficit Disorder without Hyperactivity . . . (DSM-III, 1987; p. 95)." The inclusion of UADD in the DSM-III-R encourages further research and diagnosis of children with attention deficits without hyperactivity. It also highlights a question that has far reaching implications for ADD research, namely: Does the presence or absence of hyperactivity represent a meaningful way to subtype children with attention problems? (The DSM-III terminology will be

employed throughout this review since most of the research cited and the current study employed DSM-III and not DSM-III-R criteria.)

In an attempt to clarify and provide concurrent validity to definitions of ADD, Lahey et al. (1988) performed a factor analysis of teacher ratings of (a) DSM-III ADD symptoms, (b) DSM-III-R ADHD symptoms, and (c) a broader list of ADD symptoms, using both nonreferred and clinic-referred children. Three factors emerged from the factor analysis: (a) motor hyperactivity-impulsivity, (b) inattention disorganization, and (c) sluggish tempo. Moreover, the cluster analysis resulted in three groups of children; the first group received high ratings on motor hyperactivity-impulsivity and inattention- disorganization, but low ratings on sluggish tempo. The second group received low ratings on motor hyperactivity-impulsivity, but high ratings on inattention disorganization and sluggish tempo. The final group received low ratings on all three factors. Moreover, these three clusters were found to have a strong association with the DSM-III, and not the DSM-III-R, clinical diagnoses. Taken together, the findings of the Lahey et al. (1988) study suggest that: (a) ADD groups are best categorized by separate factors that resemble the DSM-III's ADD/H and ADD/WO categories, (b) items intended to reflect the DSM impulsivity dimension load on hyperactivity, and (c) children diagnosed as ADD/WO did not load on the factor that reflected impulsivity (motor hyperactivity-impulsivity factor).

In addition to Lahey et al. (1988), several other studies have provided information that contributes to the concurrent validity of ADD subgroup diagnoses. Researchers comparing ADD/WO and ADD/H children on a variety of measures have found reliable differences in accompanying behavior problems, peer relationship problems, and behavioral ratings of cognitive processes (e.g. impulsivity). Somewhat surprisingly, less pronounced differences have been found using more objective measures of cognitive functioning. Considering the small number of studies that have employed behavioral indices of cognitive differences, the modest findings warrant further investigation. The proposed study will attempt to further explore possible differences in cognitive performance between the ADD subgroups.

The following discussion will be divided into four sections. The first section will review studies that compared the subgroups with respect to behavioral and social functioning. It will illustrate that

children in the ADD subgroups do in fact have different characteristics thereby increasing the desirability of subcategorization. The second section will review studies that employed subjective or relatively objective behavioral measures of cognitive performance in the ADD subgroups. The continuous processing tasks will be excluded from this section although it is a (behavioral) measure of cognitive performance. Since this task was employed in the proposed study, an entire section of this review is devoted to it. The third and fourth sections will review studies that employed methodologies relevant to the methodology of the proposed study. More specifically, the third section will review the effects of self-pacing and presentation rate on task performance, and the fourth section will review continuous processing task (CPT) studies.

## *Behavioral and Social Functioning of ADD Subgroups*

Soon after the DSM-III was published, Maurer and Stewart (1980) performed a study to determine whether ADD/WO is an independent syndrome. A retrospective examination of records from a children's psychiatric clinic provided the data for this study. Children were considered to have attention problems if they had a history of problems with short attention span and difficulty finishing school work or projects. The investigators did not require impulsivity symptoms nor did they exclude children who had subnormal IQs (between 55-80). Children were considered ADD/WO if they were rated as anything other than "much more active than average (p.233)." The investigators examined data from parent structured interviews and chart ratings. They found that roughly three-fifths of the children with attentional deficit in the absence of hyperactivity had unsocialized conduct disorder, and one-fifth had other identifiable psychiatric disorders. The remaining fifth fell into two overlapping groups: one characterized by learning disabilities, the other by lack of motivation. Since children who qualified for ADD/WO often qualified for other disorders, the authors concluded that ADD/WO is not an independent syndrome. However, such a conclusion may not be warranted since co-morbidity does not preclude the existence of a syndrome. A

case in point is ADD/H, a syndrome that substantially overlaps with conduct disorder and learning disabilities. Furthermore, doubt is cast on the authors' findings since the data was obtained from retrospective diagnoses and since lenient criteria were used for ADD diagnosis. (e.g. children were placed in the ADD/WO group if they were rated as less than "much more active than average.").

Many later studies that compared the behavior of ADD groups reported data that suggested that ADD/H and ADD/WO may in fact be distinct subgroups as indicated by different accompanying behavior and social characteristics. For example, most studies suggest that the two subgroups show different patterns of unpopularity, though findings are somewhat discrepant. Lahey, Schaughency, Strauss, and Frame (1984) found ADD/H children were less likely than ADD/WO children to be nominated "most liked" by their same sex peers. However, when rated by the class as a whole on this measure, the two groups did not differ reliably. Carlson, Lahey, Frame, Walker, and Hynd (1987) and Lahey et al. (1984) found that ADD/H groups were more likely to be nominated as "least liked" than were ADD/WO groups. When children with co-diagnoses were included in the analysis, ADD/H children received lower "socially preferable" (Liked Most - Liked Least) scores and were perceived by their peers as fighting more than did ADD/WO children (Carlson et al., 1987; Lahey et al., 1984). Finally, King and Young (1982), found no reliable sociometric differences between the ADD groups nor did there appear to be a trend suggesting consistent differences between them.

While the previously mentioned studies seemed to indicate that ADD/H children tended to be more unpopular than ADD/WO children, these studies also suggest that ADD/WO children tended to be more unpopular than normal children. Carlson et al. (1987) found that ADD/WO children without other co-diagnoses were less likely than controls to be nominated by their peers as "most liked." In addition, this and other studies (Carlson et al., 1987; King & Young, 1982) found that ADD/WO children received lower "social preference" scores.

Besides showing different patterns of unpopularity, ADD/H and ADD/WO children also seem to differ in the type of accompanying behavioral symptomatology that they exhibit. ADD/H children appear to exhibit more externalizing symptoms, whereas ADD/WO children appear to exhibit more internalizing symptoms. For instance, ADD/H children exhibit aggressive behavior and

conduct disorder more frequently than ADD/WO children (Edelbrock, Costello & Kessler, 1984; King & Young, 1982; Lahey et al., 1984; Lahey, Schaughency, Hynd, Carlson and Nieves, 1987; Pelham, Atkins and Murphy, 1981). Lahey et al. (1987) found that the two groups of ADD did not differ reliably on covert conduct disorder symptoms (e.g., truancy, lying, stealing without confrontation with the victim, running away overnight, vandalism and firesetting), but that ADD/H children engaged in a reliably greater total number of antisocial acts and reliably more overt antisocial acts (e.g., bullying, fighting, cruelty to animals, homicidal acts, and stealing with confrontation with the victim) than did ADD/WO children. These findings are important since the total number of conduct disorder symptoms and the presence of overt conduct disorder symptoms have been shown to predict long-term antisocial outcome (Lahey et al., 1987). While ADD/H children are more likely to exhibit externalizing symptoms, ADD/WO children are reliably more likely to exhibit anxiety, withdrawal, depression and other internalizing symptoms and/or codiagnosed disorders (Lahey et al., 1984; Lahey et al., 1987; Edelbrock et al., 1984). In sum, ADD/H and ADD/WO children seem to display different patterns of disrupted peer relationships and different types of accompanying behavior problems. These differences are potentially suggestive of differences in prognosis.

## *Cognitive Styles of ADD Subgroups*

A number of studies have focused on the cognitive styles of ADD children. These studies may be categorized as using either subjective ratings (e.g. teacher ratings of cognitive style) or behavioral indices (e.g. reaction time tests, the Stroop, Draw-a-Line-Fast, Matching Familiar Figures Test, CPT) of cognitive performance.

## Subjective Ratings of Cognitive Processing

Most research suggests that both ADD subgroups have academic problems. However, the nature of the academic problems may differ between the two subgroups. Teachers rate children in both subgroups as more likely than other children to have academic difficulty (Edelbrock et al., 1984; King & Young, 1982). ADD/WO children had lower perceptions of their academic achievement than did ADD/H children, who in turn had lower perceptions of their academic status than did normal children (Lahey et al., 1984). Edelbrock et al. (1984) found that the ADD/WO children's perceptions appear to be accurate. They were much more likely to have had to repeat a grade than were ADD/H or normal children. Edelbrock et al. (1984) did not report IQ scores, and although IQ may have contributed to their finding, most studies have not shown reliable IQ differences between ADD and normal children (King & Young, 1982; Hynd et al., 1988) or between the subtypes of ADD (Conte, Kinsbourne, Swanson, Zirk & Samuels, 1986; King & Young 1982; Hynd et al., 1988). King and Young (1982) did not find a difference between the ADD groups in academic performance as indicated by the children's report cards.

In addition to differing in academic problems, the ADD subgroups differ on ratings of attitudes and approaches to academic activities. Teacher ratings suggest that ADD/H children tend to be more irresponsible, distractible, sloppy, impulsive and more likely to answer without thinking than are ADD/WO children (Lahey et al., 1985). ADD/WO children were rated by teachers as being more sluggish and slow (Lahey et al., 1985) and less happy (Edelbrock et al., 1984) than were ADD/H and control children.

In comparing the cognitive styles of the ADD subgroups, researchers have begun to explore impulsivity as a possible cognitive dimension that differentiates the subgroups. ADD/H children have often been found to display impulsivity. They have difficulty on tasks that require delay of gratification (Rapport, Tucker, DuPaul, Merlo & Stoner, 1986), resistance to temptation (Sears, Rau & Alpert, 1965) social judgment (Milich & Landau, 1982; Dodge & Newman, 1981; Pelham & Bender, 1982), motor inhibition (Gordon, 1979), and cognitive reflection (Carlson & Alvarez,

1988). Furthermore, they are rated by their teachers as being impulsive (Lahey et al., 1984; Lahey et al., 1985; Lahey et al., 1987; Lahey et al., 1988; Berry, Shaywitz & Shaywitz, 1985).

Although a diagnosis of ADD/WO also requires impulsivity symptoms, research findings are equivocal about whether ADD/WO children are impulsive. Clearly, some studies that identified ADD/WO children did not uniformly require impulsivity as a criterion for group inclusion (King & Young, 1982). Other studies employed assessment instruments that did not differentiate between impulsivity and other factors. For example, the Attention Problem-Immaturity Factor of the Revised Behavior Problem Checklist (Quay & Peterson, 1983) reflects inattention and impulsivity. Thus, the factor score provides no information regarding the relative contributions that impulsivity and inattention made to high scores. In addition, studies that have used behavioral ratings of impulsivity as dependent measures found that ADD/WO children were not more impulsive than normal children (Lahey et al., 1985; Lahey et al., 1988).

## **Behavioral Indices of Cognitive Processing**

Behavioral indices of cognitive processing have thus far only demonstrate modest differences between the ADD subgroups in cognitive styles. Carlson, Lahey and Neeper (1986) tested ADD/H and ADD/WO children on a large battery of neurocognitive tests, including the Stroop Tasks, matching tasks, the rapid naming task, visual match-to-sample task, clinical evaluation of language function test, developmental test of visual-motor integration test, Detroit visual attention test, and basic achievement skills individual screener, on school-identified ADD/H and ADD/WO children. When it was appropriate to do so, the investigators covaried age or IQ. They found that the full scale IQ of the ADD/WO group was reliably lower than the ADD/H and control groups, which did not differ from each other. They also found that the ADD/WO group had a lower Verbal IQ but not Performance IQ than did the ADD/H group; Verbal and Performance IQ scores were not available for the control children. In none of the tasks did the performance of the subgroups reliably differ from each other, though on some tasks both subgroups differed from controls. On se-



veral tasks, both ADD groups were reliably slower than the control group but again not reliably different from each other.

Hynd et al. (1988) also behaviorally measured the cognitive functioning of clinic-referred ADD/H, ADD/WO, and clinic control children. Their study included a simple reaction time task and three speeded classifications tasks. They found that groups of children did not differ on errors. In contrast, reaction times did differentiate ADD/H and normal children on a few tasks. Specifically, ADD/H subjects with co-diagnoses performed more slowly than did clinical control subjects on the most difficult of the speeded classification task, the letter string match task. In this task, the child was asked to determine whether various pairs of trigrams were the "same" or "different." The average reaction time of the ADD/WO group was not reliably different from the ADD/H and clinical control groups but fell non-reliably between those of the other groups. Tasks requiring a relatively large cognitive load may be more likely to differentiate groups, though in this study, Hynd et al. (1988) were only able to find modest (non-reliable) differences between ADD/H and ADD/WO groups.

Carlson & Alvarez (1988), compared the cognitive processing of ADD/WO, ADD/H, and normal children by measuring cognitive styles. Carlson and Alvarez (1988) required children to complete a test battery that consisted of: (a) the Draw-a- Line-Fast Task, a task that requires the subject to trace a line inside the borders of a double-border star and has been shown to be one of the best measures of a general impulsive response style (Milich & Kramer, 1984); and (b) the Matching Familiar Figures Test, a task that requires the child to choose from six subtly different stimuli the one that is identical to a specified exemplar. The dependent measures in this task were the time to the first response to each stimulus and the total number of errors. The Matching Familiar Figures Test has been the most widely utilized measure of impulsivity.

The Draw-a- Line-Fast Task was completed under two levels of reward and three levels of difficulty. In half of the trials, children were told that they would receive tokens (later exchangeable for small toys) for both speed and accuracy. Therefore, the total number of tokens earned (or, for non-reward conditions, tokens that would have been earned) is an indication of the overall effi-

ciency of the children's strategy. In addition, three levels of difficulty were included by varying the distance of the borders of the star.

Results indicated that time did not differentiate among groups in any of the conditions. On the other hand, in the medium and difficult conditions, the ADD/H children made reliably more errors than did the normal control children, and the ADD/WO group's error score fell between those of the ADD/H and normal control's but did not differ reliably from either. With respect to the total number of tokens earned, in the easy condition, there were no differences in any scores. However, differences began to emerge as the task difficulty increased. Compared to controls, ADD/H children received reliably lower token scores in the medium conditions. Compared to controls, the ADD/WO children received reliably lower scores in both medium and hard conditions. For the ADD/H group, the low token scores resulted from more errors than normal controls. Whereas, for the ADD/WO group, the low token scores resulted from a (non-reliable) tendency to both respond more slowly and make more errors than controls.

On the Matching Familiar Figures Task, the ADD/H children responded more quickly and made more errors than did the normal controls, indicating that the ADD/H children employed a more impulsive cognitive strategy. The ADD/WO group did not differ reliably from the other groups with respect to Matching Familiar Figures Task-Time Score, but they made reliably more errors than the normal control group. Thus, the two ADD groups displayed somewhat different cognitive strategies on the Matching Familiar Figures Task.

In conclusion, ADD children's cognitive strategies on the Matching Familiar Figures Task and the Draw-a-Line-Fast Task seem inferior to those of control children. The ADD subgroups also differ slightly in the strategies that they used in these tasks.

A fourth study, Conte et al. (1986) studies the effect of presentation rate on the performance of ADD/H, and ADD/WO children on a paired associate learning task. Children were obtained through schools. They were presented with stimuli under three list conditions. In the first, all items were presented for six seconds (fixed fast list). In the second, all items were presented for 12 seconds (fixed slow list), and in the third, half of the items were presented for 6 seconds and half for 12 seconds (mixed list). Results indicated that the normal children benefited from the slow rate re-

ardless of whether the list was fixed or mixed. In contrast, both ADD groups benefited from the slow rate only in the mixed list. For the ADD/WO children the interaction was reliable, whereas for the ADD/H children it was only suggestive. In conclusion, both groups of ADD children seemed to be more sensitive to contextual feature of the task, such as average event rate or predictability of the next event, than were the normal control children. ADD/H and ADD/WO children appeared to have similar patterns of responding under these experimental conditions.

In sum, the four previous studies only found modest differences between the ADD subgroups on tasks designed to obtain objective behavioral measures of cognitive processing. Cognitive differences between the groups may not exist. However, it is possible that these studies failed to detect more profound differences due to weak statistical power, non-clinical ADD populations and/or use of tasks that may not have been sensitive to differences.

In contrast to the previous studies, Sergeant and Scholten (1985) reported more pronounced differences between two groups of children who appeared to be ADD/H and ADD/WO. The children were classified as overactive-and-distractible (ADD/H), distractible-and-normoactive (ADD/WO), or normal on the basis of teacher ratings and observer ratings of classroom behavior. The investigators used a speeded classification task in which children were required to determine whether a target letter was present by pressing a "yes" or "no" button. Display load and instructional set were varied. The display load consisted of two, three or four letters presented simultaneously, and the instructions emphasized either speed, accuracy or normal responses. Results indicated that accuracy across instruction conditions did not differentiate the groups. However, groups did significantly differ on reaction time across the different sets of instructions. The ADD/H group were slower overall than were the other groups. In the normal instructions condition, groups did not differ on reaction time with respect to display load. In the speed instructional set, normal and ADD/WO groups but not the ADD/H group were able to decrease their reaction time and trade speed for accuracy. In the accuracy instructional set, ADD/H and ADD/WO children had very slow reaction times and did not adjust their speed to changing load. The normal children, however, performed relatively fast with small load and slowed down as load increased. Finally, Sergeant and Scholten (1985) found that the performance of normal and ADD/WO and, to a lesser

extent, ADD/H children, could be predicted by a Fast-Guess Model. That is, normal and ADD/WO children were more likely to make errors the faster they responded, whereas the speed of responding was less predictive of accuracy in the ADD/H children, whose errors were related to both fast and slow latencies. The finding that ADD/H children's reaction times are slower during some tasks than control children's corroborates the Hynd et al. (1988) finding. Sergeant and Scholten (1985) conclude that ADD/H children's, "cognitive (energy) reserves required to rapidly deploy processing seem limited . . . (p. 107)," and that they therefore have deficits in cognitive resource allocation. It should be noted that many of the studies that compared the subgroups on behavioral indices of cognitive performance (Sergeant & Scholten, 1985; Conte et al., 1986; Carlson & Alvarez, 1988) had small sizes, thus their results should be viewed with caution.

To summarize the studies on cognitive functioning in ADD/H and ADD/WO children, the behavioral ratings of the ADD subtypes suggest different cognitive styles. ADD/H children may show an impulsive style and ADD/WO children may show a slow, sluggish style. Two studies (Carlson et al., 1986; Hynd et al., 1988) that utilized a global test battery to measure cognitive performance found few differences between the ADD subgroups. Similarly, Conte et al. (1986) compared the subgroups' performance on a learning task in which the stimulus presentation rate occurred at a fast fixed, a slow fixed, or a mixed rate found similar patterns of responding in the ADD subgroups. In contrast, one study Sergeant & Scholten (1985) found that ADD/H and ADD/WO children exhibited somewhat different patterns of performance. Under some instructional sets, ADD/WO children were more able to trade speed for accuracy than ADD/H children. Moreover, they found that ADD/H children's reaction times were significantly slower than those of the ADD/WO children.

## *Self- Vs. Experimenter-Pacing and Presentation Rate*

In self- pacing experiments, the subject controls when each stimulus will be display. This paradigm provides an opportunity to study the effect of control of pacing on ADD/H children's performance. Broadbent (1952) studied the effects of self- versus experimenter pacing on normal adults during a vigilance task (a five-choice serial reaction task). Performance was compared within groups over six ten-minute time blocks. In the experimenter-paced condition, the number of errors increased between the first and second blocks and remained at the elevated level thereafter. However, the number of errors in the self- paced group did not reliably increase until the sixth block. In the self-paced group during the later blocks of the task, the number of short pauses in responding (2+ seconds) increased. Subjects in the self-paced group worked faster at other times to make up for lost time during the pauses. The author suggested that these pauses may reflect inattention. Furthermore, as a result of not being forced to respond to stimuli during these brief lapses of attention, the performance of the self-paced subjects did not suffer. If self-pacing allows ADD children to similarly benefit from the opportunity to pause during lapses of attention, it seems possible that their performance would be enhanced during self-paced tasks.

Dickman and Meyer (1988) used a self-pacing procedure to study how normal people with various levels of impulsivity differed in their tendency to trade speed for accuracy. They divided their sample of normal undergraduate students on the basis of a self-report measure of impulsivity (Craig, Humphreys, Rocklin, & Revelle, 1979). In the first experiment, subjects were to compare, at a self-paced rate, pairs of complex geometric figures and to determine whether the pairs were the same or different under conditions differing in monetary payoff for speed relative to accuracy. Results demonstrated that the low impulsive subjects were reliably more accurate and reliably slower than the medium impulsive subjects, who in turn were reliably more accurate and slower than were the high impulsives. In other words, high impulsives self-paced more rapidly than the other groups and made more errors. Compared to the other two groups, the high impulsives traded accuracy for speed. The second study investigated whether or not the performance differences in the first ex-

periment could be ameliorated by requiring the subjects to spend a fixed amount of time per trial. In this experiment, the same groups and stimuli were used. However, pacing was externally controlled (as opposed to self-paced) at different presentation rates (ranging from 0.5 to 4.0 seconds) and the monetary payoff was constant across trials. Results indicated that the high impulsives obtained a lower percentage correct than the low impulsives on all but the fastest presentation rate, where the high impulsive subjects obtained a higher percentage correct than did the low impulsives. These results suggest that high impulsives may have benefited less from slowing down than did the other groups. Thus, their tendency to show faster response styles may not be detrimental to their performance on cognitive tasks.

The findings in this study and the findings of Sergeant and Scholten (1985) appear to be discordant, since Sergeant and Scholten (1985) found that ADD/H children had slower reaction times than normal subjects across instructional sets. Of course, the two studies differed along many dimensions that may account for the disparate findings. Examples include type of task, type of dependent measures, task requirements, instructional set, reward conditions, and population of subjects. It is not clear how these variables would affect the degree to which subjects trade speed for accuracy. Further investigation of the effect of these variables on ADD children's performance is warranted.

In one of the few studies that examined self-pacing in ADD/H children, Dalby, Kinsbourne and Swanson (in press) studied the effect of self-pacing on paired-associate learning in ADD/H children. The children had been judged by a pediatric neurologist as meeting the DSM-II criteria for hyperactivity and were between 7 and 12 years old. Results indicated that ADD/H children paced themselves at a fast rate. Their performance rate (about 1 stimulus per 5 seconds) was similar to the fast, experimenter-paced rate (1 stimulus per 4 seconds) used in an earlier study by Dalby et al (1977). That study showed that when a fixed number of stimuli were presented, the (experimenter paced) presentation rate did not affect the performance of ADD/H children during placebo trials. In contrast, during methylphenidate trials, ADD/H children did benefit from additional learning time (i.e. slower presentation rates). As a result, it may have been more time-efficient for ADD/H children on placebo to pace themselves at a fast rate. Therefore, the Dalby et al. (in press)

findings suggest that while the self-pacing per se does not seem to improve or impair ADD/H children's performance over experimenter-pacing at a similar rate, ADD/H children appear to choose a rate that is more time-efficient on a paired-associate learning task. The findings of Dalby et al. (1977) and Dalby et al. (in press) seem congruent with those of Dickman and Meyers (1988). Dickman and Meyers showed that high impulsive subjects did not benefit from decreasing the presentation rate as much as low impulsives did. When high impulsive subjects were permitted to control the pacing rate, they chose a fast rate. It is possible that impulsive people (including ADD/H children) may fail to benefit from or benefit less than do others from longer learning and performance times.

## *Continuous Processing Task*

The CPT has traditionally been used as a measure of attention in ADD/H children and other clinical populations. Some CPT dependent measures have been shown to differentiate among clinical populations such as schizophrenic, hyperactive, and learning disabled subjects (O'Dougherty, Neuchterlein & Drew, 1984). Consequently, if the ADD subgroups differ in cognitive abilities, the CPT may be able to differentiating their performance

During the CPT, the subject is required to monitor stimuli and report, as quickly as s/he can, the appearance of a target stimulus or a target sequence. Not only are the target stimuli unpredictable in their time of arrival, but they are also of short duration. Thus, a momentary lapse of attention coincident with the arrival of the target stimulus results in missing the target, an error of omission. In addition, researchers have traditionally thought that if a subject responds to a non-target stimulus or sequence (i.e. makes a commission error), s/he is behaving impulsively.

Sykes, Douglas, Weiss and Minde (1971) were among the first researchers to study ADD/H children's performance on a CPT. The dependent variables were the number of omission and commission errors. Each subject was exposed to stimuli presented at a 1000 ms and a 1500 ms

event rate. Unlike most other CPTs, in the Sykes et al. (1971) study the interstimulus interval was equal to the time the stimuli were projected on the screen, since stimuli were presented contiguously.

Sykes et al. (1971) showed that ADD/H children made reliably more omission errors (i.e. fewer correct responses to target stimuli) than did the control children, suggesting that the normal subjects were more attentive during the task. There was also an interaction between group (ADD/H vs. normal children) and interstimulus interval with respect to the number of responses to non-target stimuli (commission errors). At the 1000 ms rate, the groups did not differ with respect to commission errors. In contrast, the normal controls but not ADD/H children benefited from the longer interstimulus interval; normal children made reliably fewer commission errors at the 1500 ms interstimulus interval rate than did the ADD/H children.

Chee, Logan, Schachar, Lindsay, and Wachsmuth (1989) investigated the effect of event rate on CPT performance in ADD/H children without co-diagnoses, "pathological" control (including an ADD/H with Conduct Disorder co-diagnosis group) children, and a normal control group. They employed 1000, 2000, and 4000ms event-rate conditions and 200, 400, and 800ms display time conditions. Results showed that ADD/H children committed more omission errors than normal and pathological controls at the 1000ms and 4000ms event rates. ADD/H children also committed significantly more commission errors than did normal controls. This difference was constant across event rates. ADD/H children also had slower mean RTs than normal and pathological control groups. Groups differences on errors and RT were constant across display times. Finally, there was a significant event rate effect with slower event rates yielding slower RTs.

The finding that ADD/H children committed more commission errors than controls at a 1000ms event rate appears to be at odds with the Sykes et al. (1971) findings. Possibly, display time was responsible for the difference. By definition, the onset of each new stimulus was the same in both studies for the 1000ms condition. However, in the Sykes et al. (1971) study, stimuli were displayed contiguously, whereas in the Chee et al. (1989) study the stimuli were displayed briefly and followed by an interstimulus interval. The 1000ms condition may have been easier in the Sykes study since the longer display time increases the likelihood that children will see the stimuli. Easy



conditions may be less likely to differentiate ADD/H and control children than difficult ones. Both the Sykes et al. (1971) and Chee et al. (1989) CPT studies found that at a 1000ms or longer event rate, as event rate increases, ADD/H children's performance deteriorated relative to that of controls. This result parallels those of Dalby et al. (1977) and Conte et al. (1986) which employed non-CPT tasks and found that as event rate increased, the discrepancy between control and ADD/H children increased. It is unclear how different event rates would affect ADD/WO children's performance. Their performance might be expected to suffer. In the Conte et al. (1986) study, ADD/WO children did not utilize longer presentation times in the fixed list condition. Longer presentation times may also give them a greater opportunity to be inattentive. On the other hand, since this group reportedly has a sluggish cognitive tempo, longer presentation times might be helpful to them.

Unlike these studies, Schachar, Logan, Wachsmuth, and Chajzyk (1988) performed a CPT study in which they did not find ADD/H- Normal Control differences. Groups did not significantly differ on RT or omission or commission errors. None-the-less, the means for omission and commission errors were in the expected direction. The ADD/H group committed (non-significantly) more omission and commission errors and had slower RTs than normal controls.

The differences between this study and the Sykes et al. (1971) and Chee et al. (1989) studies may have been due to task and subject characteristics. Task characteristics that differed in the three studies include: time on task, event rate, target stimuli, and display time. In the Schachar et al. (1988) study, children were required to attend to the task for a total of 12.5 minutes whereas in Sykes et al. (1971) and Chee et al. (1989) children were required to attend to the task for 50 and 75.6 minutes, respectively. The longer task time may have been more likely to yield group differences for two reasons. First, the longer task times in the studies in which differences were found reflect a greater number of stimuli in those studies. This provided a greater number of degrees of freedom and, thus, more statistical power. Since the Schachar et al. (1988) study found group means that were in the expected directions, more power may have yielded significant findings. Second, ADD/H children may, as many researchers have suggested (Kupietz & Richardson, 1978; Douglas, 1985; Whalen, 1987), have deficits in sustained attention relative to normal children. Their attention to a task may deteriorate more rapidly over time than that of normal children. If

this is the case, differences are less likely to be found on short as compared to long tasks, thus explaining the discrepancy between the findings of Schachar et al. (1988) versus Sykes et al. (1971) and Chee et al. (1989).

In addition, Schachar et al. (1988) study, Schachar et al. (1988) also had smaller sample sizes than Sykes et al. (1971) and Chee et al. (1989). The small sample size may have decreased statistical power sufficiently to mask group differences. The Schachar et al. (1988) study had about the same number of ADD/H children but far fewer controls. While Schachar et al. (1988) had 15 normal control and 18 ADD/H (and 66 "pathological" controls), Sykes et al. (1971) had 40 normal control and 19 ADD/H, and in Chee et al. (1989) had 36 normal control and 14 ADD/H (and 37 pathological controls)

The event rate may also have contributed to the difference between the Schachar et al. (1988) study and the other two studies. In the Schachar et al. (1988) study, the event rate was 2000ms. Chee et al. (1989) did not find group differences at their 2000ms event rate but did find differences at faster (i.e. 1000ms) and slower (i.e. 4000ms) event rates. (Sykes et al. (1971) did not have a 2000ms condition. Furthermore, since their stimuli were presented contiguously, it is difficult to compare the effect of event rate between it and the other studies.)

Halperin et al. (1988) examined the relationship between different types of CPT commission errors and teacher ratings of behavior. They employed an A/X version of the CPT and calculated correlations between type of errors and teacher ratings of behavior for a sample of normal elementary school children (N=85). Factors from two different teacher rating scales of behavior were used as dependent measures--a Conduct Problems Factor, an Inattention-Passivity Factor and a Hyperactivity Factor from the Conners Teacher's Questionnaire, as well as an Inattention Factor, an Impulsivity Factor, and a Hyperactivity Factor from ". . . a rating scale based upon DSM-III criteria for attention deficit disorder with hyperactivity."

Letters were presented for 200 milliseconds, with an interstimulus interval of 1500 ms. The dependent measures included: (a) frequency of each type of error; (b) mean reaction time for correct responses; (c) mean reaction time for each type of error; and (d) scores on six independent behavioral measures from two teacher ratings scales. Results indicated that errors in which re-

sponses were to letters other than X preceded by an A (A/not-X error) correlated significantly with teacher ratings of hyperactivity, impulsivity, and conduct problems. These errors occurred at reliably faster reaction times than the average reaction time for correct responding. Furthermore, Halperin et al. (1988) found that omission errors and errors in which responses were made to X's preceded by letters other than A's (not-A/X errors) correlated with teacher ratings of inattention-passivity and were associated with significantly slower reaction times than were correct responses.

Halperin's findings may have important implications for future ADD research. They suggest a method of measuring cognitive impulsivity that has convergent validity with behavioral ratings of impulsivity, and furthermore, has discriminant validity since measurements reflecting impulsivity appear to be independent of measurements reflecting inattention. Thus, this method may provide greater insight into the cognitive processes involved in ADD and may help elucidate different cognitive styles in the ADD subgroups.

## *Summary*

The present review of the literature has suggested several important conclusions upon which the proposed study is based. With regard to differentiating the ADD subgroups, there appears to be a discrepancy between subjective ratings and behavioral measures of cognitive performance. Subjective ratings consistently demonstrated differences in cognitive styles. Behavioral indices typically did not find differences.

This apparent contradiction could reflect either that studies that employed behavioral measures typically had smaller sample sizes and lower power than those that employed teacher ratings or that teachers do not accurately rate children's cognitive processes. It is well known that children's reputations and diagnostic labels influence teachers' perceptions of them (Jussim, 1986). Furthermore, people often attribute other people's behavior to stable, cross-situationally general dispositions (Mischel & Peake, 1982). Therefore, teachers may tend to rate ADD/H children's cognitive tempos

as impulsive relative to ADD/WO children's, since ADD/H children typically exhibit socially impulsive behavior to a greater extent than do ADD/WO children. If cognitive differences do exist, some task characteristics utilized by studies reviewed above may increase the probability of detecting differences in behavioral measures of cognitive processes between ADD subgroups. First, the utilization of a CPT that is able to clarify the role of cognitive impulsivity and inattention during performance may differentiate subgroups. Second, fast and slow experimenter-paced, interstimulus intervals may differentiate ADD/H from ADD/WO groups. Third, under self-paced conditions, the two subgroups may choose a different average rate. All three of these components were incorporated in the present investigation. ADD/H, ADD/WO, and normal control children performed a CPT under three experimenter-paced conditions (a fast, medium, and slow stimulus presentation rates) and a self-paced condition; to further explore differences in cognitive processing, the specific types of commission errors which were described in Halperin et al. (1988) were analyzed.

## *Hypotheses:*

1. Both ADD groups were expected to commit more overall omission errors than the normal control group.
2. The ADD/H group was expected to commit more commission errors than the normal control group.
3. The ADD/H group was expected to commit more A/not-X errors than the ADD/WO and normal control groups.
4. Both ADD groups are expected to commit more not-A/X errors than the normal control group.
5. Groups and pacing conditions were expected to interact on errors.
6. The slower pacing conditions are expected to yield longer RTs than the faster pacing conditions.

7. The ADD/H group was expected to have longer RTs than the normal control group.
8. The A/not-X errors were expected to yield longer RTs than the not-A/X errors.
9. ADD/H group was expected to self-pace at a faster rate than either the ADD/WO or normal control groups.

## Method

### *Subjects*

Boys were obtained from one of four referral sources: a local pediatric neurologist, a support group for parents of children with ADD, schools, and Virginia Tech's Psychological Services Center. Teacher ratings on the SNAP checklist (Pelham, 1981) and the Revised-Behavior Problem Checklist (RBPC; Quay & Peterson, 1983) were obtained for all potential subjects. The SNAP is a brief checklist made up of five hyperactivity, five inattention, and six impulsivity items. Teachers are asked to rate a child as "Not At All," "A Little," "Pretty Much," or "Very Much" on each item. The Revised Behavior Problem Checklist is a more extensive scale. It contains 89 items making up six different scales-- Conduct Disorder, Socialized Aggression, Attention-Problem Immaturity, Anxiety-Withdrawal, Psychotic Behavior, Motor-Tension Excess. Teachers are asked to rate children from 0 "Not a Problem" to 2 "Severe Problem" on each item. The Lahey et al. (1987) criteria were used to assign children to groups. Specifically, children in the Attention Deficit groups were required to receive ratings at least 12 on the Attention Problem- Immaturity Factor of the RBPC. Those scoring greater than or equal to 5 on the Motor Excess Factor were included in the ADD/H group; those who fall below this criteria were included in the ADD/WO group. Normal boys were

required to obtain scores at or below 12 on the Attention Problem-Immaturity Factor and at or below 5 on the Motor Excess Factor of the RBPC.

The ADD children's Wechsler Full Scale Intelligence Quotient (IQ) scores were obtained from the schools. To obtain estimates of IQ for control children, they were administered the Peabody Picture Vocabulary Test, a measure of receptive vocabulary that correlates highly with IQ. All boys were required to have IQ scores between 80 and 140 to qualify for the study.

Eight control and two ADD/WO children tested while the noise level was high outside of the testing room were excluded from the analyses. In addition, two control children were excluded to make the distribution of CPT orders as equal as possible between groups. (CPT orders are discussed at length below.) Within the particular order that had excess control subjects, controls were randomly selected for exclusion. The final number of children in the ADD/H, ADD/WO, and control groups were 10, 8, and 12, respectively. Of these, 5 ADD/H, 5 ADD/WO, and all 12 control children were obtained from schools, 1 ADD/H child was obtained from the Psychological Services Center, and 3 ADD/WO and 4 ADD/H children were obtained from the ADD parent support group or the pediatric neurologist.

One-way analyses of variance were conducted for each demographic and descriptive variable; means are displayed in Table 1 (analyses of variance are summarized in Appendix C, Table 3.). Mean age and IQ did not differ significantly among the groups. On other factors, teachers rated the groups in a predictable fashion. Duncan's Multiple Range Tests indicated that both ADD groups scored significantly higher than controls on the RBPC Attention-Problem Immaturity and Motor-Tension Factors and the SNAP Impulsivity factor. The ADD/H group also scored higher than the ADD/WO group on the Motor-Tension Excess Factor. The ADD/H group scored significantly higher than both ADD/WO and control children on the SNAP Hyperactivity and RBPC Conduct Disorder and Anxiety-Withdrawal factors.

Table 1. Group Means and Standard Deviations for Diagnostic and Descriptive Characteristics

	CONTROLS	ADD/WO	ADD/H
	MEAN (S.D.)	MEAN (S.D.)	MEAN (S.D.)
AGE	124.5(14.4)	126.2(21.1)	128.2(16.8)
IQ	104.3(14.1)	96.8(19.8)	101.0(18.8)
<b>Revised-Behavior Problem Checklist</b>			
Conduct Disorder	1.5(2.5)a	4.4(4.5)a	21.6(12.7)b
Socialized Aggress	0.7(1.0)	0.9(1.6)	2.8(4.3)
Attention Problem- Immaturity	3.1(3.1)a	17.1(4.3)b	17.4(4.5)b
Anxiety-Withdrawal	1.8(2.0)a	4.8(3.4)a	6.3(4.6)b
Psychotic Behavior	0.2(0.6)	1.1(1.9)	2.3(2.3)
Motor-Tension Excess	0.6(1.0)a	2.4(0.7)b	7.2(1.6)c
<b>SNAP</b>			
Hyperactivity	0.0(0.0)a	0.6(0.9)a	3.7(2.0)b
Inattention	0.4(1.0)a	3.9(1.5)b	3.9(1.5)b
Impulsivity	0.2(0.4)a	2.6(1.3)b	3.2(2.3)b

\*Means with different subscripts are significantly different at alpha = .05.



## *Procedure:*

The parents of children obtained through the pediatric neurologist and from the support group were contacted directly. If they agreed to have their child tested, they were asked to sign a consent form (Appendix D). In contrast, special education teachers were asked to send home a cover letter (Appendix E) and a consent form to parents of children with attention problems. Regular classroom teachers were asked to send home a cover letter (Appendix F) and consent form to parents of "average" children. Children obtained from clinical settings were either tested at home, in a Virginia Tech extension office, or at the Psychological Services Center, whereas, children obtained from schools were tested at school. Written informed consent was obtained from the parents of all subjects.

After signing a consent form, children completed the CPT. The CPT was modeled after the A-X task of Halperin et al. (1988). Stimuli were presented on a computer screen. The CPT program was written using the Micro Experimental Laboratory (MEL) language. MEL is a new, third generation computer language that requires the programmer to write the general format and parameters of the experiment; MEL in turn writes the program in a Fortran-like language. The CPT program presented each stimulus to the child for a duration of 200 ms and measured the occurrence and latency of the response. Subjects were instructed to push the space-bar as quickly as possible each time he saw an "X" following an "A". All children were exposed to four different pacing conditions: experimenter-paced at a event rate of 500ms, 1000ms, and 2000ms, and a self-paced interstimulus interval. In the self-paced condition, children were given the same instructions with the additional instruction to press the number "1" as soon as they were ready for the presentation of the next letter. Children were given one of six different versions of the CPT; the versions differed in the order of the experimenter-paced conditions. The distribution of orders for each group is displayed in Table 2. An attempt was made to match the versions across groups to guard against effects of order of pacing condition on performance. The self-paced block was always presented last to ensure that each subject had identical exposure to the experimenter-paced conditions. Within

each pacing condition, 4 blocks of 64 letters (comprised of 8 of each type of sequence, A-X, not-A/X, A/not-X, not-A/not-X) were presented in a random fashion without replacement. Hence, there were 32 of each type of sequence (256 letters) per pacing condition and 1024 letters in the whole experiment. The not-As and the not-Xs were randomly selected without replacement from the following set of letters: K, R, G, V, W, Z, S, D, U, and C. This was the set of letters used by Beale et al. (1987), though they gave no rationale for choosing these letters. The proportion of target sequences (e.g. A-X) in this experiment (a quarter of the letters) coincided with the high probability target sequences in the Beale et al. (1987) study. This target proportion was shown to hinder performance across both reading disabled and normal groups and therefore was hoped to increase the number of errors in the present investigation. However, unlike Beale et al. (1987) and Halperin et al. (1988), the proposed study employed equal numbers of each type of stimuli sequence to enable more balanced statistical analyses to be performed.

For each pair of letters reaction times were measured between the onset of the previous letter and the space- bar press. All responses that had reaction times of 150 milliseconds or less were eliminated from the analyses. According to Halperin et al. (1988), it is not possible to determine whether such responses represent very slow responses, random errors, or impulsive responses initiated before the stimulus onset.

Prior to the CPT task, each child received instructions (Appendix G) and a brief practice block to ensure that he fully understood the task and was familiar with the sequences of letters. The practice block was identical for each child and consisted of 16 letters presented for 200 ms separated by an interstimulus interval of 2000 ms. The letters consisted of the four CPT sequences of interest (A-X, not-A/X, A/not-X, and not-A/not-X) presented two times each. The practice was repeated if the child committed more than one omission error or more than two commission errors. Three ADD/H and one ADD/WO children required a second practice block. The self-paced condition had a similar practice except that a) there were 4 presentations of each of the sequences of interest, b) the child was required to control the rate of stimulus presentation by pressing the number "1" each time he was ready for the next stimulus. It was not necessary to more than one practice in the self-paced condition. Children rarely made errors on the self-paced practice since they already

Table 2. Number of Children at Each CPT Order in Each Group

CPT ORDER	CONTROLS	ADD/H	ADD/WO
500mS/1000/ 2000/SELF-	2	1	2
500/2000/ 1000/SELF-	2	1	2
1000/2000/ 500/SELF-	1	1	0
1000/500/ 2000/SELF-	2	1	2
2000/500/ 1000/SELF-	2	2	1
2000/1000/ 500/SELF-	3	2	3

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had had considerable experience responding to the target stimuli and not responding to the non-target ones. On the other hand, after pressing the number "1" the first time, children often forgot or did not understand that they needed to press the "1" each time they wanted the next letter. Therefore, when necessary, they were prompted to press the "1." None of the children required prompting after the third or fourth letter of the practice.

## Results

Since there were several variables (i.e. block, pacing condition, sequence, group) with several levels and error rates were low, empty cells often occurred. As a result, it was necessary to average some variables over all blocks: namely, omission errors, RT to target sequences, and rate of self-pacing. Empty cells occurred even more frequently for commission errors and RT to non-target sequences. As a result, it was necessary to collapse across blocks, non-target sequences and blocks.

### *Omission Errors*

Figure 1 (Appendix A) shows mean number of omission errors at each pacing condition for each group averaged over all blocks. A table of the same data is presented in Appendix B. A 3 (Groups: ADD/H, ADD/WO, control) X 4 (Pacing Conditions: 500ms, 1000ms, 2000ms, Self-Paced) Analysis of Variance (Appendix C) revealed a marginally significant Pacing Condition effect. The Duncan's Multiple Range Test (DMRT) indicated that none of the means were significantly different. The ADD/H group committed non-significantly fewer omission errors than did the other

groups. Fewer omission errors were made in the 2000ms and self-pacing condition than in the other two conditions. However, these differences were not significant at an alpha-level of .05.

## *Commission Errors*

Two separate analyses were performed on commission errors with the group factor and each one of the other two factors (i.e. sequence or pacing condition) collapsed over the third factor and all blocks. Figure 2 displays the mean number of commission errors for each non-target sequence for each group collapsed over all pacing conditions and averaged over all blocks. A 3 (Groups) X 3 (Sequence: A/not-X, not-A/X, not- A/not-X) Analysis of Variance (Table 5) over these data showed that there was a significant effect for sequence. DMRT indicated that not-A/not-X errors were committed significantly less often than were A/not-X and not-A/X errors, which did not differ significantly from each other. The ADD/WO group made more commission errors than did the ADD/H group who in turn made more errors than controls, but the differences were not significant. Both ADD groups committed more not-A/X errors than controls. Again, the difference were not significance.

Figure 3 displays the mean number of commission errors at each pacing condition for each group collapsed over all blocks and non-target sequences. A 3 (Groups) X 4 (Pacing Conditions) Analysis of Variance (Table 6) showed only a significant Pacing Condition effect. DMRT comparisons revealed that significantly more errors were committed in the self-paced condition than in the 1000ms or 500ms conditions and more errors were committed in the 2000ms than the 500ms conditions. Although the ADD/H group committed fewer errors than the other two groups in the 500ms pacing condition, the group effect was not significant.

## *Reaction Time to Target Sequences*

Figure 4 presents mean RT to target sequences at each pacing condition for each group averaged over all blocks. A 3 (Groups) X 4 (Pacing Conditions) Analysis of Variance (Table 7) of these data showed significant effects for group and pacing condition but no significant group by pacing condition interaction. DMRT comparisons indicated that the mean RT of the ADD/H group was slower than that of the controls. The mean RT of the ADD/WO group did not differ significantly from those of the other two groups. DMRT comparisons revealed that mean RTs were significantly slower in the self-paced and 2000ms conditions than in the 1000ms condition than in the 500ms condition.

## *Reaction Time to Non-Target Sequences*

In order to fill empty cells on this variable, it was necessary to collapse the data across all but the Groups factor. Figure 5 shows the mean RT to non-target sequences for each group collapsed over blocks, pacing conditions, and non-target sequences. An Analysis of Variance (Table 8) showed a significant effect for group. The DMRT comparisons revealed that the mean RT for the ADD/H was significantly slower than that of either of the other groups, which did not differ significantly from each other. While it was not possible to analyze interactions between group and pacing condition or group and sequence, the means are illustrated in Figures 6 and 7. Figure 6 presents the mean RT to non-target sequences for each group collapsed over all blocks and pacing conditions. Mean RT was slowest to the not-A/X sequence and fastest to the A/not-X sequence. Figure 7 illustrates the mean RT to non-target sequences at each pacing condition for each group collapsed over blocks and sequences.

## *Self-Pacing Rate*

Figure 8 shows the mean rate of self- pacing at each sequence for each group averaged over all blocks. A 3 (Groups) X 4 (Sequence Conditions) Analysis of Variance (Table 9) revealed a significant effect for sequence and for no other factors. DMRT comparisons indicated that the rate of self- pacing to the A/X sequence was slower than that to all of the other sequences.



## Discussion

Results of this study showed that the ADD/H group had a significantly slower mean RT to non-target sequences than did the ADD/WO group and a significantly slower mean RT to both target and non-target sequences than did the normal controls. No significant group differences were found on omission or commission errors and on rate of self-pacing. Since CPT performance is based on speed and accuracy, the ADD/H group performed somewhat more poorly than the other groups.

The present results for RT were consistent with those of studies that employed tasks other than the CPT (Sergeant & Scholten, 1985; Hynd et al., 1988) and several CPT studies (Klorman, Salzman, Pass, Borgsted, & Dainer, 1979; Schachar et al., 1988; and Chee et al., 1989) that found ADD/H children had a slower mean RT than did normal controls. The present results for omission and commission errors were inconsistent with some CPT studies in the lack of significant differences between the ADD/H and normal control groups.

Except for the ADD/H-ADD/WO difference on mean RT to non-target sequences, the ADD/WO group's performance did not significantly differ from that of the other two groups on any other measure. Most studies that behaviorally assessed the cognitive performances of ADD/H and ADD/WO children (Carlson et al., 1986; Conte et al., 1986; Carlson & Alvarez, 1988; Hynd et al., 1988) also failed to find significant ADD/H-ADD/WO differences. These findings seem to

contradict the findings of King and Young (1982), Edelbrock et al. (1984), and Lahey et al. (1984, 1985) who employed subjective ratings of ADD/H and ADD/WO children's cognitive performance and found that ADD/H children had a faster cognitive tempo than did the ADD/WO children. This apparent contradiction could reflect either that studies that employed behavioral measures typically had smaller sample sizes and lower power than those that employed teacher ratings or that teachers do not accurately rate ADD children's cognitive processes.

In addition to not finding the expected group differences on errors, the current study also failed to find a significant interaction between group and sequence or group and pacing condition on omission and commission errors or RT measures. However, results for omission and commission errors showed non-significant trends in the expected directions. For example, in the 500ms pacing condition, the ADD/H group made fewer omission and commission errors than the ADD/WO group. In the 2000ms condition, the ADD/H group made more commission errors than the ADD/WO group. Overall, the group means on errors lent some support to the notion that ADD/H children may have faster cognitive tempos than do ADD/WO children and suggests that further investigation may be warranted.

Many factors appear to have contributed to the lack of significant group differences on the errors, these include brief total time on task, insufficiently extreme event rates, low statistical power, and low levels of symptomatology for ADD groups. Table 3 summarizes the total time on task for CPT studies that measured omission and commission errors. These studies suggest that as total time on a CPT decreases, the likelihood of finding significant group differences decreases. The total time that children spent on the CPT was shorter in the current study than that spent on the task in Chee et al. (1989) and Sykes et al. (1971), both of these studies found significant group differences on each dependent variable. The total time was longer in the current study than that spent on the task in Schachar et al. (1988) that found no significant group differences. Lengthy tasks may be necessary in order to detect deficits in sustained attention in ADD/H children.

The event rates in the experimenter-paced conditions may not have been sufficiently extreme to yield group differences. Though non-significant, group means of ADD/H and ADD/WO children were in the expected direction in the 500ms pacing condition (i.e. ADD/H children made

Table 3. Total time on task for CPT studies that measured omission and commission errors

Study	Total Time on CPT	Summary of Results
Chee et al '89	76min	ADD/H-NC signif differed on omis & commis errors & RT
Sykes et al. '71	50min	ADD/H-NC signif. differed on omis & commis errors
Needleman et al. '89	21min	ADD/H-NC signif differed on RT not omis or commis errs
Schachar '88	12min	No ADD/H-NC et al. differences on errors or RT

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non-significantly more errors than the ADD/WO children). Possibly, a faster event rate than 500ms may have amplified group differences on errors and yielded significant findings. Further, Chee et al. (1989) did not find group differences at a 2000ms event rate but did find such differences at faster (1000ms) and slower (4000ms) rates. These data suggest that an event rate of 2000ms may not have been sufficiently slow to find the expected group effects on errors.

In the current study, low statistical power was caused by both low error rates and small sample sizes. The sample sizes in the current study were smaller than those in any of the CPT studies cited in the introduction. Further, the low number of errors prevented performing the analyses in the desired manner. It was necessary to average some dependent variables over blocks which decreased the degrees of freedom.

Finally, the severity of ADD symptomatology in children in the current study may have contributed to the lack of significant group differences on errors. Approximately half of the ADD children in the current study were school-referred, whereas in Sykes et al. (1971), Schachar et al. (1988), Chee et al. (1989), ADD/H children were recruited only from clinics. Thus, ADD/H subjects in the current study were probably less "pathological" than the ADD/H subjects in other CPT studies.

The failure to find group differences in rate of self-pacing may have been an artifact of the computer task. While subjects were able to self-pace as slowly as they liked, there was a lower limit on how fast they could self-pace. Possibly, there was a floor effect on rate that may have masked group differences. It is not possible to determine whether accuracy scores would have improved with self-pacing since children may not have been able to select a rate that was most suitable for them. However, the failure to find differences in accuracy scores within groups in the self-pacing condition as compared to the other conditions may suggest that children did benefit from self-pacing. Performance gains may have been masked by the complicated motor responses that were required during the self-pacing condition but not during the three experimenter-paced conditions. When the current study was designed, we recognized that control of pacing (i.e. self- versus experimenter-) and complexity of response were confounded between the self-paced and experimenter-paced conditions. Only if a group performed better in the self-paced condition than the

experimenter-paced conditions would we have drawn conclusions regarding their relative performance in the self- versus the experimenter-paced conditions. *Future Directions*

To increase the probability that future experiments will obtain significant group effects on accuracy and significant ADD/H-ADD/WO differences, several steps could be taken. Total time on task should be increased. Event rates should be more extreme than those used in the current study. A larger sample of more severely disordered ADD subjects should be obtained. In addition, several other task manipulations are described below that may suggest future directions for this work.

Douglas (1985) suggested that increasing task difficulty may result in group differences. One manipulation that may be effective is to frequently change the target criteria. Van der Meere and Sergeant (1988) have shown that children with ADD/H had a higher rate of omission errors than did controls on such a task. On each trial, the child was presented with a new target letter. After briefly seeing a blank screen, s/he was presented with four other letters and had to determine whether the target was or was not present. A CPT could be modified to incorporate a changing criterion manipulation similar to the one just described. For example, after every 20 stimuli, a new target could be introduced.

A second task manipulation may be to degrade the stimuli with visual "noise." O'Dougherty et al. (1984) compared ADD/H and control children on a conventional and a degraded-stimulus CPT. In the degraded stimulus condition, the lens of the projector was blurred and a transparency with randomly located "+" signs covered 75% of the screen. While groups did not differ in their ability to discriminate signal stimuli from noise stimuli (perceptual sensitivity) in the conventional CPT, the ADD/H group had lower perceptual sensitivity than controls in the degraded stimulus condition. The authors suggest that degrading stimuli increases cognitive processing demands by burdening early stimulus encoding and analyses processes.

A third task manipulation may be to employ an auditory CPT. Sykes et al. (1972) found that ADD/H children committed more omission errors on an auditory than on a visual CPT. (For normal control children, the auditory-visual comparison was not reported.) Since the auditory version appears to increase error rates (i.e. increase difficulty) compared to the visual version, it may yield different effects for the ADD/H and control groups.

In conclusion, this study and other studies that compared the ADD/H and ADD/WO subgroups on behavioral indices of cognitive performance found modest or no differences. However, due to limitations in these studies (e.g. small sample sizes), the question concerning whether the subgroups differ in cognitive functioning has not been definitively resolved. Further research is necessary to address this important issue.

## **Appendix A. Illustrations**

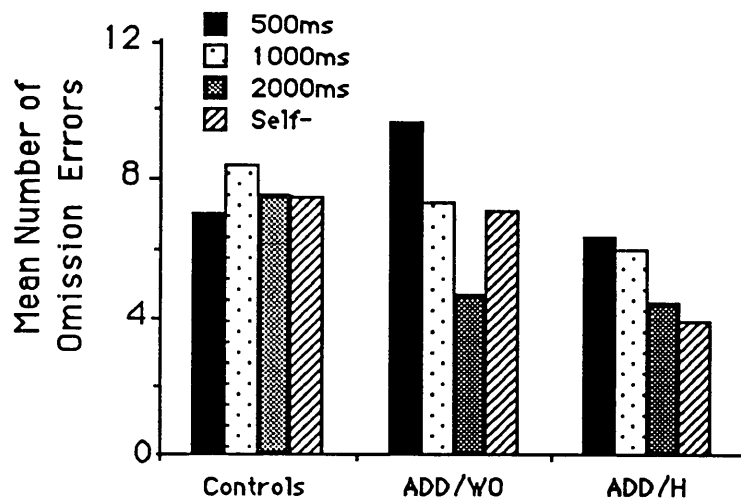


Fig. 1 Mean number of omission errors at each pacing condition for each group averaged over all blocks.



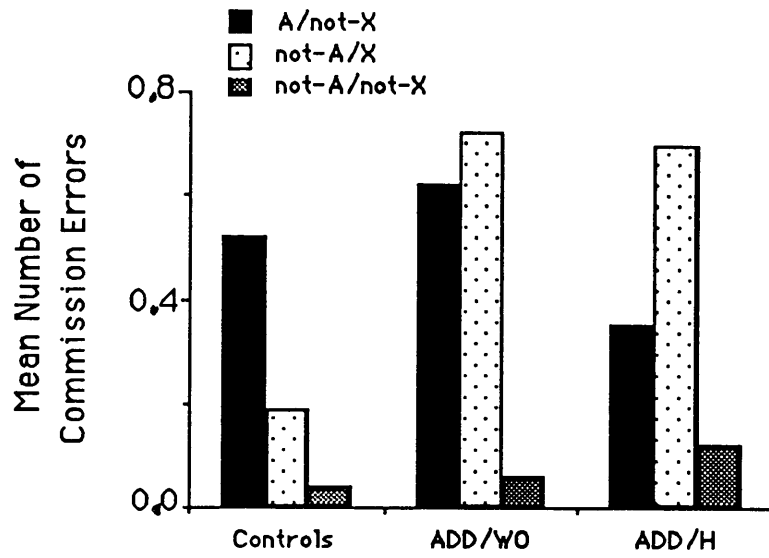


Fig. 2 Mean number of commission errors for each non-target sequence for each group collapsed over all pacing conditions averaged over all blocks.

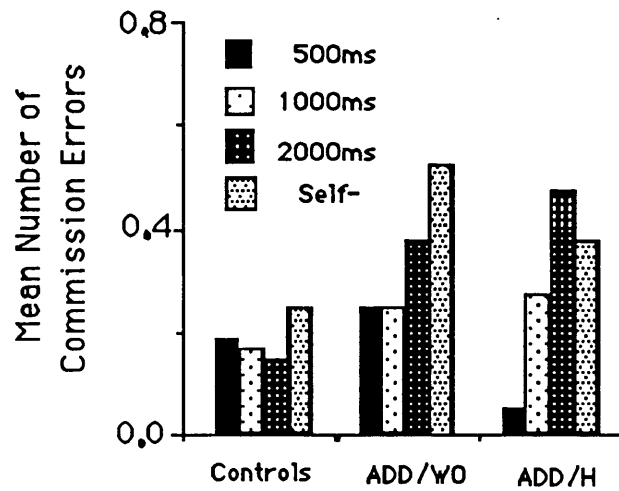


Fig. 3 Mean number of commission errors at each pacing condition for each group collapsed over non-target sequences averaged over all blocks.

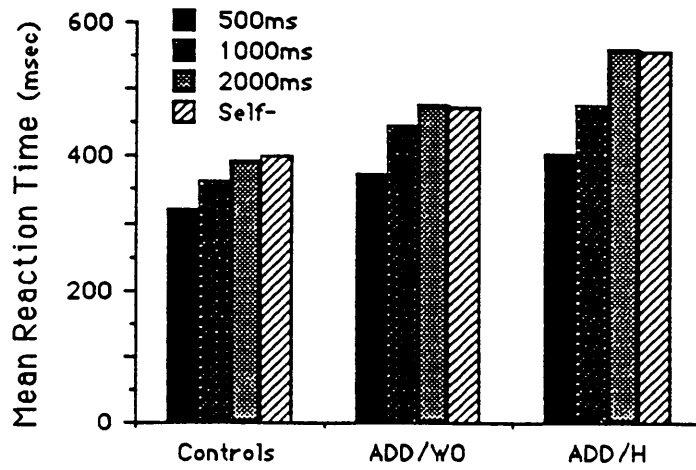


Fig. 4 Mean reaction time to target sequences at each pacing condition for each group averaged over all blocks.

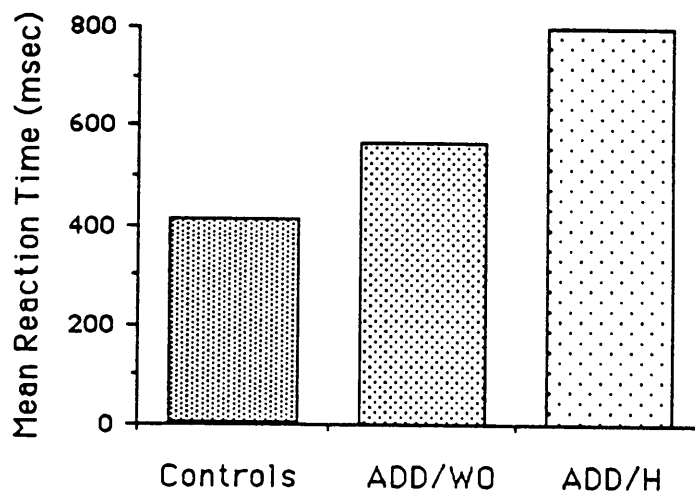


Fig. 5 Mean reaction time to non-target sequences for each group collapsed over blocks, pacing conditions, and sequences.

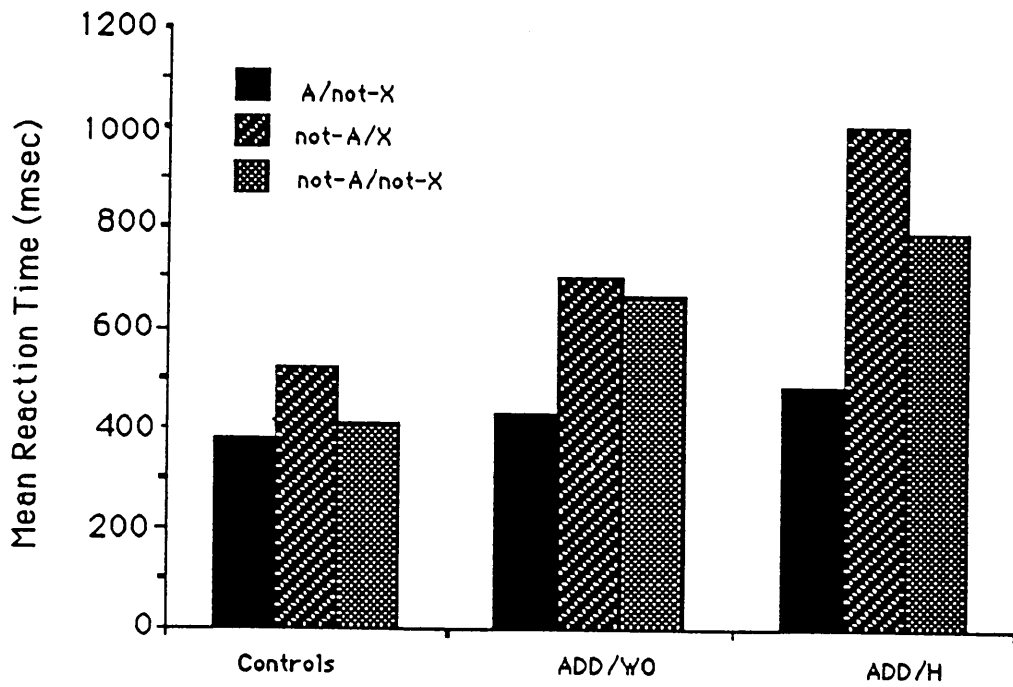


Fig.6 Mean reaction time to non-target sequences for each group collapsed over all blocks and pacing conditions.

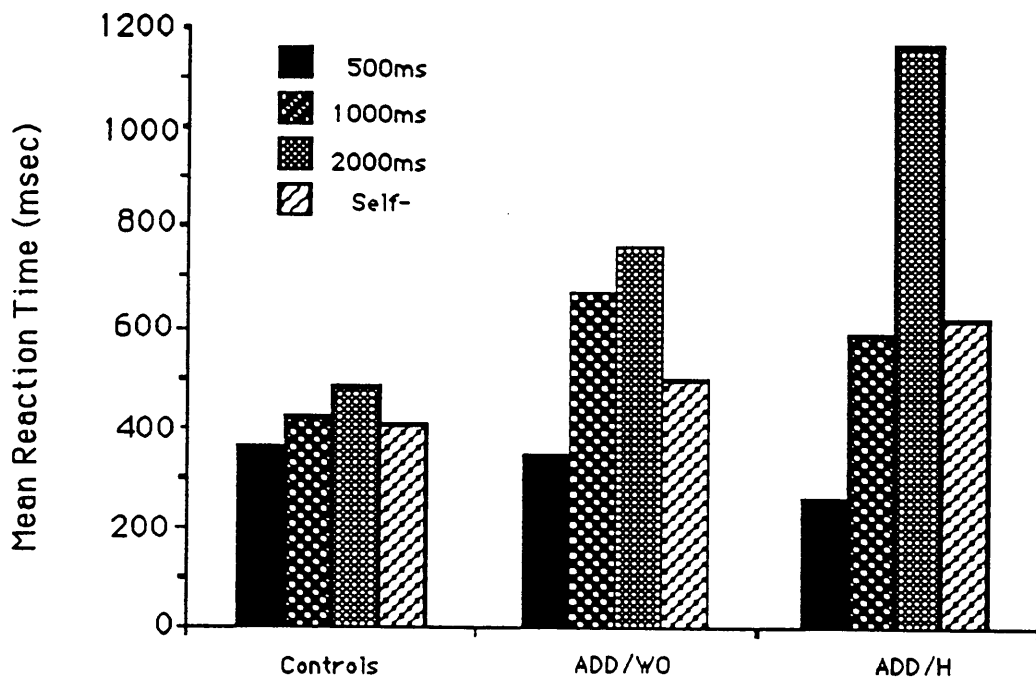


Fig. 7 Mean reaction time to non-target sequences at each pacing condition for each group collapsed over blocks and sequences.

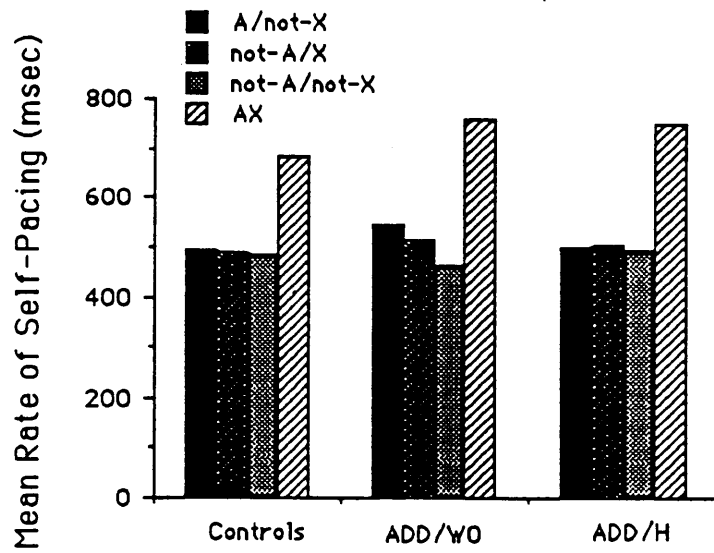


Fig. 8 Mean rate of self-pacing at each sequence for each group averaged over all blocks.

# **Appendix B. Tables of Means and Standard Deviations**



Table 4. Mean number of omission errors at each pacing condition for each group averaged over all blocks.\*

	CONTROL	ADD/WO	ADD/H	TOTAL
500ms	1.75(1.63)	2.41(1.38)	1.58(1.20)	1.87(1.43)
1000ms	2.10(1.67)	1.84(1.27)	1.50(1.27)	1.83(1.42)
2000ms	1.90(1.75)	1.16(0.78)	1.10(0.88)	1.43(1.30)
Self-	1.88(1.44)	1.78(1.46)	.98(0.67)	1.55(1.27)
-----				
TOTAL	1.93(1.61)	1.80(1.27)	1.29(1.03)	

\*No means differed significantly at alpha = .05.

Table 5. Mean number of commission errors for each non-target sequence for each group collapsed over all pacing conditions averaged over all blocks.\*

	CONTROL	ADD/WO	ADD/H
A/not-X	.13 (.35)	.16 (.40)	.09 (.28)
notA/X	.05 (.21)	.18 (.49)	.18 (.50)
not-A/ not-X	.01 (.10)	.02 (.12)	.03 (.17)
-----			
TOTAL	.06 (.25)	.12 (.38)	.10 (.35)

\*No means differed significantly at alpha = .05.

**Table 6.** Mean number of commission errors at each pacing condition for each group collapsed over non-target sequences averaged over all blocks.\*

	Control	ADD/WO	ADD/H
500ms	.06 (.24)	.08 (.31)	.02 (.13)
1000ms	.06 (.26)	.08 (.31)	.09 (.32)
2000ms	.05 (.22)	.12 (.42)	.16 (.47)
Self-	.08 (.28)	.18 (.46)	.12 (.38)
-----			
Total	.06 (.12)	.38 (.25)	.10 (.35)

\*No means differed significantly at alpha = .05.

**Table 7. Mean reaction time to target sequences at each pacing condition for each group averaged over all blocks.\***

	500ms	1000ms	2000ms	Self-
CONTROLS	322(44)	361(62)	394( 82)	402(140)
ADD/WO	375(38)	447(111)	478(103)	473(169)
ADD/H	405(69)	476(114)	563(171)	558(198)
-----				
TOTAL	364(63)a	421(106)b	472(140)c	473(176)c

Table 8. Mean reaction time to non-target sequences for each group collapsed over all blocks and pacing conditions.\*

	CONTROL	ADD/WO	ADD/H
A/not-X	373.2 (167.1)	425.4 (242.0)	483.9 (364.2)
notA/X	516.2 (390.5)	706.1 (317.5)	1008.5 (505.6)
not-A/ not-X	404.5 (149.1)	666.5 (156.2)	791.2 (604.7)
-----			
TOTAL	411.8 (243.6)a	567.4 (304.7)a	797.7 (521.6)b

\*Means with the same subscripts do not differ significantly at alpha = .05. Only group means were analyzed for differences.

Table 9. Mean reaction time to non-target sequences at each pacing condition for each group collapsed over blocks and sequences.\*

PACING CONDITION	CONTROL	ADD/WO	ADD/H
500ms	355 (148)	343 (114)	260 ( 53)
1000ms	420 (161)	671 (245)	585 (286)
2000ms	481 (474)	767 (381)	1168 (637)
Self-	407 (156)	498 (260)	616 (234)
-----			
	411 (243)a	567 (304)a	797 (521)b

\*Means with the same subscripts do not differ significantly at alpha = .05. Only group means were analyzed for differences.

Table 10. Mean rate of self-pacing at each sequence for each group averaged over all blocks.\*

	A/not-X	not-A/X	not-A /not-X	A/X
CONTROL	494( 78)	487( 86)	482( 94)	681(128)
ADD/WO	544(126)	516(122)	462( 74)	761(193)
ADD/H	502( 82)	503( 86)	496(119)	748(150)
-----				
TOTAL	509( 92)	500( 93)	482( 96)	724(150)a

\*Means with the same subscript did not differ significantly at  
alpha = .05

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## **Appendix C. Analyses of Variance Tables**



Table 11. Descriptive Variables

Source	D.F.	Sum of Squares	F Ratio	P-Level
<b>Age</b>				
Group	2	276.6333	.4606	.6358
Error	27	8108.1667		
<b>IQ</b>				
Group	2	74.7000	.1267	.8815
Error	27	7958.1000		
<b>Conduct Disorder</b>				
Group	2	2433.6917	19.7294	.0000
Error	27	1665.2750		
<b>Socialized Aggression</b>				
Group	2	28.2250	1.9134	.1671
Error	27	199.1417		
<b>Attention-Problem Immaturity</b>				
Group	2	1439.6750	47.4396	.0000
Error	27	409.6917		
<b>Psychotic Behavior</b>				
Group	2	22.9417	4.0105	.0299
Error	27	77.2250		
<b>Motor-Tension Excess</b>				
Group	2	247.4750	91.8043	.0000
Error	27	36.3917		
<b>Hyperactivity</b>				
Group	2	81.2250	26.1236	.0000
Error	27	41.9750		
<b>Inattention</b>				
Group	2	86.8083	25.0990	.0000
Error	27	46.6917		
<b>Impulsivity</b>				
Group	2	99.4250	22.3924	.0000
Error	27	59.9417		

Table 12. Omission Errors for Groups and Pacing Conditions averaged over all Blocks

Source of Variation	SS	DF	F	P-Level
BETWEEN				
Group	9.05	2	.86	.433
Error	141.42	27		
WITHIN				
Pacing Condition	5.16	3	2.44	.071
Group by Pc	5.58	6	1.32	.258
Error	57.13	81		

**Table 13. Commission Errors for Groups and Sequences collapsed across all Pacing Conditions and averaged over all Blocks**

Source of Variation	SS	DF	F	P-Level
<b>BETWEEN</b>				
Groups	.05	2	.80	.458
Error	.78	27		
<b>WITHIN</b>				
Sequence	.24	2	6.75	.002
Group X Sequence	.10	4	1.42	.239
Error	.95	54		

Table 14. Commission Errors for Groups and Pacing Conditions collapsed across all Sequences and averaged over all Blocks

Source of Variation	SS	DF	F	P-Level
<b>BETWEEN</b>				
Group	.06	2	.81	.457
Error	1.05	27		
<b>WITHIN</b>				
Pacing Condition	.10	3	2.82	.044
GroupXPacing Conditon	.08	6	1.15	.342
Error	.93	81		

Table 15. Reaction Time to Target Sequences for Groups and Pacing Conditions averaged over all Blocks

Source of Variation	SS	DF	F	P-Level
<b>BETWEEN</b>				
Group	378035.21	2	6.29	.006
Error	811122.25	27		
<b>WITHIN</b>				
Pacing Condition	241201.85	3	9.40	>.001
Group By Pacing Cond.	28164.79	6	.55	.769
Error	692465.95	81		

**Table 16. Reaction Time to Non-Target Sequences for Groups collapsed over all Blocks, Pacing Conditions, and Non-Target Sequences**

Source of Variation	DF	SS	F	P-Level
Between Groups	2	2842943.141	9.6981	.0001
Within Groups	109	15976405.14		

Table 17. Rate of Self-Pacing for Groups and Sequences averaged over all Blocks

Source of Variation	SS	DF	F	P-Level
<b>BETWEEN</b>				
Group	107528.21	2	.08	.928
Error	19281573.75	27		
<b>WITHIN</b>				
Sequence	4771356.87	3		<.001
Group by Sequence	138506.09	6		.720
Error	3052260.55	81		

## Appendix D. Parent/Guardian Consent Form

I, \_\_\_\_\_, parent or legal guardian of \_\_\_\_\_, give permission for my child to participate in the testing study to be conducted by Mr. Needleman and Dr. Carlson at Virginia Tech (please sign below if you give consent).

Children in the study will first be rated by their teacher on forms that rate children's classroom behavior, and children's individual and/or group achievement and/or IQ test scores will be obtained from school records, if available. If these scores are not available, we will give the children a short test of receptive vocabulary to assess their general level of intellectual functioning. In the second phase of the study, children who have been selected based on these ratings will be asked to complete a task in one 30 to 45 minute session at school during regular school hours. The children will complete a computer task in which they will be asked to push a button as soon as certain letters appear on the screen. This test measures how well children are able to maintain their attention. In addition, during part of the task, children will be asked to control the rate at which they do the task by pressing a foot pedal. We will keep a copy of the results, with the names removed for our research purposes. To maintain complete confidentiality, no one outside of our project will see the results of your child's testing. However, if you request the test results, they will be shared with you.

We do not anticipate negative effects due to participation in the testing, although some children may become fatigued from working on the computer task. If this occurs, children will be given the opportunity to discontinue the test. While the children without attention problems who participate in the study may not directly benefit from this participation, we anticipate that the results may benefit children who do have attention problems. The results of this study and others like it are likely to provide information relevant to understanding and treating attention problems.

If you agree to allow your child to participate, please sign below and return this form to your child's teacher. If you do give permission, you may, of course, withdraw it at any time and for any reason. We will also be asking children for their consent. This will give them an opportunity to independently decide if they would like to participate.

This research project has been approved by the Human Subjects Research Committee and the Institutional Review Board at Virginia Polytechnic Institute and State University. Any questions about this project should be directed to Lawrence Needleman, principal investigator (231-8184); Dr. Caryn Carlson (231-6304), supervisor; or Dr. Helen Crawford, Chair of Human Subjects Committee (231-6581). Please sign here and return to your child's teacher.

---

Signature of Parent or Legal Guardian



## Appendix E. Cover Letter to Parents of Children with Attention Problems

March 1989

Dear Parent or Guardian:

We are conducting a study in the local public schools. Our project will be carried out with the cooperation of the Floyd County Schools and the Virginia Tech Department of Psychology. The purpose of this study is to better understand the factors that affect learning in children with attention problems obtained from special education classrooms. We are especially interested in the types of cognitive errors these children make. We hope that our study will better define some of the cognitive processes that differentiate these children from children who do not have attention problems.

We would like your permission to include your child in our study. First, we would like to record your child's group and/or individual achievement test scores from school records and ask your child's teacher to rate your child's classroom behavior. Based on the teacher's ratings, some children will be selected to participate in further testing. The extra tests, which are described in the consent form, require about an hour outside of class and should not interfere with your child's regular classroom instruction.

If you have any questions, please call one of us at 231-6581. If you want to help us and allow your child to be included in the study, please sign one of the attached consent forms (you may keep the other) and return it to your child's teacher as soon as possible.

Thank you very much.

Sincerely,

Caryn Carlson, Ph. D.  
Assistant Professor

Lawrence D. Needleman  
Graduate Assistant

## Appendix F. Cover Letter for Parents of Children without Attention Problems

March 1989

Dear Parent or Guardian:

We are conducting a study in the local public schools. Our project will be carried out with the cooperation of the Floyd County Schools and the Virginia Tech Department of Psychology. The purpose of this study is to better understand the factors that affect learning in children with attention problems obtained from special education classrooms. We are especially interested in the types of cognitive errors these children make. We hope that our study will better define some of the cognitive processes that differentiate these children from children who do not have attention problems. For comparison purposes, we would like to include *normal children*, such as your child, who are not in any special education classes.

We would like your permission to include your child in our study. First, we would like to record your child's group and/or individual achievement test scores from school records and ask your child's teacher to rate your child's classroom behavior. Based on the teacher's ratings, some children will be selected to participate in further testing. The extra tests, which are described in the consent form, require about an hour outside of class and should not interfere with your child's regular classroom instruction.

If you have any questions, please call one of us at 231-6581. If you want to help us and allow your child to be included in the study, please sign one of the attached consent forms (you may keep the other) and return it to your child's teacher as soon as possible.

Thank you very much.

Sincerely,

Caryn Carlson, Ph. D.  
Assistant Professor

Lawrence D. Needleman  
Graduate Assistant

## Appendix G. Instructions for the Continuous Processing Task

THIS IS CALLED A SPACE-BAR. PRESS IT TWO TIMES  
SO YOU'LL KNOW HOW IT FEELS. GOOD.

DURING THIS EXERCISE YOU'LL SEE LETTERS FLASH  
ON THE SCREEN ONE AT A TIME. IF YOU SEE AN 'A'  
AND THEN AN 'X' RIGHT AFTER IT,  
PRESS THE SPACE-BAR AS QUICKLY AS YOU CAN  
LET'S DO SOME FOR PRACTICE. REMEMBER,  
PRESS THE SPACE-BAR AS QUICKLY AS YOU CAN  
WHEN YOU SEE AN 'A' FOLLOWED BY AN 'X'.  
WHEN YOU ARE READY FOR THE PRACTICE,  
PRESS THE SPACE-BAR

\* \* EXPERIMENTER-PACED PRACTICE \* \*

THE NEXT SET OF LETTERS WILL BE LIKE THE PRACTICE  
THAT YOU JUST DID. HOWEVER, THE LETTERS MIGHT  
APPEAR FASTER OR SLOWER THAN BEFORE. I WILL NOT  
WATCH YOU OR TELL YOU IF YOU ARE RIGHT OR WRONG  
THIS TIME, BUT DO THE BEST YOU CAN. REMEMBER TO  
PRESS THE SPACE-BAR WHEN YOU SEE AN 'A' AND THEN AN 'X'.

HIT THE SPACE BAR TO BEGIN.

\* \* EXPERIMENTER-PACED CONDITIONS \* \*

SEE THIS 'I'. PRESS IT TWO TIMES  
SO YOU'LL KNOW HOW IT FEELS. GOOD.

THIS TIME WILL BE A LITTLE DIFFERENT. INSTEAD OF THE COMPUTER DECIDING WHEN YOU WILL GET THE NEXT LETTER, YOU WILL DECIDE. WHEN YOU ARE READY FOR THE NEXT LETTER, PRESS THE NUMBER '1'. EVERYTHING ELSE WILL BE THE SAME AS BEFORE. IF YOU SEE AN 'A' AND THEN AN 'X' PRESS THE SPACE-BAR AS QUICKLY AS YOU CAN AFTER THE 'X'. DO YOU HAVE ANY QUESTIONS? REMEMBER, TO GET THE NEXT LETTER, PRESS THE NUMBER '1' AND WHEN YOU SEE AN 'A' FOLLOWED BY AN 'X' PRESS THE SPACE-BAR.

\* \* \* SELF-PACED PRACTICE \* \* \*

THE NEXT SET OF LETTERS WILL BE LIKE THE PRACTICE THAT YOU JUST DID. I WILL NOT TELL YOU IF YOU ARE RIGHT OR WRONG THIS TIME BUT DO THE BEST YOU CAN. REMEMBER TO PRESS THE SPACE-BAR WHEN YOU SEE AN 'A' AND THEN AN 'X', AND PRESS THE NUMBER '1' WHEN YOU ARE READY FOR THE NEXT LETTER.

HIT THE NUMBER '1' TO BEGIN.

\* \* \* SELF-PACED CONDITION \* \* \*

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