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PLANNING IN CHILDREN WITH AND WITHOUT ATTENTION DEFICITS

BY

TIMOTHY C. PAPADOPOULOS ©

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To: The Faculty of Graduate Studies and Research
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From: Dr. J. P. Das, Professor
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Date: September 29, 1995

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This letter is to certify that my student, Timothy C. Papadopoulos, has been given the rights to reproduce figures of the "Crack-the-Code" task, in his thesis submitted to the Faculty of Graduate Studies and Research as a partial fulfillment of his degree of Master of Education.

Sincerely Yours,

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *Planning in Children With and Without Attention Deficits* submitted by Timothy C. Papadopoulos in partial fulfillment of the requirements for the degree of Master of Education in Special Education.

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Dedicated to

my father and my mother

for their unconditional love and faith

in me

ABSTRACT

This study examined the problem solving performance of nine Grade 6 students with ADHD and nine Grade 6 regular students on the Crack-the-Code problem solving task, while thinking aloud. Both product analysis (computer protocols) and process analysis (verbal protocols) were conducted. The results indicate that the students with ADHD performed better than the students in the comparison group, especially in terms of using more complex strategies and regulating their performance more successfully. These results are not consistent with earlier findings in the literature that children with ADHD exhibit problems involving either the generation of and/or the application of appropriate strategies during problem solving. Data were interpreted in light of the four components of a planning model in order to facilitate the comparison of results from this and subsequent studies.

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CHAPTER I

INTRODUCTION

The purpose of this study is to examine the problem-solving performance of children with and without attention deficits on an action-planning task. Research has shown that children with attention deficits experience difficulties in both producing and applying a variety of strategies to solve a problem (Hamlett, Pellegrini, & Conners, 1987; Reardon & Naglieri, 1991; Tannock, Purvis, & Schachar, 1993; Tant & Douglas, 1982). It has also been shown that these children apply fewer self-corrections while performing problem-solving tasks (Reardon & Naglieri, 1991). These studies, however, have focused mainly on the final output of the performance of children with Attention Deficit Hyperactivity Disorder. As a result, the process involved in working toward the solution of problems has not been addressed in the literature. For this reason, the present study examines in greater depth the problem-solving performance of children with attention deficits, using the Crack-the-Code task and the think-aloud method to collect participants' verbal protocols as the main instruments to collect the data on problem solving.

In the remainder of this chapter, a definition of Attention Deficit Hyperactivity Disorder is provided and the characteristics of this disorder are described. The planning model that is used to assess the planning process of children with and without attention deficits is also discussed.

A. Defining Attention Deficit Hyperactivity Disorder

The definition and classification of the behavior disorder commonly referred to as "hyperactivity" has been a controversial issue, as evidenced by its repeated reformulation in each edition of the Diagnostic and Statistical Manual of Mental Disorders (APA, 1968, 1980, 1987, 1994). In the first edition of the DSM (1952), a category for attention deficit hyperactivity disorder was not present and the only diagnostic classification for hyperactive children was under the category of organic brain syndromes. In the second edition, DSM-II (APA, 1968), the classification system was changed to include the category of hyperkinetic reaction in childhood and adolescence. The category of attention deficit disorder first appeared in DSM-III (APA, 1980). In the DSM-III-Revised (APA, 1987), 14 diagnostic characteristics were identified and the child was required to manifest any eight of these in order to receive a diagnosis of "attention deficit hyperactivity disorder." Finally, the DSM-IV (APA, 1994) contains two categories that focus on different disorders. Specifically, the first category includes nine criteria-symptoms for inattention, while the second category includes six criteria-symptoms for hyperactivity and three criteria-symptoms for impulsivity. In order to be diagnosed as having attention deficit hyperactivity disorder, six of the symptoms included in each category must persist for at least six months and to a degree that they are maladaptive and inconsistent with the child's developmental level. The current diagnostic criteria for the disorder (DSM-IV, 1994) are presented in Appendix A.

Despite the changes in criteria and terminology that have occurred, it is generally assumed that children who are diagnosed as having ADHD evidence a common set of symptoms that emanate from a common etiology (or at least from one of several etiologies). Moreover, the ADHD terminology is also assumed to offer those who use it the advantages of other types of labels applied in the fields of education and psychology. Some of these include providing concerned parties with the ability to relate the diagnosis to specific treatment, providing professionals with abbreviated means of communicating, delineating clear and appropriate methods for classifying child behavior, establishing criteria for interpreting and assessing research findings, and promoting specific programs for certain special interest groups (Goodman & Poillion, 1992; Heilveil & Clark, 1990).

Given the changes that have occurred in the diagnosis of ADHD, all of the participants in this study were selected by using the criteria in DSM-IV for attention deficit hyperactivity disorder, and by consulting both school and medical records.

B. Characteristics of Children with ADHD

In their review of the professional literature on the identification of causes and characteristics of attention deficit hyperactivity disorder (ADHD) in school-age learners, Goodman and Poillion (1992) concluded that a large number of characteristics were identified by different authors. These characteristics were very diverse in range and often subjective. In general, there was a lack of agreement regarding the characteristics associated with ADHD, and, at times, characteristics mentioned by different authors were contradictory.

According to Goodman and Poillion (1992), however, most researchers supported making a diagnosis of ADHD on the basis of DSM-III-R criteria of developmentally inappropriate attention, impulsivity, and motor restlessness or hyperactivity. In their review, Goodman and Poillion (1992) indicated that

82.05% of researchers considered a short attention span to be one of the main characteristics of children with ADHD, 74.36% of researchers selected hyperactivity and poor motor control as a main characteristic, and 71.79% of researchers chose impulsivity as one of the main characteristics of children with ADHD. These four symptoms were identified most often by researchers in the symptom list provided by Goodman and Poillion.

The term *"inappropriate attention"* is used to refer to a child's difficulties in either concentrating, listening, beginning or completing tasks, and following directions (especially when three or more steps are given at one time) (Council of Exceptional Children of Virginia/CEC, 1992; Heilveil & Clark, 1990). It is also related to a child's difficulties with any or all of the following attention skills: selective attention (i.e., determining where attention needs to be focused), focusing attention (i.e., knowing where attention needs to be focused, but experiencing difficulty in "zeroing in" on the relevant task), sustaining attention (difficulty maintaining attention as a result of distractions) and dividing attention (difficulty in performing two or more tasks at one time) (CEC, 1992; Fowler, 1991; Grodzinsky & Diamond, 1992; McLarty, 1992; Melnyk, 1988).

Moreover, acting without thinking and experiencing difficulty waiting for one's turn are components of impulsivity (CEC, 1992). In class, the child with ADHD may rush through assignments, shift excessively from one task to another, or frequently call out or ask irrelevant questions (Hamlett et al., 1987; Heilveil & Clark, 1990). The impulsive child will often interrupt others and display outbursts of inappropriate responses such as silliness or anger.

Finally, hyperactivity can involve excessive running, difficulty sitting still, fidgeting or physical activity that is not related to the task (e.g., finger tapping) (Fowler, 1991; Goodman & Poillion, 1992). It may also be related to excessive vocalizations, noises, or talking in a loud voice (Kirby & Williams, 1991).

This broad range of characteristics associated with children with ADHD has resulted in a large number of studies aimed at either identifying the cognitive characteristics of children with ADHD (Carter, Zelko, Oas &, Waltonen, 1990; Hamlett et al. 1987; Naglieri, 1989; Reardon & Naglieri, 1991; Stolzenberg & Julkowski, 1991; Tannock et al., 1993; Zentall & Ferkis, 1993) or determining if the behaviors of ADHD children are parallel to the behaviors of the adults with frontal lobe damage (Barkley, Gronzinsky, & DuPaul, 1992; Grodzinsky & Diamond, 1992; Loge, Staton, & Beatty, 1990; Matazow & Hynd, 1992a; Shue & Douglas, 1992). In these studies, the tests used focused on deficits typically associated with frontal lobe dysfunction: cognitive flexibility, problem solving and distractibility. In the next chapter, these studies are examined from two perspectives: a cognitive approach and a neuropsychological approach.

C. Defining Planning

Planning allows cognition and behavior to be more than "passive and nonstrategic" (Kirby & Williams, 1991, p. 211). It is also what is required in approaching a problem or task for which we do not have a ready solution (Kirby & Williams, 1991; Saiz & Breuleux, 1991). Planning is a set of decisions or strategies that an individual adopts and modifies to solve a problem and to reach a goal (Das, 1980). Moreover, planning permeates all voluntary behaviors and it is not possible to propose a theory of human behavior that lacks a set of constructs referring to plans or planning (Parrila, Das & Dash, 1995).

As the above definitions indicate, the underlying process involved in planning is thoroughly discussed by many researchers. For the purposes of this study, however, the planning model that will be used is that which has recently been proposed by Parrila and Das (Das, Kar & Parrila, in press; Parrila, Äystö, & Das, 1994; Parrila et al., 1995).

According to this definition, planning consists of three levels and five components. The three levels of planning include *activity-planning, action-planning* , and *operation-planning.* Activity-planning "can be conceptualized as a method of realizing or aiming toward one's general life goals and motives," (Parrila et al., 1994, p. 215) such as occurs in career development, education, or even planning for retirement (Parrila et al., 1995). The consideration of planning as an activity provides us with many insights into an individual's choices and decisions in real-life tasks. For example, the plans made by a college student about his or her future career provide a framework within which that person's behaviour can be explained and understood (Parrila et al., 1995). Therefore, the purpose of activity-planning is to "mediate between a person's life goals and the external, objective world" (Parrila et al., 1995).

The second level of planning, *action-planning,* is what is generally referred to as problem solving. As Parrila et al. (1994) state "while activity-planning is understood best as a movement toward realizing one's general life goals, action-planning aims to realize a particular goal or to solve a particular problem." For example, if an athlete's activity plan is to become a world champion in his particular sport, then during action-planning he selects exercises, he chooses a coach, he participates in important competitions, and so forth.

The third and final level of planning involves executing the desired plan. *Operation planning* involves "plans that are equivalent to strategies and tactics" (Parrila et al., 1994, p. 215) and refers to working toward the solution of a problem. Parrila et al. (1994), state that "the main feature of an operation-plan is that it needs to satisfy the specific conditions associated with the task and, consequently, it is oriented towards the present" (p. 215). This is the basic difference between action-planning and operation planning: during operation planning, an individual works toward the answer in accordance with task-imposed constraints. In contrast, during action-planning, an individual has a greater number of options for making his or her decisions: he or she can form as many representations as possible in order to arrive at the solution. The individual has the ability to build hypotheses and to test and evaluate them in order to arrive at an answer. Operation-planning may also include all of the components of planning identified in Figure 1 (see below for a description) but it differs in that the arrows in Figure 1 are now unidirectional to reflect task constraints (Parrila et. al., 1995).

Another difference between action-planning and operation-planning is that during operation-planning, the decisions made to proceed are not necessarily conscious, since they can be based on information that is already automated (Parrila et al., 1995). This automated information includes strategies and tactics that have been used successfully in the past. For example, a visual search task can be solved efficiently because the necessary visual search strategies are already automated through daily visual search tasks (e.g., a child tries to find his or her favorite cookies in a package of assorted cookies).

Crack-the-Code, the task used in this study to examine the cognitive performance of children with and without attention deficits, represents the second level of planning, because it is considered an action-planning task (i.e., permits the participant to use as many means as possible to obtain the correct answer). The participants must integrate a series of steps in a coherent way in order to obtain the correct answer. They are shown six items each of which consists of two to four lines of colors that are accompanied by information about the number of correct colored chips displayed on that line. The participants must then combine all of the information provided so that their answer line meets the criteria established for each line. For example, Item 3 (see following page) contains the following information lines:

- Line 1: Blue, White, Black, Yellow; "0 correct"
- Line 2: White, Blue, Yellow, Black; "2 correct"
- Line 3: Black, Blue, Yellow, White; "1 correct"
- Line 4: White, Black, Yellow, Blue; "0 correct"

The only correct answer that could be obtained based on these information lines is: Yellow, Blue, White and Black. There are several ways of solving this task (Parrila et. al., 1995). First, the individual can use the information to eliminate positions for a color or to find the correct position for a color (e.g., Yellow cannot be placed in position 3, because it is in this position on line 4, which provides information that none of the colors are in correct positions). Second, the individual can build a hypothesis (e.g., "Blue and the Black appear to be correct on the line with "2 correct", so I am going to try Blue first"). Finally, the participant can test and evaluate his or her hypothesis (e.g., "Blue definitely goes in position 2 because it is not correct on line 4, which indicates that none are correct, or on line 1, which also indicates that none are correct).

The participants must go through this process in order to obtain the correct answer. They can execute these steps mentally before actually placing the chips on the answer line or they can place the chips on the answer line and then evaluate their answer. Using either method, there are five components that may be employed during this process: goals and objectives, anticipation, representation, execution, and regulation (Das et al., in press; Parrila, et al, 1994). These components are presented schematically in Figure 1. As stated previously, the goals and objectives form an integral part of planning activity. "All planning is guided by a goal or purpose, although the objective may not be readily available to the planner" (Das et al., in press).

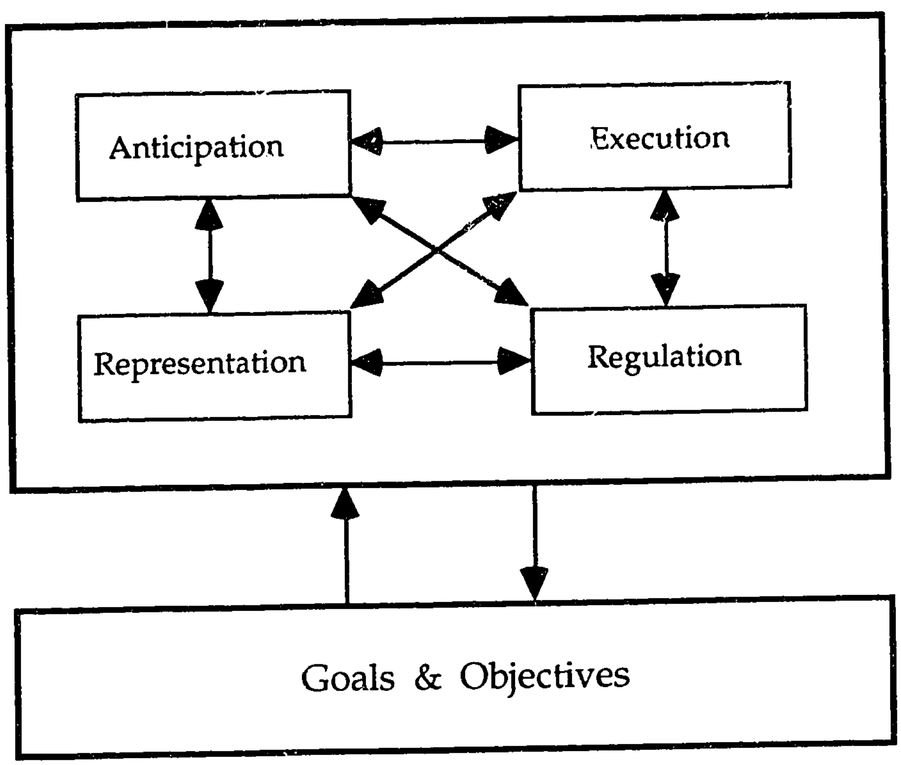
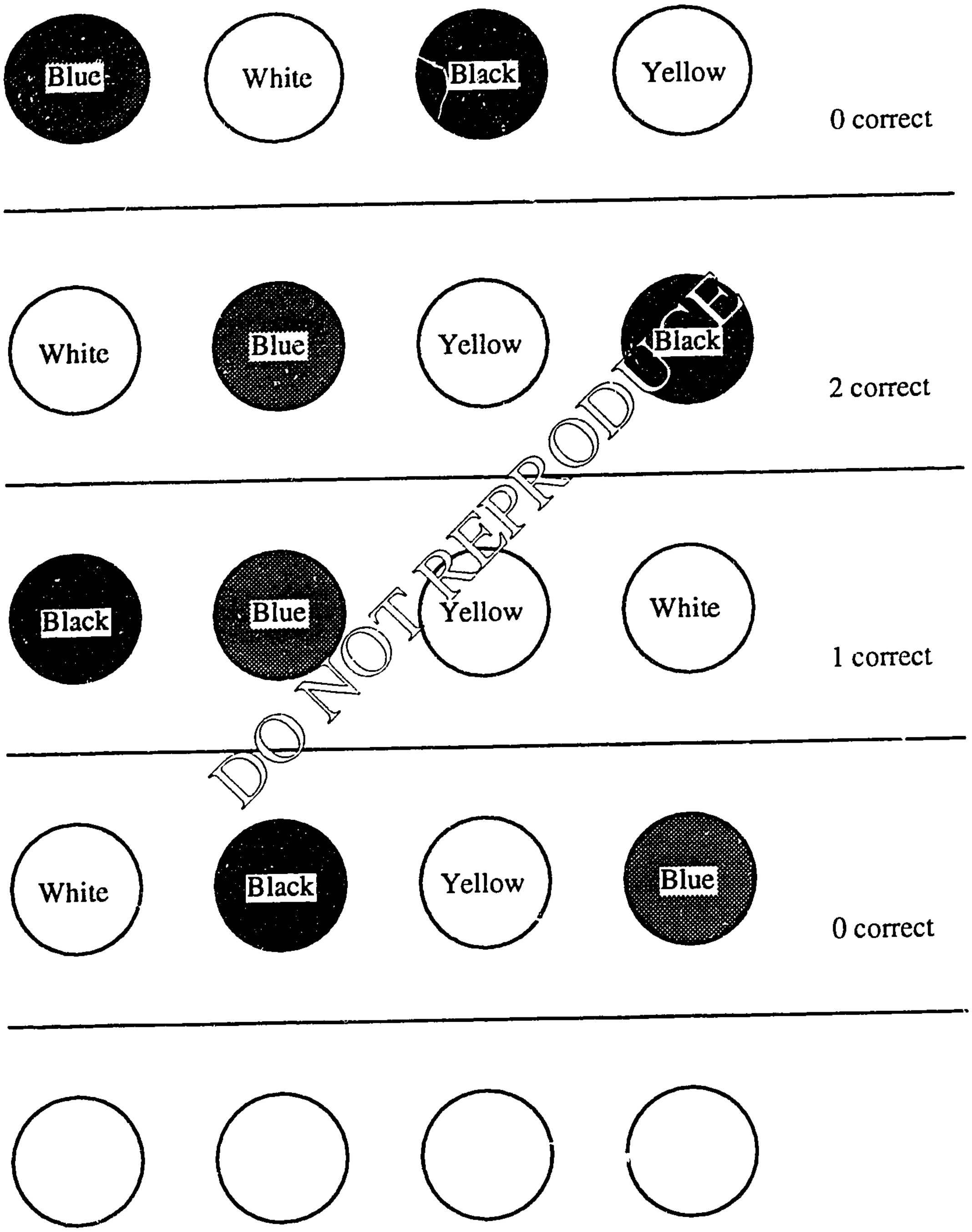


Figure 1. Components of Planning



ITEM 3 of Crack-the-Code

Anticipation includes the ability to predict the consequences of a plan or a behavior, the selection and shaping of environments in order to reach favorable consequences, and the selection of subgoals. *Representation* involves several activities: making plans, considering conditions for their application, and setting up subgoals when the ultimate goal is too distant and requires a complex set of activities. It includes both the original plan of action and a dynamic sequence of alternative activities. *Execution* can consist of planning-in-action or carrying out an advance plan of action, while, *Regulation* refers to the monitoring and controlling of behavior according to the plan and revising the plan when necessary (Das et al., in press).

According to this model, planning is divided into two units. Goals and objectives are present in the first unit and the remaining four interdependent components (i.e., anticipation, representation, execution, and regulation) are present in the second unit. The arrows that join the two units, however, are bidirectional. This implies, that any new information found in the components in the second unit may influence the first unit by changing goals and objectives (Das et al., in press; Parrila et al., 1994).

The present study, however, focuses specifically on the four components in the second unit and their interplay. Participants are given the goal of the problem solving task and it is assumed that they agree to this goal (i.e. placing the colors in the correct order on the answer line). They must attain this goal, satisfying and meeting the task-constraints. For example, on Item 3 (see the description given earlier) they are aware that they must place the colors in the correct order. In order to obtain the correct answer, they must form hypotheses and plans (i.e., representation), evaluate their performance and maintain an organized approach to the task (i.e., regulation), predict the consequences of their plans and moves (i.e., anticipation), and execute their decisions (i.e., execution).

It is important to mention, however, that although these four components are distinguished conceptually, it is difficult to distinguish them in the participants' performance, because these components are highly interrelated.

CHAPTER II

SELECTED REVIEW OF THE RELATED LITERATURE

A. Children with ADHD and Problem Solving: The Cognitive Approach

Given the importance of attention for perception, learning, and logical thinking, one might reasonably expect that ADHD children would show performance deficits on a wide range of planning and problem solving tasks (see e.g., Tant & Douglas, 1982). Indeed, several studies have demonstrated such attention related deficits both on relatively simple problem solving tasks (see e.g., Reardon & Naglieri, 1991) and on more complex planning tasks such as matrix solution (Tant & Douglas, 1982), use of memory strategies (Voelker, Carter, Sprague, Adowski, & Lachar, 1989), and production of narratives (Tannock et al., 1993).

The reasons suggested for why children with ADHD perform at a lower level than the regular children, however, have varied from study to study. The two most common explanations, as they have been originally stated by Flavell (1970) are *"production deficiency"* and *"mediational deficiency."* Production deficiency is offered as a description of the hypothetical case where potential mediators (i.e., verbal symbols or visual schemes) are not produced and hence, cannot mediate the plan (see e.g., Voelker et al., 1989). Alternatively, mediational deficiency is offered as a description of the hypothetical case where potential mediators are produced but do not mediate the plan (see e.g., Tant & Douglas, 1982).

In their study of complex cognitive processing in children with ADHD, Tant and Douglas (1982) compared the performance of 97 boys: 36 of these boys were normal, 36 were diagnosed as having ADHD, and 25 were reading disabled but non-hyperactive (RD). The children were matched on age (they were 7 to 12 years of age and drawn from grades 2 through 6) and IQ (all had Peabody IQ's that were above 85). ADHD children who were receiving stimulant medication were tested after being off of the medication for a period of approximately 72 hours. All of the children were given a problem solving task developed by the researchers that consisted of four different matrices: a letter matrix, a flower matrix, a number matrix and a practice matrix. The task required that each child generate strategies and hypotheses to identify the correct concept, monitor and evaluate strategies and hypotheses, and if necessary, adapt them in order to arrive at a solution. The researchers examined each group's problem solving process through the children's explanations of their own decision-making in arriving at an answer. The results indicated that the ADHD group showed evidence of a mediational deficiency. The boys with ADHD were least likely to generate and use problem solving strategies in order to obtain a solution. Tant and Douglas suggested that non-hyperactive children demonstrated a greater and more efficient use of problem solving strategies and self-monitoring that are required for complex problem solving tasks of this kind.

Hamlett, Pellegrini, and Conners (1987) examined the "executive" processes of 16 normal children and 16 children clinically diagnosed as meeting DSM-III criteria for ADHD. The age range for both groups was 6 years 3 months to 11 years 6 months, with a mean age of 9 years. A memory task requiring organization and self-monitoring was employed for this purpose in conjunction with a social communication task to examine the production and coordination of problem solving strategies. In order to uncover possible medication effects, the scores of 9 ADHD children were compared when the children were on and off medication. No significant differences in performance, however, were evident between both assessment conditions. Thus, subsequent analyses comparing children with ADHD and children in the control group used data derived from all 16 cases of ADHD that were assessed while they were on medication.

No significant differences were evident in the time that ADHD and control children took to sort the cards in the task or in the number of incorrect responses made during recall. The results, however, showed that controls recalled a marginally greater number of items correctly than ADHD children ($p<.10$, one tail t-test). Moreover, significant group differences were also apparent with regard to executive processes as reflected in the quality of instructions and organizational strategies that children provided on the social communication tasks, communicative effectiveness, and fluency of communication. In general, Hamlett et al. (1987) concluded that, relative to normal children, children with ADHD were characterized by a poor level of functioning on aspects of problem solving associated with "executive processes". They were probably less likely to generate and utilize such problem solving strategies spontaneously when actually performing tasks of this kind.

Similarly, Reardon and Naglieri (1991) compared the performances of 28 males diagnosed as ADHD and 28 males from regular education classrooms, (aged 7 to 12 years), on measures of (a) planning (Visual Search, Planned Connection and Crack-the-Code), (b) attention (Receptive Attention Pictures, Receptive Attention Letters, and the Expressive Attention Task), (c) simultaneous processing (Figure Memory Test, Design Construction Test, and Matrix Analogies Test-Expanded Form), and (d) successive processing (Word Recall Task, Sentence Repetition and Questions, Color Ordering Task). In this study, Crack-the-Code required the participants to solve the correct arrangement of three or four colored chips when given a matrix of patterns in which each line showed either no color in the correct order, one color in the correct order, or two colors in the correct order. The task was scored for time as well as for accuracy of the child' s solution. Children with ADHD who were currently receiving psychostimulant medication were tested after a minimum abstinence period of 48 hours.

The results showed that the ADHD group earned consistently lower scores than the control group for most of the tasks; significant differences, however, were observed only on tests of planning, attention, and successive processing. On planning tasks, significant differences were obtained on two of the three tasks: Planned Connections ($p<.01$) and Crack-the-Code ($p<.05$). The results also indicated that the cognitive processing deficiencies of the ADHD group were quite pervasive, while predictably, the greatest deficiency involved attention. Children in the ADHD group also demonstrated significant weaknesses on measures of selective attention and automaticity of information processing (i.e., word naming, color reading). Moreover, Reardon and Naglieri (1991) argue that the successive processing differences between the children in the ADHD group and the children in the control group can be explained in terms of the demands inherent in this type of task. The more complex the successive task, the greater the influence that attention (to properly receive temporally presented stimuli) and planning (to control attention and impulses) will have on the successful repetition of the item. Finally, the results indicated that the children with ADHD made more errors of commission and fewer self-corrections, generated and employed less efficient problem solving strategies, and processed overlearned or automatic types of information more slowly than did normal children while engaged in tasks involving selective attention.

Finally, Tannock et. al. (1993), sought to assess the narrative abilities of 30 boys with ADHD and 30 regular boys, who were matched for age (7 to 11 years) and IQ (all had full scale IQ's above 80) by using a story telling task. Although 5 boys in the ADHD group were receiving stimulant medication, this treatment was discontinued 48 hours before both days of assessment. Also, 6 boys in the ADHD group and 4 boys in the control group exhibited learning disabilities. Each boy in the study listened to two stories and then retold them to another child. The results indicated that although boys with ADHD recalled less overall, they were as sensitive to thematic importance as boys in the control group, indicating that the two groups did not differ in terms of their comprehension of the studies. Significant differences, however, were observed on verbal productivity and on organization and monitoring. Boys in the ADHD group used significantly more ambiguous referents and semantically inappropriate word substitutions, and gave more incorrect and misinterpreted information than did boys in the control group. Boys in the ADHD group also exhibited a higher frequency of sequence errors and errors of cohesion, which reflects, according to the researchers, breakdowns in the global organization of story theme and in the local organization of information across utterances. Consequently, their stories were often confused and difficult to follow. Moreover, given that organization and monitoring of information are functions of executive control, Tannock et al. suggested that deficits in narrative production in children with ADHD may reflect underlying deficits in executive processes.

Discussion of Cognitive Studies

The results of the above studies appear to be consistent, with respect to the problem-solving performances of children with ADHD. All of the researchers demonstrated that because of their deficiencies in the areas of attention and planning, children with ADHD encounter a great deal of difficulty when required to generate their own plans and evaluate their performance while engaged in a cognitively challenging task. Some of the main difficulties evident in ADHD children's performance on these tasks includes (a) low level of functioning on aspects of problem solving associated with executive processes (Hamlett et al., 1987); (b) low scores on planning, attention, and simultaneous and successive processing (Reardon & Naglieri, 1991); and (c) deficiencies in automaticity of information processing, fewer self corrections and employment of less efficient problem-solving strategies (Tannock et al., 1993; Tant & Douglas, 1982).

Moreover it was apparent that the ADHD children appear to be impaired in their ability to sustain an organized approach to problem solving (Reardon & Naglieri, 1991; Tannock et al., 1993) while simultaneously trying to avoid responding in an impulsive manner. They possess cognitive deficits that involve (a) a failure to invest, organize, and maintain attention and effort; and (b) an inability to inhibit impulsive responding or modulate arousal levels to meet task demands (Douglas, 1980; Stolzenberg & Julkowski, 1991; Tant & Douglas, 1982).

Examining these results from the perspective of the definition of planning used in this study, it seems that ADHD children's performance on problem solving tasks may be deficient with respect to all four components of the planning model (Figure 1). In terms of representation impairments, children with ADHD are found to (a) be less likely to generate and use problem solving strategies (Hamlett et al, 1987); (b) have difficulties generating their own plans (Reardon & Naglieri, 1991); and (c) have coherence of thinking that is easily broken down (Tannock et al., 1993). In terms of regulation, children with ADHD exhibit more errors of commissions than regular peers and apply fewer self-corrections while doing tasks (Reardon & Naglieri, 1991). They also have difficulties evaluating their performance as well as sustaining an organized approach to tasks (Tannock et al, 1993; Tant & Douglas, 1982; Voelker et al; 1989). In terms of execution, the children with ADHD are less likely than the regular children to use problem solving strategies to find a solution (Hamlett et al., 1987; Tant & Douglas, 1982). Finally, in terms of anticipation, the learning process for children with ADHD, especially regarding how to apply appropriate strategies, appears to be slower than for regular children (Tannock et al., 1993). Some of these underlying deficits in planning will be examined in the present study.

B. Children with ADHD and Problem Solving: The Neuropsychological Approach

The cognitive impairments and behavioral symptoms observed in ADHD have also been compared to the symptoms of children with known brain damage, especially frontal lobe resulting from encephalitis, lead poisoning, or head injury (Grodzinsky & Diamond, 1992). The apparent similarity in behavior between ADHD children and frontal lobe injured patients has prompted a number of studies examining the performance of children with ADHD on neuropsychological tests that show some sensitivity to frontal lobe injury in adults (Barkley et al., 1992).

Chelune, Ferguson, Koon, and Dickey (1986) compared the performance of 24 boys (aged 6 to 12 years) who were either normal or diagnosed with ADHD on the Wisconsin Card Sorting Test (WCST). The battery of tests used also included measures of sequential processing and cognitive flexibility, which the authors considered to be central to frontal lobe dysfunction. Significant differences were found between regular children and children with ADHD on three of four measures included in the WCST (i.e., categories achieved, perseverative errors and percentage of correct responses). Both groups did not differ, however, on number of failures that occurred to maintain set. Findings from the sequential processing tasks did not demonstrate a clear pattern. On the cognitive flexibility measures, children with ADHD made more errors than regular children on only one of the tests, Color-Forms. The groups did not differ on time measures for either task. In interpreting their results, Chelune et. al. emphasized the high incidence of perseverative errors on the WCST for the children with ADHD. They concluded that their results suggested an underlying dysfunction of the inhibitory forebrain system.

Grodzinsky and Diamond (1992) compared 66 boys with ADHD and 64 regular children at two different age levels (6 and 11 years). These groups were administered a battery of neuropsychological tests that are sensitive to frontal lobe damage in adults. The results indicated that as predicted, boys with ADHD were inferior to boys in the control group on both tasks that were considered sensitive to inhibition/impulsivity (i.e., the Vigilance subtest of the Gordon Diagnostic Systems and the Stroop Test) and on three tasks requiring planning and organization of output (i.e., the Controlled Oral Word Association Test, Rey-Osterrieth Complex Figure, and Porteus Mazes). The group differences on all of these tasks were significant at $\underline{a}<.01$ level. In contrast, two tests that were considered particularly sensitive to cognitive flexibility (i.e., Trail Making and

WCST) did not produce significant differences between both groups. The control group tended to perform more quickly on both portions of the Trail Making Test but in neither case did the difference approach the a=.05 level. On the WCST, boys in the control group required fewer trials in order to attain the first category (p<.04); however, other WCST measures failed to differentiate both groups. As also expected, boys in each group did not differ on the Vocabulary and Block Design Subtests of the WISC-R, which was also used for matching purposes (i.e., to determine Full Scale IQ scores that were within the range from 85 to 125).

Shue and Douglas (1992) were also interested in investigating whether the deficits that children with ADHD display on tests of frontal lobe functioning reflect a specific neuropsychological performance pattern associated with frontal lobe dysfunction or whether these deficits merely reflect part of a more generalized dysfunctional pattern. To pursue this question, the authors used two types of measures to test 24 children with ADHD (21 males and 3 females) and 24 regular children (21 males and 3 females), all of whom were aged 8 to 12 years. The first type of measure involved a battery of tasks previously shown to be sensitive to diverse aspects of frontal lobe dysfunction (i.e., motor inhibition and higher-level problem solving activities). The second type of measures consisted of a battery of relatively simple memory measures on which patients with frontal lobe dysfunction typically do not display deficits but on which patients with temporal lobe dysfunction perform poorly. The first study included four measures of motor control (i.e., Go-No-Go, Conflicting Motor Response Test [adapted from the Luria-Christensen 1975 battery], Compatible and Incompatible Discrimination tasks, and the Trail Making test) and two measures of complex problem solving (i.e., the WCST and the Self-Ordered Pointing Task). The results of the motor control tasks indicated that children with ADHD showed motor control difficulties similar to those reported for patients with frontal lobe dysfunction. The ADHD group made significantly more errors than the control group on the motor control measures at both a= .05 and a=.01 levels.

Results from the WCST indicated that children with ADHD had difficulty formulating and testing hypotheses and using feedback to modify and guide their responding. Compared to the control group, the ADHD group completed significantly fewer categories ($p<.002$) and made significantly more perseverative ($p<.004$) and non-perseverative errors ($p<.007$). Significant differences between the groups, however, were not found for the number of unique errors committed or the number of extra correct responses given. The children with ADHD also experienced significantly more difficulty in organizing and directing their responses than the regular children. On the Self-Ordered Pointing Task, significant differences were found only on the Representational Designs subtest, where the regular group performed better than the ADHD group. No significant differences between the groups were observed on the Abstract Design subtest.

In the second study by Shue and Douglas (1992), children with ADHD and regular children were administered a battery of memory tests that included Logical Memory, Paired Associate Learning, and Digit Span subtests from the Weschler Memory Scale (WMS), and the Recall of Spatial Location Test (Smith & Milner, 1981, 1984). The performance of children with ADHD did not differ significantly from that of normal children on any of the WMS recall measures. These results suggest that children with ADHD can perform at the same level as the regular children on tests which do not require the use of complex mnemonic strategies. It is noteworthy, however, that much like frontal lobe patients, children with ADHD had difficulties with more complex memory measures (i.e., WMS and Logical Memory test) that required generating organizational strategies. Alternatively, children with ADHD and regular children did not differ in accuracy of object recall or object location on the Location Recall Task.

In contrast, Loge et al. (1990) arrived at different conclusions based on their results. They compared the performances of 20 children with ADHD and 20 regular children on a battery of neuropsychological tests. Each group consisted of 17 males and 3 females, aged between 6 to 12 years. Both groups were matched in that none of the children had learning disabilities or neurological or psychiatric illnesses. Analysis of the scaled scores on the various subtests of the WISC-R revealed significant differences between both groups on Information, Arithmetic, Digit Span, Block Design, and Coding Subtests ($p<.05$). Significant differences were also observed on measures of attention (Gordon Diagnostic System) and memory (California Verbal Learning). On the various tests of frontal lobe function (i.e., WCST, Letter Fluency, Category Fluency, and Design Fluency) the children with ADHD generally performed normally . On each of the three fluency measures, they produced as many correct responses as, and made no more repetitions than, the children in the control group. Therefore, Loge et al.'s hypothesis that disturbances in frontal lobe function that are related to impulse control may be responsible for the cognitive impairments observed in children with ADHD was not supported. The inability to control and direct attention appeared to be more central to the pathophysiology of this disorder. Furthermore, the authors concluded that the physiological frontal lobe abnormalities that are involved in ADHD likely occur in the frontal components of complex, widely distributed circuits involved in the "executive control" of attention. These circuits, according to Loge et al., are anatomically and functionally linked to the parietal lobes. Dysfunction within these circuits may produce the diverse cognitive impairments observed in children with ADHD.

It is also important to note that several researchers (Matazow & Hynd, 1992) have postulated that the problems in visual-spatial perception, math achievement, and social skills exhibited by children with ADHD may constitute a

"Right Hemisphere Deficit Syndrome" (RHDS). Matazow and Hynd (1992b) examined 21 children with attention deficit disorder with hyperactivity, 11 children with attention deficit disorder without hyperactivity, and 10 children with dyslexia (LD) to determine if they could be differentiated on the basis of problem solving tasks that tap RHDS functions (e.g., hemispatial neglect, failure to shift operations, weak visual-motor skills, and judgment and reasoning deficits). The children were 6 to 16 years of age and both sexes were included. It was expected that children with ADHD would demonstrate problems on visual spatial tasks, math achievement, and socioemotional measures, whereas the LD group would not demonstrate such deficits. Furthermore, it was expected that children with ADHD would demonstrate difficulties on tests that measure sequential, cognitive operations that are presumed to be indices of frontal lobe functioning (i.e., Trails B, and the Digit Span and Coding Subtests of the WISC-R).

The results provided limited support for the hypothesis that children with ADHD exhibit problems similar to children who are diagnosed as having RHDS. In particular, differences between children with ADHD and children with LD were noted on one visual-spatial measure (i.e., Judgment of Line Orientation) and one socioemotional measure (i.e, Achebach Sum-T). In contrast, no significant differences were observed between the groups on tests related to frontal lobe functioning. From these results, it was concluded that ADHD is not simply a RHDS but, instead, involves a number of different brain systems, possibly implicating different functional systems related to spatial attention in children with ADHD and ADD. Thus, the authors concluded that RHDS may relate differentially to subtypes of ADHD and may also provide important clues as to the neuropsychological basis of ADHD.

Discussion of Neuropsychological Studies

The results of the aforementioned studies appear to be somewhat contradictory and for this reason, several cautionary notes are necessary in interpreting the results of these studies.

Chelune et al. (1986) and Shue and Douglas (1992) discovered significant differences between children with ADHD and regular children on several problem solving tasks (i.e., WCST, Self-Ordered Pointing Task). Both studies concluded that their findings suggested the existence of an underlying dysfunction of the inhibitory system of the forebrain.

In contrast, other studies (e.g., Grodzinsky and Diamond, 1992; Loge et al., 1990; Matazow & Hynd, 1992b) did not find significant group differences on the problem solving tasks (i.e., WCST, Letter Fluency, Category Fluency, Design Fluency, Controlled Oral Word Association Test, Rey-Osterrieth Complex Figure and Porteus Mazes). They did, however, find significant differences between children with ADHD and regular children on tasks assessing inhibition and impulsivity (i.e., Vigilance Subtest of the Gordon Diagnostic System), tasks considered especially sensitive to planning and organization of output (e.g., the Controlled Oral Word Association Test, and Porteus Mazes), the WISC-R, and measures of memory (e.g., California Verbal Learning).

This inconsistency in the results of different studies may be due to various reasons. ADHD is representative of a highly heterogeneous population and therefore, prior differences between examined groups may influence the results of each study. For example, if we examine the medication condition in each of these five samples, it is evident that only some of the children with ADHD were receiving stimulant medication. Additionally, these children's medication was not withheld for the same period of time prior to testing. In the Shue and

Douglas (1992) and Chelune et al. studies (1986), the children with ADHD were not medicated for at least 20 hours prior to testing, while the children with ADHD in the other three studies were not medicated for at least 48 hours prior to testing.

Another possible explanation for the inconsistency of the results obtained in the aforementioned studies involves age effects. First, two studies (Chelune et al., 1986; Loge et al., 1990) used subjects who were 6 to 12 years of age. Another study (Grodzinsky & Diamond, 1992) included subjects who were 6 to 11 years of age, while in the remaining two studies, subjects were 8 to 12 years of age (Shue & Douglas, 1992) or 6-16 years of age (Matazow & Hynd, 1992b). As noted by some researchers (see e.g., Grodzinsky & Diamond, 1992), the large differences in age within these groups constitutes a weakness of neuropsychological studies dealing with the frontal lobe regions of the brain, because age-related improvement is associated with almost all of the tasks included in the test batteries used in such studies. This age-related improvement is consistent with a hypothesis of maturation of the frontal regions of the brain during adulthood (Loge et al., 1990).

In addition to age differences, the discrepancies between studies may be due to different task demands in each study. In other words, discrepancies may have resulted from differences on the way in which tasks were presented to subjects and the way in which subjects were asked to perform these tasks (Shue & Douglas, 1992). For children with ADHD, the increase in the simultaneous use of memory and attention may constrain their problem-solving abilities.

Despite these cautionary notes, it may, as suggested by various researchers (e.g., Grodzinsky & Diamond, 1992; Loge et al., 1990; Shue & Douglas, 1992), be theoretically and clinically useful to consider ADHD as impairment in higher order cognitive processing in the frontal lobes of the brain.

From this perspective, deficits involving attention and impulse control, and the failure to inhibit responses to salient stimuli would be seen as resulting from difficulties in integrating information that is used to plan, set goals, monitor progress, anticipate outcomes, use problem solving strategies, and so forth.

Finally, I believe that if future studies demonstrate that frontal lobe dysfunction provides a viable neuropsychological explanation for ADHD, it will nevertheless be necessarv to establish whether the deficits on frontal lobe measures shown by children with ADHD are a consequence of actual frontal lobe dysfunction. Various hypotheses and approaches, such as RHDS, for example, may be useful in furthering research to examine in greater depth the predictions of a theory based on frontal lobe deficit.

C. Effects of Medication on the Cognitive Functioning of Children With ADHD

Over approximately the last 30 years, the management of attention deficit has been dominated by three approaches: behaviour modification, stimulant medication, and more recently, cognitive behaviour therapy. The most common and preferred approach has, until recently, involved the use of medication. According to Kirby and Williams (1991), the popularity of this form of treatment is a result of (a) the child being viewed from the perspective of the medical model, and (b) the apparent success of medication with a significant proportion of children with attention deficits.

A great deal of research has been conducted on the effects of stimulant medications on the functioning of children with ADHD. Numerous studies have clearly demonstrated medication-induced, short-term enhancement of behavioral, academic, and social functioning in the majority of children treated

(Barkley, 1991). Psychostimulants, such as Ritalin (methylphenidate), Dexedrine (Dd-amphetamine), and Cylert (pemoline) enhance the action of certain neurotransmitters and are thus thought to stimulate both the reticular activating system and the limbic system, as well as other regions of the brain that are thought to be responsible for attention, arousal, and the inhibitory processes (Anastopoulos, DuPaul, & Barkley, 1991). Anastopoulos et al. (1991) also maintain that these stimulants may lower the central nervous system's threshold for reinforcement. This would explain the behavioral effects of stimulants, where children are able to stay on task for a longer period of time and with greater accuracy.

Numerous studies have also found that psychostimulants improve performance on measures of vigilance, memory, and impulse control, and that they enhance fine motor coordination, reaction time, attention, concentration, and learning (for a review, see Barkley, 1977b; Gadow, 1985). Furthermore, positive drug effects have been obtained on measures of short term-memory and learning of paired verbal or non-verbal material (Swanson & Kinsbourne, 1976). In an earlier review of the literature (Barkley & Cunningham, 1979b), stimulants were found to significantly reduce a number of types of activity, especially in structured, task-oriented situations.

Solanto and Wender (1989) conducted a study using tests of divergent thinking in order to test the effects of stimulant medication on children with attention deficits. The decrease in performance observed on those days when subjects received a placebo suggests that stimulants enable children with ADHD to maintain an optimal level of physiological arousal. On the task used in this study (i.e., the Alternate Uses Test), the performance of ADHD children showed a decline during subsequent sessions. The researchers suggested that this finding provides support for the theory that boredom emerges after repeated exposures to similar tasks, even when such tasks are spaced over weekly intervals. This is also consistent with Barkley's (1991) theory of motivation. Children with ADHD seem to attend well to novel stimuli or when they receive frequent reinforcement but they tire of, or get bored with, tasks more quickly than do other children.

Everett, Thomas, Cote, Levesque, and Michaud (1991) tested 7 children with ADHD (aged 8.5 to 12 years) on two tests. The Wisconsin Card Sorting Test is a neurocognitive test that is sensitive to a functional deficit of the prefrontal cortex, and measures the capacity to shift strategies in response to changing tasks demands, while the Stroop Test is a test of selective attention. The pre-test results showed that the participants displayed significant deficits on both measures. After one year of psychostimulant medication, however, the children showed clinical and neurocognitive improvements, although they continued to display a selective attention deficit relative to regular children. According to the authors, these results suggest that the impact of psychostimulant medication may vary across cognitive functions and underscore the persistence of attentional deficits in children with ADHD.

Difficulty with auditory memory tasks and difficulty following sequential instructions seem to be especially prevalent in children with ADHD (Keith & Engineer, 1991). These behaviors are reflective of an auditory processing disorder and the inability to attend for sustained periods of time has obvious significance for children's social and cognitive development. Keith and Engineer found that when children with ADHD were treated with methylphenidate, a significant improvement was observed in their performance on an auditory continuous performance test and a screening test for auditory processing disorders. They hypothesized that the attentional problems of these children caused them to lose auditory information that was presented at a fast rate. They suggested that classroom management recommendations aimed at enhancing listening opportunities be developed.

Some authors, however, have expressed concern about the academic achievement of children with ADHD who are taking medication for the disorder. The results of different studies have shown that the level of improvement in academic achievement for such children is disappointing (Gadow, 1983). Weiss, Kruger, Danielson, and Elman (1975) conducted a five-year study of children with ADHD, some of whom received methylphenidate or chloropromazine, and some of whom received no medication. The results of this study indicated no significant differences in academic performance between both groups. Barkley and Cunningham (1978) reviewed more than 100 studies on the effects of medication on academic performance and concluded that behaviour appears to improve but cognitive abilities are not enhanced. Two possible explanations for these results involve *state-dependent learning* and *drug dosage levels.*

State-dependent learning refers to the possibility that information learned under the influence of a drug may be recalled with maximum strength only when the drug state is reintroduced (Kirby & Williams, 1991; Overton, 1978; Swanson, Eich & Kinsbourne, 1978; Swanson & Kinsbourne, 1976). The underlying assumption in this explanation is that information, that is learned while a specific drug is present, is lost or partially lost when its retrieval is required in a different state (i.e., in the absence of the drug, at a different dosage level of the drug, or even in the presence of a placebo).

The second possible explanation for the poor academic gains associated with the use of medication involves drug dosage levels. A particular amount of a drug may have a beneficial effect, much less of it may have no effect, and much more of it may have disastrous effects. Some researchers fear that overly large doses of medication may prevent school learning from occurring, even when the child is not restless (Barkley, 1991; Kirby & Williams, 1991).

Sprague and Sleator (1977), for example, investigated the effects of two dosage levels of Ritalin on the ability of children with attention deficit to perform a simple learning task and on their classroom behaviour. The drug dosage levels were .3mg/kg and 1 mg/kg. Learning was measured using a simple short-term memory task in which children were presented repeatedly with a matrix of pictures. After several seconds, they were required to decide if a new picture had or had not previously been present in the matrix. Classroom behaviour was also assessed using the Connors Teachers Rating Scale. Spraque and Sleator's results clearly indicated that learning on the memory task peaked at the dosage of .3 mg/kg and declined at the dosage of 1 mg/kg. Alternatively, teacher ratings of classroom behaviour as being disruptive peaked at 1 mg/kg level. These results suggest that children at the higher dosage were able to sit quietly, but were unable to learn even simple information.

Recent investigations using a wider variety of dependent measures and a wider range of medication dosages indicate that the conclusions derived from Sprague and Sleator's (1977) results may need to be qualified. For example, Rapport, Jones, DuPaul, Kelly, Gardner, Tucker, and Shea (1987) evaluated the individual responses of 42 children with ADHD to several dosages (i.e., placebo, 5 mg, 10 mg, 15 mg, and 20 mg) of methylphenidate that were administered in a randomly determined sequence. Multiple measures were taken across clinic and classroom settings, including performance on a vigilance task, teacher ratings on the ADHD Comprehensive Teachers Rating Scale (ACTeRS; Ullmann Sleator, & Sprague, 1984a), and direct observations of on-task classroom behaviour. From the results of the study, the authors concluded that the responses of individual children to methylphenidate could be categorized as follows: (a) improvement occurred with stepwise increases in dose, (b) improvement is subject to a "threshold" effect at a moderate or high dose, (c) improvement reaches a peak at a moderate dose, with a decrement in performance occurring at higher doses, or (d) improvement is inconsistent across doses.

These results showed that several factors moderate the dosage effects of methylphenidate and related medications on the functioning of children with ADHD. First, despite the fact that rather consistent group-level dose-response findings are obtained across studies, these results are highly variable across individual children and must be assessed at the individual level in order to be clinically useful. Second, dosage effects may vary across areas of functioning but not necessarily in the systematic fashion suggested by Sprague and Sleator (1977). The task specificity of dosage effects also appears to be subject to individual differences.

The aforementioned evidence clearly indicates that drug therapy continues to be a controversial topic. Although psychostimulant treatment may result in clinical improvement, it does not appear that its effects are similar across either subjects or assigned tasks. This suggests that one cannot rely on psychostimulants alone to assess attention and treat hyperactivity; it is also necessary to seek treatments - perhaps of a cognitive-behavioral orientation - that target attentional deficits more specifically.

D. General Conclusions

In studying children with ADHD from the two different perspectives of neuropsychology and cognitive psychology, as they relate to problem-solving, it appears difficult to draw firm conclusions.

The extreme heterogeneity of the ADHD population, age effects, medication effects, the academic standing of subjects, and the different tasks and task demands present must be taken into account before conclusions can be reached.

In general, however, it is clear that there is a trend in the literature to characterize the ADHD population as deficient in executive processes and in generating and applying appropriate problem solving strategies on complex cognitive tasks. For this reason, the cognitive impairments and behavioral symptoms observed in ADHD have often been compared to the symptoms of children with known brain damage, especially damage involving the frontal lobes. Several studies that have been conducted take this position and use instruments that measure attention (e.g., the Continuous Performance Test, the Stroop Test), impulsivity (e.g., Kagan's Matching Familiar Figures Test), and planning (e.g., Porteus Maze). The lack of a theoretical base from which to understand and interpret the cognitive process or processes being evaluated, however, has lead to inconsistencies in the methods used and in data interpretation, and consequently, diminishes the generalizability of the findings of these studies. The heterogeneity of the ADHD population, as well as the other aforementioned problems associated with this population, make it necessary to develop a new theoretical framework for understanding the disorder. For this reason, this study examines the cognitive performance of children with ADHD on a problem solving task using the planning model described earlier. Our hope is that by examining and interpreting the cognitive performance of children with ADHD using this model, it will provide us with clear answers about the intergroup and intragroup differences and similarities in planning for children with attention deficits and children without such deficits.

CHAPTER III

METHODOLOGY

A. Participants

The sample used in this study consisted of two groups: (1) nine Grade 6 students (1 female and 8 males) with a medical diagnosis of attention deficit hyperactivity disorder who attended a regular classroom, and (2) a comparison group of nine Grade six regular students (6 females and 3 males). Four of the participants with ADHD had been diagnosed as having speech delay and language weaknesses and had attended an individualized adaptation program for language development the year before the study. All the participants with ADHD were receiving Ritalin and were on this medication during the testing period. None of the regular children had diagnosed educational, language, or emotional problems. Moreover, none of the participants had problems in terms of doing tasks on the computer. Both males and females were at the same level of proficiency in manipulating the mouse and executing commands on the computer. All participants were volunteers (informed consent was obtained from their parents or guardians, see Appendix B), Caucasian, and spoke English as their first language. Participants came from three schools in the Edmonton Public School district that serves predominantly middle class neighborhoods.

The mean age of the participants with ADHD was 11.41 years (SD = 0.48), and ranged from 11.04 to 12.08 years. The mean age of the regular participants was 11.16 years (SD = 0.33), with a range from 11.01 to 12.03 years. Test results on the Mathematics Achievement Test (MAT), Language Arts Achievement Test (LAT), and Canadian Cognitive Ability Test (CCAT; three categories: Nonverbal

IQ, Verbal IQ and Quantitative IQ), which are administered district-wide, were obtained from the cumulative file of each of the participants. Means, standard deviations (SD), t-values from independent samples t-tests comparing the groups, and effect sizes (d) for group differences in these variables are shown in Table 1.

Independent samples t-tests showed no significant differences between the groups in age or in any of the test scores. Effect sizes (see the data analysis section for details), however, show that the groups were somewhat different for both LAT and CCAT Quantitative IQ scores, with regular students outperforming students with ADHD on both variables.

B. Task

Crack-the-Code is based on the popular Master Mind game and has been used previously by Das, Mensink and Janzen (1990), Parrila et al. (1994) and, Parrila, Papadopoulos and Mulcahy (1995) as a measure of planning. It requires the participant to determine the correct order of colored chips on an answer line on the basis of a limited amount of provided information (see example on the following page). The version used in this study consisted of six items presented on a computer (a Macintosh IIsi with a10 in. color monitor). These six items represented three levels of difficulty. The first two items consisted of two lines of information (or instruction lines) and three chips of different colors. For items 3 and 4, both the number of instruction lines and the number of colored chips was increased to 4. Finally, for items 5 and 6, the number of instruction lines was reduced to 3, while the number of the colored chips remained at 4. Although items 5 and 6 had fewer information lines than items 3 and 4, they have been found to be more difficult in previous studies because of their more open-ended

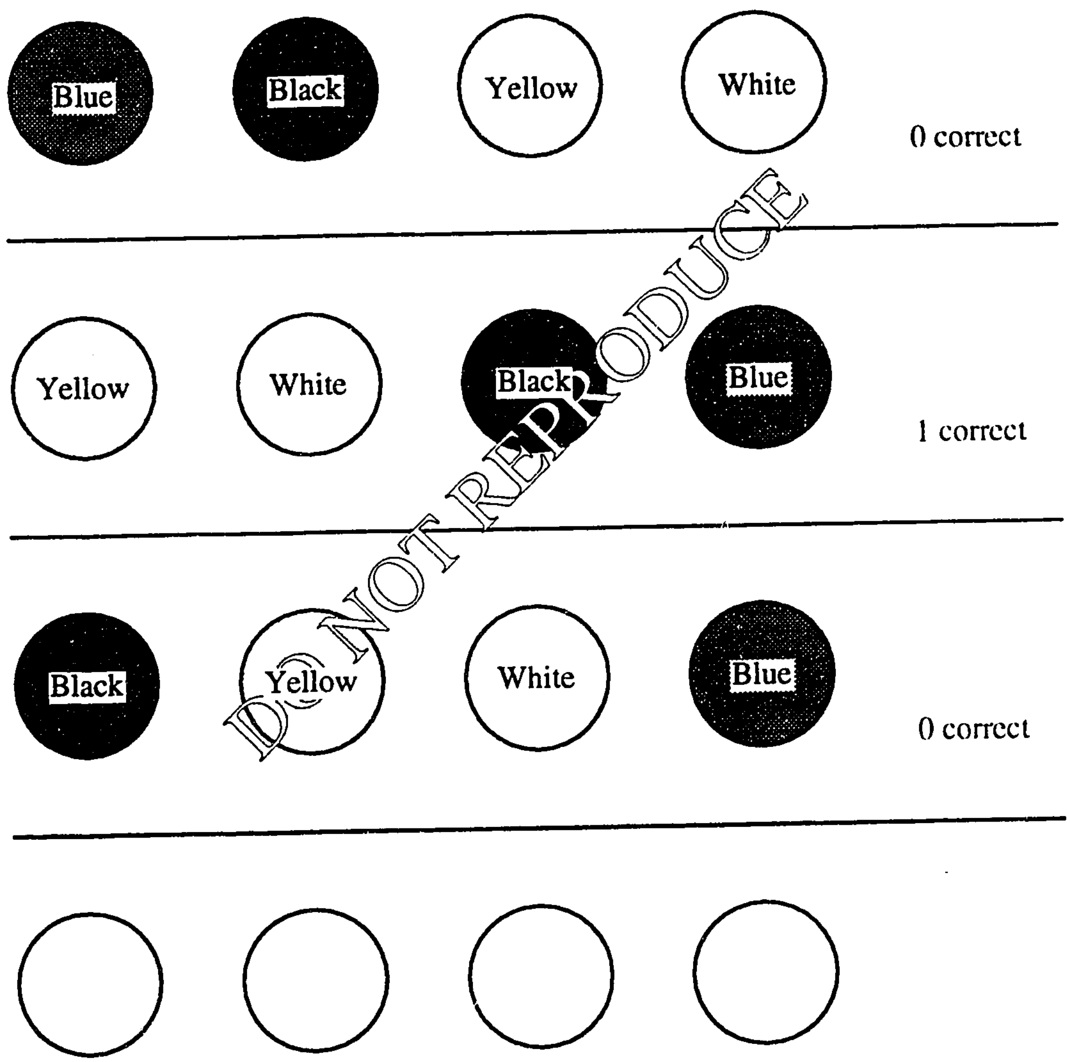
Table 1

Means, Standard Deviations, t-values and Effect Sizes for ADHD and CG groups on age, Mathematics Achievement Test, Language Arts Achievement Test, CCAT Nonverbal IQ, CCAT Verbal IQ and CCAT Quantitative IQ

	ADHD children (N = 9)		Regular children (N = 9)			
	Means	SD	Means	SD	t	d
Age	11.41	0.48	11.16	0.33	1.31	0.62
Math Achievement Test	38.89	7.70	43.67	4.06	-1.65	0.78
Language Arts Ach. Test	39.78	10.53	47.44	3.43	-2.08	0.98
CCAT Non Verbal IQ	102.33	11.73	103.78	10.81	-0.27	0.13
CCAT Verbal IQ	96.44	20.48	107.78	8.10	-1.54	0.73
CCAT Quantitative IQ	102.33	12.62	112.11	9.39	-1.87	0.88

small effect $.2 \le d < .5$
medium effect $.5 \le d < .8$
large effect $.8 \le d < \infty$

CCAT Canadian Cognitive Abilities Test



ITEM 5 of Crack-the-Code

nature.

Item 5 is presented on the previous page. The participants were asked to move the chips that were located in a quasi-random fashion on the left-hand side of the computer screen to the answer line provided at the bottom of the screen. By using the mouse, the colored chips could be dragged anywhere on the screen, as long as the participant did not indicated that the answer line was correct by clicking the "Done" button at the lower left corner of the screen. During performing the task, the computer recorded the time spent by the participant contemplating moves without actually moving the chips (thinking time), the time spent to move and manipulate each chip (dragging time), and provided an accuracy measure (i.e., the number of correct answers). The maximum time allowed for completion of each of the items was 180 seconds.

C. Procedure

The Crack-the-Code task was administered individually to the participants in their respective schools by one of the two experimenters during January and February of 1995. Both experimenters were graduate students in the Department of Educational Psychology at the University of Alberta and were trained to administer the task and to collect verbal protocols. The participants were asked to talk aloud while performing the task and a tape-recorder was used for recording their verbal responses. All of the participants completed the task in one session, which lasted approximately 20 to 30 minutes.

Before the Crack-the-Code task was presented, the participants were trained briefly in thinking aloud and were given the following instructions:

In this experiment I am interested in what you say to yourself as you are doing some problems on the computer. I will ask you to talk aloud as you work on the problems. What I mean by talking aloud is that I want you to say loud everything that you say to yourself silently when you are trying to solve the problem. Just act as if you are alone in the room speaking to yourself. If you are silent for any length of time I will remind you to keep talking aloud. Do you understand what I want you to do?

After the instructions were given, participants were asked to visualize walking in their home and to count the number of windows, they saw and/or to multiply 12 by 3 out loud. If the participants were silent for 10 seconds or more, then they were reminded to keep talking aloud. They were also presented three sample items of Crack-the-Code, during which they were given instructions about the nature of the task, how to manipulate the colors using the mouse, how to use the instruction lines and the goal of the task. This training was followed by the six experimental items. The instructions used for establishing rapport and setting the guidelines for the testing session are available from the author.

D. Data Analysis

The collected data was divided into two groups of measures. *Product* analyses concentrated on numerical data obtained from the participants' computer protocols and *process* analyses concentrated on the think aloud protocols.

1. *Product analysis.* The computerized version of Crack-the-Code collected various types of information regarding participants' performance on each item. The following variables were included in the product analyses:

(a) the number of items correctly answered;

(b) the total length of time to complete each item,

(c) the thinking time, which refers to the amount of time spent contemplating moves without actually moving the chips;

(d) the dragging time (or manipulation time), which refers to the amount of time spent manipulating the chips on the screen;

(e) the first thinking time, which refers to the amount of time spent at the beginning of the item deciding about the first move; and

(f) the evaluation time at the end of the task, which involves the time that elapsed between placing the last chip on the answer line and clicking the "Done" button).

Analysis of Variance was used to compare the ADHD and comparison group on means for the aforementioned variables. Effect sizes (d) were also calculated for all of the differences in group means because the power of the t-tests was relatively low (.66 to find 1 standard deviation difference with a significance level of .10).

The formula used for calculating effect sizes (d) when $n_A = n_B$, $\sigma_A \neq \sigma_B$ and $m_A \neq m_B$ was taken from Cohen (1969, p. 38, 41-42):

$$d = \frac{|m_A - m_B|}{[(\sigma_A^2) + (\sigma_B^2)]^{.5} / 2}$$

where m_A is the mean of the first group

m_B is the mean of the second group

σ_A is the standard deviation of the first group and

σ_B is the standard deviation of the second group

The denominator of this formula expresses an average within-population standard deviation to standardize the difference between the means, given that there is a difference between σ_A and σ_B (Cohen, 1969).

Cohen (1969) offers three conventional operational definitions for use in the effect sizes: "small", "medium", and "large" (pp. 23-25). According to Cohen, these three definitions are relative not only to one other but to the specific theoretical framework and research design employed in any given investigation. Although there is a risk inherent in using conventional terms, he believes that "more is to be gained than lost by supplying a common conventional frame of reference which is recommended for use when no better basis for estimating the effect size index is available" (Cohen, p. 23). Therefore, for the purpose of this study, the terms "small", "medium", and "large" are used with their respective values as follows:

small effect	$.2 \le d < .5$
medium effect	$.5 \le d < .8$
large effect	$.8 \le d < \infty$

2. *Process analysis.* Each of the verbal protocols was transcribed and then divided into "segments" representing an instance of a single decision made by a participant. All analyses were based on a priori item analyses and coding schemes that attempted to cover all possible means of proceeding with an item. Before the actual analyses, the experimenters received training in the use of the analyses schemes. Each protocol was analyzed independently by both experimenters, who then compared their results. In the case of disagreement, consensus was arrived at through negotiation.

The analysis of the verbal protocols was twofold. During the first analysis, decisions were made about the *strategies* used by the participants, whereas during the second analysis, decisions were made about the individual *statements* made by the participants while elaborating on the task (i.e., task definitions, verbalization of decisions or manipulations, evaluation statements, metacognitive statements, confusion statements, etc.).

a. Analysis of Strategies

The following four strategies (or search methods) were determined a priori as possible approaches to solving the Crack-the-Code task:

(1) Trial-and-Error (TE): the participant forms hypotheses without using the given information, uses only selected parts of the information and violates other parts, or creates "own information" that is not relevant.

(2) Climbing: There are three different types of climbing. The first type is based on the idea that the participant uses at least one information line while forming a hypothesis (CL1). The second based on the idea that the participant uses more than one information line while forming a hypothesis (CL2). The third is what we refer to as application error and is present whenever the built hypothesis violates other information lines (CL0).

(3) Pattern (PA): the participant tries to simultaneously locate at least two colors at the same time based on one information line only.

(4) Combination (CO): the participant uses two or more information lines in deciding the correct location of two or more colors.

The Combination statements were also categorized according to the number of colors and information lines attended to while making the decision. Based on this idea, the combination strategies were classified as:

(i) 2 colors x 2 lines (items 1 to 6)

(ii) 3 colors x 2 lines (items 1 to 6)

(iii) 2 colors x 3 lines (items 3 to 6)

(iv) 3 colors x 3 lines (items 3 to 6)

(v) 4 colors x 3 lines (items 3 to 6)

(vi) 3 colors x 4 lines (items 3 & 4)

(vii) 4 colors x 4 lines (items 3 & 4)

b. Application of Strategies

After agreement over search methods was reached between the experimenters, decisions were made about Strategy Application, with regard to the following three categories:

(1) strategy applied as intended to its completion (i.e., the manipulation that follows is a logical consequence of the stated strategy and its application is taken until it is completed);

(2) strategy applied as intended but incompletely (i.e., application of the strategy begins as above but it is abandoned before the strategy is completed); or

(3) error in application (manipulation is not congruent with stated search strategy).

c. Statement Analysis

The coding scheme for statements consisted of seven categories:

(1) Task definition at the beginning of the task refers to the information that the participant attends to at the beginning of the task prior to making any moves. Task definition may include: (a) stating parts of the available information (data statement; DS); (b) limiting the

possible moves by color (noticing the legitimate and illegitimate places for a color; L1) or by spot (noticing the legitimate and illegitimate colors for a spot; L1); (c) limit by line (limits possible moves by combining information from two or more lines; L2); (d) addition of parameters or assumptions (assuming one line is more important or one color is correct, etc.; AA); (e) elaboration of the problem after considering additional information (EP); and (f) evaluation of assumptions without executing a move (EA).

(2) Verbalization of Decisions and/or Moves refers to the information that the participant attends to while defining data for a move or an attempt. All of the elements included in the task definition may also be present in this category. The data statements in this category, however, can be referred to either all of the relevant parameters (DM2) (i.e., number of colors, lines, and infolabels) or to partial parameters (DM1) (i.e., one of the above three). They can also be right (+) or wrong (-). Similarly, the assumptions made for a move may be right or wrong. A new type of statement (CD), where the participant states only the color and destination of the move, was also included.

(3) Evaluation statements refer to the evaluation of the correctness of a partial (EV1) or complete answer (EV2). Both types of evaluations were classified according to their quality: positive/correct (+) or erroneous/misguided (-).

(4) Organization of New Data refers to possible new task definitions after manipulation of chips. The elements used here are the same as in the task definition.

(5) Metacognitive statements that deal with either the task (MS1) (i.e., comparing it to something else) or with the participants themselves (MS2) (i.e., evaluation of their own abilities, limitations, etc.).

(6) Evaluative statements that deal with the task (ES1) (i.e., "This is difficult."), the participant's opinion of the task (ES2) (i.e., "I don't like this"), or performance (ES3) (i.e., "I'm done").

(7) Verbalization of a Strategy occurs whenever the participant verbalizes or selects a method (i.e., "I am going to find the two correct on line 2.").

(8) Confusion statements included statements such as "I don't know", "whatever", and so forth.

All the above categories are available from the author in more details.

d. Error Analyses

Two different types of errors were observed:

(1) Error during manipulations: this type of error was present in single moves while attempting to place the colors on the answer line. On item 5, for example, this error could occur when either (i) violating a "0 correct" line, placing Yellow in spot 3 (L4/0), or (ii) violating the "1 correct" line, placing Blue and White as correct ones (L3/1), or a "2 correct" line, placing 3 correct on the line 2 (L2/2). This type of error was correctable during the performance of the task.

(2) Error in the final answer: this type of error was present in the final answer when errors that have been made before (type 1 errors) had not been corrected. In this case, the final answer may again violate either a "0 correct" line [e.g., by placing Blue at spot 1) (L1/0)], a "1 correct" line [e.g., by placing two correct ones on line 3) (L3/1)]

and/or a "2 correct" line [e.g., by having more than 2 correct chips on line 2) (L2/2)].

Information from search method and statement analyses is presented below in tables. For the most part, no statistical analyses were performed with this information; instead, the analyses aimed at (a) summarizing the defining features of both groups' performance on different items, and (b) comparing the groups in order to find possible consistent differences between them.

CHAPTER IV

RESULTS AND DISCUSSION

A. Product Analysis

The effect of Group (ADHD vs. Comparison) on product measures was assessed by using analysis of variance (ANOVA). For the first two items, Group was used as the only independent variable and different time scores (Performance Time, Thinking Time, Dragging Time, First Thinking Time, and Evaluation Time) were used as dependent variables. On the remaining four items, Accuracy (correct vs. incorrect) was used as a second independent variable in order to determine if there were consistent differences between correct and incorrect performances. Interaction between Group and Accuracy was also computed. Accuracy was not included in the analysis of variance for the first two items because almost all of the participants solved these items correctly. Also, the following tables present only results from the group comparisons. Whenever accuracy comparisons and interaction effects are significant, they are discussed.

1. Performance Time and Accuracy. Table 2 presents the means, standard deviations (SD), $\underline{F}$-values and effect sizes ($\underline{d}$) for the mean differences on the two most commonly used performance measures: performance time (i.e., the time taken to complete the item) and accuracy (i.e., the number of correctly solved items). The number of participants who correctly solved each item is also presented separately for both groups.

The ANOVA indicated no significant differences between the ADHD and the comparison group on any of the six performance times. Significant

Table 2

Means, Standard Deviations, F-values and Effect Sizes for ADHD and CG groups on Performance Time and Number of Correct Items on the six Items of Crack-the-Code: Number of Correct by item

	ADHD children (N = 9)		Regular children (N = 9)			
	Means (SD)	N Correct	Means (SD)	N Correct	F	d
Performance Time						
Item 1	57.78	8	55.38	9	0.01	0.05
	(38.91)		(26.05)			
Item 2	56.28	6	53.17	8	0.05	0.10
	(36.11)		(23.37)			
Item 3	86.71	4	115.84	3	1.61	0.60
	(45.48)		(50.03)			
Item 4	89.46	4	113.56	3	0.74	0.43
	(66.07		(42.99)			
Item 5	76.39	6	84.77	3	0.11	0.19
	(49.98)		(33.31)			
Item 6	69.58	5	83.84	3	1.08	0.31
	(48.76)		(40.72)			
Number of Correct						
Items 1 - 6	3.67		3.22		0.38	0.29
	(1.94)		(0.97)			

small effect .2≤d<.5
medium effect .5≤d<.8
large effect .8≤d<∞

differences were found, however, between correct and incorrect performances on item 4, $F(1,14) = 5.73$, $p = .03$. The participants spent more time working on the incorrect attempts ($M = 125.08$, $SD = 55.31$) than on the correct attempts ($M = 64.46$, $SD = 31.66$). It is interesting to note that these differences did not occur for item 3, which is of similar difficulty. It is possible that practice with item 3 taught the participants to at least determine whether and when they made wrong decisions, if not how to solve those items correctly. Consequently, they were working longer with their incorrect decisions, having an idea that something was wrong with their answers, but being unable to arrive at the correct solution.

The ADHD group tended to perform more quickly than the comparison group on the last four items. On item 3, the difference in the mean performance times was large enough to produce a medium effect size ($d = 0.60$), indicating that the children in the comparison group took considerably more time to complete this item. Table 2 shows that children in the ADHD group were also more successful on these items, particularly on items 5 and 6. Thus, the longer performance times for the comparison group could have resulted from more of the participants in this group not accepting their incorrect answers. The Group X Accuracy interaction, however, was not significant for any of these items.

Both groups produced an almost equivalent number of correct answers over the six items. Children in the ADHD group, however, seemed to be more successful, particularly on the last two items, than the comparison group (11 correct performances and 6 correct performances, respectively). Closer examination of the distribution of correct performances within each of the two groups indicated that there was considerable variance in performance among the participants of the ADHD group, whereas the comparison group seemed to be more homogeneous. Specifically, in the ADHD group, one child produced no correct answers, another child produced one correct answer, four children produced four correct answers, two children produced five correct answers, and one child solved all of the items correctly. In the comparison group, however, the frequencies of correct answers were more normally distributed: Two children produced 2 correct answers, 4 children produced 3 correct answers, 2 children produced 4 correct answers and only one child produced 5 correct answers. None of the children in the comparison group solved all of the six items correctly.

2. Thinking Time and Dragging Time. In order to examine the performance time more closely, it was first divided into two conceptually independent components: Thinking Time and Dragging Time. Thinking Time represents that portion of the total performance time during which a participant is not manipulating the chips. It is assumed here that Thinking Time indicates the amount of time that the participant spends planning in advance or evaluating his or her moves. Dragging Time, in turn, is assumed to represent the amount of time that the participant spends executing his or her plans.

Table 3 shows the means, standard deviations, F-values and effect sizes for Thinking Time and Dragging Time for the six Crack-the-Code items. Because performance times were not equal for both groups, Ratio scores were also calculated by dividing Thinking Time by Dragging Time, thereby providing a more accurate representation of the relationship between thinking and dragging times.

An ANOVA indicated no significant differences between both groups for Thinking Time and Dragging Time on any of the six items. Significant differences, however, were observed for time spent thinking about a plan during correct and incorrect attempts in item 4 [F (1,14) = 5.08, p = .04]. Moreover, thinking time was much greater on the incorrect attempts (M = 83.59, SD = 48.37)

Table 3

Means, Standard Deviations, F-values and Effect Sizes for ADHD and CG groups on Thinking Time, Dragging Time and Ratio Scores [(Thinking Time)/(DraggingTime)] on the six Items of Crack-the-Code

	ADHD children (N = 9)		Regular children (N = 9)			
	Means	SD	Means	SD	F	d
Thinking Time						
Item 1	33.77	32.05	34.22	17.84	0.01	0.02
Item 2	29.33	26.48	36.50	21.58	0.40	0.30
Item 3	54.29	48.68	81.26	41.04	1.48	0.60
Item 4	56.01	57.81	73.31	33.81	0.65	0.36
Item 5	37.41	27.03	54.97	27.70	0.85	0.64
Item 6	38.27	39.30	57.48	36.34	2.11	0.51
Dragging Time						
Item 1	23.31	11.46	21.16	11.20	0.16	0.19
Item 2	26.94	22.38	16.67	9.31	1.62	0.60
Item 3	32.42	21.00	34.59	19.19	0.08	0.11
Item 4	33.44	19.35	40.24	22.85	0.16	0.32
Item 5	38.98	25.52	29.81	14.09	0.27	0.45
Item 6	31.31	14.19	26.37	11.43	0.43	0.39
Ratio Scores						
Item 1	1.49	1.00	1.75	0.99	0.32	0.27
Item 2	1.38	1.01	2.81	2.88	1.99	0.66
Item 3	3.80	7.26	2.72	1.52	0.09	0.20
Item 4	2.02	2.96	2.38	1.79	0.16	0.15
Item 5	0.99	0.43	2.13	1.47	2.52	1.05
Item 6	1.17	0..94	2.38	1.10	5.92*	1.18

small effect $.2 \leq d < .5$
medium effect $.5 \leq d < .8$
large effect $.8 \leq d < \infty$

* $p < 0.5$

than on the correct attempts (M = 34. 91, SD = 24.80). This result clearly contributes to the significant difference between both groups on the Performance Time for item 4, and supports our earlier interpretation.

In general, the comparison group tended to spend more time thinking about a move and less time manipulating the chips on the screen. On items 3, 5, and 6, the differences between the means for Thinking Time were large enough to produce a medium effect size (ds = 0.60, 0.64 and 0.51, respectively). Furthermore, the standard deviations for Thinking Time and Dragging Time suggest that the ADHD group may have been more heterogeneous than the comparison group.

Ratio scores pro[illegible] a somewhat more accurate picture of how participants appro[illegible]k since the effect of total performance time is now controlled. The com[illegible]up displayed a higher ratio score on all but one of the items (item 3). [illegible]er words, they tended to spend more time thinking about the task than they did manipulating the chips, as noted above. The differences between the two groups were significant for item 6 [$F(1,14) = 5.92$, $p = .03$]. It is interesting to note that although the comparison group seemed to approach the last two items in a more thoughtful manner, their performance accuracy was poorer than that of the ADHD group (Table 2). This suggests that the ADHD children may have been successful in planning during action rather than planning before action.

3. First Thinking Time and Evaluation Time. Next, First Thinking Time and Evaluation Time were calculated. First thinking time represents the time that a participant took to define the task environment and to decide about the first move or moves at the beginning of the task (i.e., prior to moving any of the chips). In contrast, evaluation time, in turn, represents the amount of time that a

Table 4

Means, Standard Deviations, F-values and Effect Sizes for ADHD and CG groups on First Thinking Time and Evaluation Time on the six Items of Crack-the-Code

	ADHD children (N = 9)		Regular children (N = 9)			
	Means	SD	Means	SD	F	d
First Thinking Time						
Item 1	17.93	25.23	14.13	9.35	0.18	0.20
Item 2	14.58	14.93	15.00	10.99	0.01	0.04
Item 3	39.52	52.80	25.73	18.15	0.67	0.35
Item 4	19.84	21.95	16.92	14.37	0.05	0.16
Item 5	13.97	12.34	10.98	7.36	0.57	0.29
Item 6	11.71	13.74	18.73	18.10	1.67	0.44
Evaluation Time						
Item 1	3.60	1.98	6.74	5.64	2.49	0.74
Item 2	3.64	3.07	12.88	20.97	1.71	0.61
Item 3	3.10	2.86	14.43	20.70	6.68*	0.77
Item 4	7.19	17.59	9.98	9.38	0.19	0.20
Item 5	6.22	6.54	13.13	12.88	0.93	0.68
Item 6	2.51	2.48	16.27	13.91	6.50*	1.38

small effect $.2 \leq d < .5$
medium effect $.5 \leq d < .8$
large effect $.8 \leq d < \infty$

** $p = .01$

participant took at the end of the task to confirm his or her answer. Thus, differences in both of these measures might indicate different approaches to problem solving. Means, standard deviations, F-values and effect sizes (for both measures) are presented in Table 4 .

Although the ADHD group spent more time thinking prior to the first move on 4 of the 6 items, the differences between both groups (in the First Thinking Time variable) were generally small. Significant group differences however were obtained for the Evaluation Time on item 3, [$F(1,14) = 6.68$, $p = .02$], and item 6, [$F(1,14) = 6.50$, $p = .02$]. This may explain the significant difference between the ratio scores for item 6 (Table 3).

On item 3, significant differences were also obtained between the evaluation times for correct and incorrect attempts, [$F(1,14) = 4.88$, $p = .045$]. In this instance, however, the pattern of results was the opposite of that obtained for thinking time: participants generally spent more time evaluating their answers for correct attempts ($M = 15.57$, $SD = 22.19$) than for incorrect attempts ($M = 4.43$, $SD = 7.66$). Finally, in terms of evaluation time, the Group X Accuracy interaction was also marginally significant, [$F(1,14) = 4.36$, $p = .06$], for item 3. A closer examination of the means within the groups indicated that in the ADHD group, evaluation times for correct and incorrect performances were similar (3.48 and 2.80 respectively), whereas in the comparison group, evaluation times for correct and incorrect performances differed considerably (31.70 and 5.80 respectively).

The remaining differences in evaluation times, although not significant, were large enough for items 1, 2, and 5 to produce medium effect sizes (ds=.74, .61, .77 and .68, respectively). Taken together these results suggest that at the end of the task, the regular children took considerably more time than the ADHD children to evaluate their correct and incorrect answers. It is important to emphasize again that the standard deviations for First Thinking Time and in Evaluation Time for both groups were generally large. For this reason, the evaluation time was re-calculated after excluding the participant from the comparison group, who had the highest evaluation time on five of the six items. As a result, the comparison group means were reduced across all of the items and for two of the items, they were reduced by one half (i.e., for item 2: new M=6.11, SD=5.64 and for item 3: new M=8.76, SD=12.61). The significant difference between both groups on item 6, however, remained the same (p<.01), even after the outlier's performance was excluded from the analysis. In the ADHD group, no single participant was responsible for the large variance; instead, their evaluation times varied considerably from item to item.

For First Thinking Time, however, one participant in the ADHD group clearly obtained highest values across all of the items. After he was excluded from the analysis, the means for First Thinking Time for items 1, 3 and 6 were reduced by approximately one half (i.e., item 1: new M = 9.90, SD = 7,98; for item 3: new M = 22.90 , SD = 18.57; and for item 6: new M = 7.79, SD = 7.57). These differences were not statistically significant but the effect sizes were made somewhat larger (ds=0.50, 0.53, and 0.79, respectively). Moreover, the mean differences were reversed for five of the six items, indicating that the ADHD group spent less time thinking prior to making a move (or moves) than the comparison group.

4. Correlations between Time and Accuracy Measures. Pearson's correlation coefficients were calculated between the time measures (i.e., Performance Time, Thinking Time, Dragging Time, First Thinking Time, and Evaluation Time) - all of which were summed over the six items - and the accuracy score (i.e., the number of correctly solved items) in order to explore whether a particular time

measure was associated with better performance. No significant correlations were observed among these variables.

B. Process Analysis

The results of the process analysis are presented in two sections: (a) an analysis of the search methods (or strategies) applied by the participants and (b) an analysis of the statements made by the participants while they were performing the task. Moreover, the items for Crack-the-Code have been divided into groups consisting of two items (i.e. items 1 and 2, items 3 and 4, and items 5 and 6) based on difficulty level. Participants' performances are also presented individually in order to facilitate a more detailed analysis.

1. Search Methods

Item 1 and Item 2. Table 5 shows the search methods used by the participants on items 1 and 2. The search methods are presented in the order of their application. For example, on item 1, participant A1 first used the Trial and Error search method, followed by the Combination search method (with 3 colors and 2 lines; thus 3x2). Similarly, on item 2, he used only a Combination search method (again with 3 colors and 2 lines). All search methods were applied as the participants intended unless otherwise indicated by the researchers. Table 5 also identifies successful (Pass) and unsuccessful (Fail) performances on items 1 and 2.

All but one of the participants completed item 1 successfully. The most commonly used search methods for item 1 were Climbing, where the participant

Table 5

Strategies applied by the ADHD and the Comparison group participants on the Item 1 and Item 2 of Crack-the-Code

	Strategies			
	Item 1	Pass/ Fail	Item 2	Pass/ Fail
ADHD				
A1	TE/CO(3x2)	P	CO(3x2)	P
A2	CL1/CO(2x2)	P	CO(3x2)	P
A3	CL2/CL1/CL2	P	CO(3x2)	P
A4	CO(3x2)^{I}/CO(3x2)	P	CO(3x2)/CO(3x2)/CO(3x2)	P
A5	CO(3x2)^{E}	F	TE/TE/TE	F
A6	CL1/CL1/CL1	P	CL2/CL1/CL1	P
A7	CL1/CO(2x2)	P	CL2/CL2/CO(2x2)^{E}	F
A8	CL1/CL2/CL1	P	CL0/CL1/CL0/CL1	F
A9	CL1/CL1/CL2	P	CL1^{I}/CO(3x2)	P
Comparison				
B1	CL2/CL2/CL2	P	CL2^{I}/CL1/CO(2x2)	P
B2	CO(3x2)	P	CL0/CL2/CL2	F
B3	CL1/CL1/CO(2x2)	P	CL1/CL1/CO(2x2)	P
B4	CL2/CL2/TE/TE/TE/TE	P	CL2/TE/TE	P
B5	CO(3x2)	P	CO(3x2)	P
B6	CO(3x2)	P	CO(3x2)	P
B7	CO(3x2)^{E}/CO(2x2)	P	CL2/CL2/CL2	P
B8	CL2/CL0/CL2/CL2	P	CL2/CO(2x2)	P
B9	CL2/CL2/CL2	P	CO(3x2)	P

CL1 = Climbing using only 1 information line
CL2 = Climbing using more than 1 information line
CL0 = Climbing violating 1 or more information lines
TE = Trial and Error
CO = Combination (the first number indicates N of colors, the second indicates N of lines used)
I = Incomplete Strategy
E = Error in strategy application

uses one or more information lines while forming a hypothesis to determine the position of a color (used by 11 participants) and Combination where the participant uses two or more information lines to determine the correct position of two or more colors (used by 10 participants). There were small differences between the groups in their use of strategies. The use of Climbing resulted in 4 participants from the ADHD group and 3 participants from the comparison group obtaining a correct solution. Two other children in the ADHD group used Combination successfully, w[illegible] comparison children in the group applied Combination successfully. One participant from the ADHD group (A[illegible]d to produce the correct answer, since his Combination strategy was applied incorrectly. Moreover, 2 children in the ADHD group (A2 and A7) and 1 child in the comparison group (B3) achieved the correct answer by first using the Climbing and then the Combination search method. The Combination strategy used by these 3 children, however, included decisions involving fewer colors (i.e., two colors). Finally, one child in the comparison group (B4) achieved the correct answer by first applying the Climbing and then the Trial and Error search method.

In general, it seems that the most successfully applied strategy for Item 1 was Climbing for the ADHD group and Combination for the comparison group. Both 2x2 and 3x2 Combination strategies were used by both groups, although the comparison group appeared to be more proficient in using the more complicated 3x2 Combination. Moreover, the comparison group produced no incorrect answers using the Combination search method. Also, the Climbing strategies used by the comparison group mainly involved both lines of information, while the Climbing strategies used by the ADHD group mainly used information from one line only.

On Item 2, Climbing and Combination were again the most commonly used strategies (10 and 12 participants, respectively). The exclusive application of Climbing as a strategy resulted in correct only solutions for one child in each group (A6 and B7) and lead 2 other children (A8 and B2) to an incorrect solution. The use of only Combination(s) as a strategy lead 4 participants in the ADHD group and 3 participants in the comparison group to a correct answer, while 4 other participants (A9, B1, B3, and B8) began with the Climbing strategy but changed to the Combination strategy and arrived at a correct solution. Finally, the Trial and Error strategy used in conjunction with the Climbing strategy lead participant (B4) to a correct solution.

Thus, Combination was the strategy that lead participants in both groups to a correct answer most often on item 2. In contrast, on item 1, the ADHD group seemed to use more complex Combinations (3x2), whereas several participants in the comparison group seemed to first limit the search space by Climbing and then using the simpler 2X2 Combination. However, the differences that were observed between both groups in their application of the Climbing strategy on Item 1 remained the same.

Summarizing the above results, we can say that both groups used functional approaches to solve items 1 and 2. However, the comparison group used their search methods somewhat more successfully than the ADHD group and produced more correct answers on both items. Moreover, a small difference was observed between both groups in terms of the level of complexity of the search methods used for item 1 but not for item 2. Five children from the ADHD group and 3 children from the comparison group used a more advanced strategy for item 2 than the strategy they used for item 1, indicating that they may have learned from their early experience. In contrast, 3 participants from the ADHD group and 2 participants from the comparison group used a simpler strategy for item 2 than for item 1, and all but one of these participants failed to solve item 2 correctly.

<u>Item 3 and Item 4</u>. Table 6 displays the search methods applied by the participants while solving items 3 and 4. As the table indicates, these items were considerably more difficult than the first two items. Both items were solved by 4 children in the ADHD group and 3 children in the comparison group.

All possible search methods were used on item 3. The most commonly used method was Climbing (used by 13 participants), followed by Trial and Error (used by nine participants). The Pattern strategy (i.e., where the participant attempts to simultaneously locate at least two colors based on only one information line) which was absent for items 1 and 2, was evident for item 3 and always resulted in an incorrect answer. This occurred because all of the participants, who used Pattern as a search method (A1, B5, B7, and B8), applied it incorrectly. In these cases two different types of errors were observed in the application of the Pattern strategy: participants either (a) placed two chips on the answer line as correct colors for an information line with only one correct color, although they stated that they were looking for only one correct color (e.g., placing Black and Blue as the correct colors on L3 for item 3); or (b) although they assumed that Blue was the correct color on the line containing one correct (L3), they nevertheless placed Black on the answer line.

Two of the 4 participants in the ADHD group who solved item 3 correctly (A2 and A4) used Combination as their sole search method, while a third participant (A9) used the Combination strategy after first determining the position of one of the colors by using the Climbing strategy. This shift from a Climbing to a Combination strategy was also used by 2 participants in the comparison group who solved this item correctly (B1 and B3). These 3

Table 6

Strategies applied by the ADHD and the Comparison group participants on the Item 3 and Item 4 of Crack-the-Code

	Strategies			
	Item 3	Pass/ Fail	Item 4	Pass/ Fail
ADHD				
A1	CL2/CL1/TE/PA^{E}	F	CL2/CL1/CL1/PA	P
A2	CO(4x4)	P	CL2/CL2/CL2/CL2	P
A3	CL2/CL0/CL1/TE	F	PA/CO(2x2)	P
A4	CO(4x4)	P	CL2/CO(3x4)	P
A5	TE/TE/TE/TE	F	TE/TE/TE/TE	F
A6	CL1/CL2/CL1/TE/CO(3x2)^{E}	F	CL1/CL1/CL0/CL1	F
A7	CL2/CL2/CL2/CL1	P	CL2^{I}/CL2/CL0/CL1^{I}/CL2	F
A8	CL1^{I}/CL1^{I}/CL1^{I}	F	CO(4x4)^{I}	F
A9	CL2/CO(3x4)	P	CL1/CL1^{I}/CL0/TE/TE/PA^{E}	F
Comparison				
B1	CL2/CL2/CL0/CL1/CO(3x2)	P	CL0/CL1^{I}/CL0/TE/CL2/PA^{E}	F
B2	TE/TE/TE/TE	F	CL0/CL1/CL0/PA^{E}/PA^{E}	F
B3	CL2/CL2/CO(2x2)	P	CL2/CL2/CO(2x2)	P
B4	TE/CL2/CL2^{I}/TE/TE	P	TE/TE/TE/TE/CL1/CL0/TE/ TE/CL2/CL0	F
B5	TE/PA^{E}/TE	F	CL2/CL2/PA^{E}/CO(3x4)	P
B6	CL1/CL1/TE/TE	F	CL2/PA^{E}	F
B7	PA^{E}/TE/TE/CL2/TE	F	CL2^{I}/CL2/CL2^{I}/CL2/CL2	P
B8	CL2/PA^{E}	F	CL2/CL2/CL2^{I}/CL0/CL2	F
B9	CL2^{I}/CL0/CL2^{I}/CL2^{I}	F	CL2/CL2/CL0/CL1/CL1/ CL1/PA	F

CL1 = Climbing using only 1 information line
CL2 = Climbing using more than 1 information line
CL0 = Climbing violating 1 or more information lines
TE = Trial and Error
CO = Combination (the first number indicates N of colors, the second indicates N of lines used)
PA = Pattern
I = Incomplete Strategy
E = Error in strategy application

participants may initially have been unable to deal with the large search space (defined by four colors and four lines of information) but managed to reduce it to a more manageable size by first using the Climbing strategy. The fourth child in the ADHD group who was able to provide the correct answer for item 3 (A7) worked exclusively with the Climbing strategy. In terms of the third successful performance in the comparison group (B4) on item 3, it appears to have been based on luck, since it was the result of a Trial and Error search method. It is also important to note that the Combination search methods used by the ADHD group (i.e., 3x4 and 4x4) were more advanced than the Combination search methods used by the comparison group (i.e., 3x2 and 2x2).

The results for item 3 *generally* suggest that most of the participants experienced difficulties with this item because of both its complexity and the quantity of information present. Participants in the ADHD group mainly applied different types of Climbing strategies to complete this item, while several participants in the comparison group relied on the Trial and Error strategy for their decisions.

Two of the participants in the ADHD group and 1 of the participants in the comparison group who correctly solved item 3 also correctly solved item 4. A Climbing strategy was by far the most commonly used approach on item 4, (used by 15 participants) followed by Pattern (used by 8 participants) and Combination (used by 5 participants) strategies. Three of the seven correct performances involved using only the Climbing strategy while the other four performances included the Combination strategy as the final strategy in the sequence.

The application of the Climbing search method failed to produce a correct answer for 2 of the participants in the ADHD group (A6 and A7) and 1 participant in the comparison group (B8). An incompletely executed

Combination strategy resulted from a participant (A8) running out of time, before successfully locating all of the colors. In all but one case (A1), participants who used Pattern as their final strategy were unable to arrive at the correct solution. Moreover, all of the participants who used the Pattern strategy ultimately reproduced either the line with two correct colors (participants A9, B2, and B5) or the line with one correct color (participants B1 and B6), thereby resulting in an incorrect answer. The Trial and Error search method was also used by participants in both groups but did not lead to any correct answers.

Generally, the performance of the two groups on items 3 and 4 could be characterized as follows: (1) the majority of the children in both groups failed to complete these difficult items, with children in the ADHD group being somewhat more successful than children in the comparison group; (2) the comparison group was more persistent, particularly on item 4, in terms of the number of decisions made prior to accepting an incorrect answer or running out of time; and (3) the ADHD group seemed more proficient in using Combinations, the most difficult search method.

<u>Item 5 and Item 6.</u> Table 7 displays the search methods used for items 5 and 6. The ADHD group produced more correct answers on both items than the comparison group. Specifically 6 children, in the ADHD group, produced the correct answer on item 5 and 5 children produced the correct answer on item 6, while only 3 children in the comparison group arrived at the correct answer on both items.

Climbing and Trial and Error were the most commonly used search methods for item 5 (16 participants and 8 participants respectively). It is also noteworthy that the Pattern strategy was used by 4 children in the comparison group (B3, B4, B5, and B6) and that it was most often applied incorrectly (B3, B4,

Table 7

Strategies applied by the ADHD and the Comparison group participants on the Item 5 and Item 6 of Crack-the-Code

	Strategies			
	Item 5	Pass/ Fail	Item 6	Pass/ Fail
ADHD				
A1	CL1/CL2/CL2/CL1	P	CL2/CL2/CL2/CL2	P
A2	TE/TE/TE/TE/CL2/TE/TE/ TE/TE/TE/TE/TE	P	TE/TE/TE/TE/TE/CL2/ CL2/CL2/CO(3x2)	P
A3	CL2/CO(4x3)	P	CL2/TE/TE/TE/TE/TE/TE/ TE/TE/TE/TE/TE	F
A4	CL2/CL1/CL2/CL2/CO(4x3)	P	CL1/CL2/CO(2x3)^{E}	F
A5	TE/TE/TE/TE	F	CL1/TE/TE/TE	F
A6	CL1/CO(3x3)	P	CO(4x3)	P
A7	CL1/CL1^{I}/CL2/CO(3x3)	P	CL2/CL2/CL2/CL2	P
A8	CL2/TE/TE/TE	F	CL1/CL1/CL2/TE/TE/TE	F
A9	CL1/TE/TE/CL1	F	CL1/CL1/CL1/CL1/CO(2x3)	P
Comparison				
B1	CL2/CL1/CL1/CL1	P	CL2/CL2/CL2/CL2	P
B2	TE/CL1/CL1/CL1	P	CL1/TE/TE/TE	F
B3	CL1/CL1/PA^{E}	F	CL1/CL1/CL0/CL1	F
B4	TE/TE/TE/TE/TE/TE/PA^{E}	F	PA^{E}	F
B5	CL1/PA^{E}	F	CL1/CL1/CL1/TE/TE/TE	F
B6	CL1/PA^{E}/TE/PA^{E}	F	CL1^{I}/CL1/PA^{E}	F
B7	CL2/CL2/CL0/CL2/TE	F	CL1/CL1/CL1^{I}/CO(4x3)	P
B8	CL2/CL2/CL2^{I}/CL0/CL2	F	CL2/CL0/CL2^{I}/CL0/CL2/ CL2/CL2	P
B9	CL1/CL1/CL1/CL0/CO(4x3)	P	CL1/CL1/CL1/TE/CL1	F

CL1 = Climbing using only 1 information line
CL2 = Climbing using more than 1 information line
CL0 = Climbing violating 1 or more information lines
TE = Trial and Error
CO = Combination (the first number indicates N of colors, the second indicates N of lines used)
PA = Pattern
I = Incomplete Strategy
E = Error in strategy application

B5, and B6). Participant B6, who used the Pattern strategy twice, had an error in application on his first attempt and then reproduced the line containing one correct color on his second attempt. Finally, none of the participants used only the Combination strategy, but when used in conjunction with Climbing, it resulted in 4 children from the ADHD group and 1 child from the comparison group (B9) arriving at the correct solution. That is, all children who used the Combination strategy also solved the item correctly. Three participants (A1, B1, and B2) obtained the correct solution mainly by using the Climbing strategy, whereas participant A2 used mostly Trial and Error yet solved item 5. In contrast, in two other cases (A8 and A9), this shift from the Climbing to the Trial and Error strategy and vise versa, was not successful.

In general, the extensive use of the simplest search methods (Climbing and Trial and Error) suggests that the majority of participants reacted to the complexity of this item by attending to a very limited amount of information at any given time.

Four of the 6 participants in the ADHD group who solved item 5 correctly, also solved item 6. One of them (A1) used the same search method for both items (i.e., Climbing), while 2 other participants used part of the search methods they employed for item 5. Specifically, participant A6 used a more advanced Combination (4x3), while participant A7 used only Climbing. The Trial and Error search method lead participant A2 to adopt the Climbing search method and then replace it with the Combination search method in arriving at the correct answer. Finally, participant A9 answered item 6 correctly using Climbing in conjunction with Combination. Climbing was again the most common search method (used by 16 participants), resulting in 2 children from the comparison group obtaining the correct solution (B1 and B8). The third child in the comparison group who solved item 6 correctly (B7) also used Climbing in conjunction with Combination. Trial and Error was also used frequently (by 7 participants), while the Pattern strategy again failed to result in any correct answers, since its use lead to reproduction of the line with the single correct color chip. *Again, children in the ADHD group* seemed more capable than their regular peers of using the Combination search method (i.e., it was used successfully by 3 children in the ADHD group, as compared to 1 child in the comparison group).

2. Statement Analysis

The analysis of the statements made by the participants while solving each of the six Crack-the-Code problems are presented in six different tables. Each table is divided into two pages in order to accommodate all of the necessary data for both groups. Statements are presented for each participant in numerical order so as to show their actual sequence and how this sequence facilitated (or failed to facilitate) the individual's performance. Moreover, it should be noted that if similar statements were produced several times, they were only marked as a single occurrence. For example, in cases where three or four consecutive statements were different from one other (e.g., limit by spot, limit by line, add assumptions, and color and destination stated) they were indicated separately in the table. In cases, where consecutive statements were the same (e.g., color and destination were stated four times in a sequence) they were included only once in the table. It should also be noted that all the abbreviations used in the tables are explained in the notes following each table.

Items 1 and 2.

Items 1 and 2 consisted of three colors and two information lines, making them the easiest items. Moreover, because they were similar to the last practice item, the participants had experience with this level of problems prior to attempting item 3.

Item 1. The statements made by the participants while completing item 1 are presented in Table 8. The first half of Table 8 displays the statements made by the ADHD group, while the second half of the table displays the statements made by the comparison group.

All but 1 of the participants in the comparison group (B1) verbalized a task definition at the beginning of Item 1. They either stated existing data (B2, B3, B5, B6, B7, B7), added assumptions (B4), or limited the search space by defining legitimate/illegitimate colors for a position or positions for a color (B4) or combining information from both lines (B4, B7, B8). In contrast, only 4 participants in the ADHD group produced a task definition at the beginning of item 1. Three of these participants added assumptions prior to their first move and 2 of these 3 participants also evaluated their assumptions (A4 and A8). Participant A5 also elaborated on the problem after noticing additional information, although this elaboration did not lead him to arrive at the correct answer.

Two children from the ADHD group directly proceeded to state the colors that they were about to work with and the destinations of their moves (A1 and A2), while 4 other participants from this group made assumptions while trying to define data for a move (A6, A7, A8, and A9). Three of the 5 ADHD

Table 8

Statements Analysis for Item 1 of Crack-the-Code

	Pass/ Fail	Statements - Item 1: Task Definition		Statements - Item 1: Verbalization of Decisions and/or Moves			Evaluation	Other
ADHD Group								
A1	P			1. CD	3. CD		2. EV1(+)	
A2	P			1. CD	2. L1	3. CD		
A3	P	1. DS	2. L2	3. CD	4. DS			
A4	P	1. L1 2. DS	3. AA 4. EA	5. DS	6. L1	7. L2 8. IM		
A5	F	1. L1	2. EP 3. AA	4. CD				
A6	P			1. AA	2. CD	4. CD	3. EV1(+)	
A7	P			1. AA	2. L1	3. DS		
A8	P	1. DS	2. AA 3. EA	4. AA	5. CD			
A9	P			1. AA	2. CD	6. L1 7. L2	3. EV1(+)	4. CO 5. ND

(Table 8 is continued)

Table 8 (continued)

		Statements - Item 1						
	Pass/ Fail	Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
Comparison Gr.								
B1	P			1. L1				
B2	P	1. DS		2. CD				3. CO
B3	P	1. DS		2. CD	4. CD		3. EV1(+)	
B4	P	1. AA	2. L1 3. L2	4. L1	5. CD		6. EV2(+)	
B5	P	1. DS		2. AA	3. CD			
B6	P	2. DS		3. CD				4. CO 1. RS
B7	P	1. DS	2. L2	3. DS	4. CD	6. DS	5. EV2(+) 7. EV2 (-) 8. EV2 (+)	
B8	P	1. DS	2. L2	3. L1	4. AA 5. L1	6. AA 8. CD	7. EV1(+) 9. EV2(+)	
B9	P	1. L2	2. EP	3. L1	4. CD		5. EV2(+)	

DS = Data Stated; L1 = limit by color or by spot; L2 = limit by line; AA = add assumptions/parameters; EP = elaboration on the problem after adding information; EA = evaluation of assumptions; CD = only color and destination stated; IM = implications of a move EV1 = evaluation of a partial answer; EV2 = evaluation of a complete answer; CO = confusion; RS = regulative statements (i.e., metacognitive or evaluative statements); VS = verbalization of strategy; ND = new task defintion/all the previous types in the first task definition applied; (+) = correct; (-) = incorrect

participants who did not define data at the beginning of the task controlled their performances during the task by evaluating partial answers.

Five participants from the comparison group continued to attempt to find the legitimate places for their colors prior to proceeding with moves (B4, B5, B7, B8, and B9). Participant B8 built assumptions that were incorrect but the evaluation of his answer appeared to assist him in ultimately determining the correct answer. Moreover, the ADHD group verbalized their evaluations less often than the comparison group (3 cases vs. 5 cases, respectively), while B7 and B8 evaluated their answers more than once. Finally, there was not a significant difference between both groups in terms of displaying confusion (B2, B6, A9) or verbalizing new data after a move or moves (only A9 did this).

In sum, it seems that the comparison group verbalized limiting the search space and defining data for a move more so than the ADHD group. Moreover, the participants in the ADHD group did not evaluate their progress and their answers as much as the participants of the comparison group.

Item 2. Table 9 shows the statements made by the participants while performing item 2.

With the exception of participant B1, the children in the comparison group who verbalized a task definition in item 1 did the same in item 2. In contrast, only 4 participants in the ADHD group verbalized task definitions. Three participants from the comparison group (B5, B6 and B8) and 2 participants from the ADHD group (A3 and A9) limited the search space, whereas the others mainly just stated existing information (e.g., which line contained 1 correct color).

Five participants in the ADHD group (A1, A2, A5, A6, and A7) and 1 participant from the comparison group (B1) started by defining data for a move or by directly verbalizing the color that would be placed in a particular location.

Table 9

Statements Analysis for Item 2 of Crack-the-Code

		Statements - Item 2						
	Pass/ Fail	Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
ADHD Group								
A1	P			1. CD				2. VS
A2	P			1. CD				2. RS
A3	P	1. DS	2. L1	3. L2	4. CD			
A4	P	1. DS		3. L1	4. L2	5. IM 6. L1	7. EV2(+)	2. RS
A5	F			1. CD				
A6	P			1. L2	2. AA	3. CD		
A7	F			1. AA	4. L1	6. CD 7. DS	2. EV1(+) 5. EV1(-)	3. RS
A8	F	1. DS		2. CD	4. CD		3. EV1(+)	
A9	P	1. L2	2. AA 3. EA	4. AA	5. CD		6. EV1(+)	

(Table 9 is continued)

Table 9 (continued)

	Pass/ Fail	Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
Comparison Gr								
B1	P			1. L2	2. DS	3. CD 4. DS		
B2	F	1. DS		2. DS			4. EV2(-)	3. CO 5. CO
B3	P	1. DS		2. CD	4. CD		3. EV1(+)	
B4	P	1. DS		2. L1	3. [illegible]		4. EV2(+)	
B5	P	1. [illegible]		2. AA	3. [illegible]			
B6	P	2. L2		4. CD				1. RS 3. CO
B7	P	1. DS	2. L2 3. EP	4. L1	6. L2		5. EV1(+) 7. EV2(+)	
B8	P	1. DS	2. AA 3. L2	4. L1	5. DS			
B9	P	1. DS	2. L2 3. EP	4. CD	5. L2		6. EV2(+)	

DS = Data Stated; L1 = limit by color or by spot; L2 = limit by line; AA = add assumptions/parameters; EP = elaboration on the problem after adding information; EA = evaluation of assumptions; CD = only color and destination stated; IM = implications of a move EV1 = evaluation of a partial answer; EV2 = evaluation of a complete answer; CO = confusion; RS = regulative statements (i.e., metacognitive or evaluative statements); VS = verbalization of strategy; ND = new task defintion/all the previous types in the first task definition applied; (+) = correct; (-) = incorrect

This latter approach was more prevalent with the participants in the ADHD group, while participants in the comparison group seemed to use more limiting statements or to verbalize existing data while deciding on the next move.

Only 1 child in the comparison group (B1) but 4 children in the ADHD group (A1, A2, A5, and A6) failed to evaluate their answers in any way. The remaining 5 children in the comparison group and the remaining 3 children in the ADHD group used both task definitions and evaluations of partial or complete answers. One child in each group produced an incorrect evaluation (A7 and B2), which lead them to accept a false answer. Finally, only 1 child in the ADHD group (A7) regulated his performance by evaluating partial answers during his performance. His evaluations, however, did not result in a correct answer because the second evaluation was incorrect.

To summarize, it appears that in terms of their performance on item 2, there were some differences between both groups with respect to the task definitions used to limit the search space. Participants in the comparison group used more task definitions at the beginning of the item (8 cases) than did the children in the ADHD group (4 cases). Another difference between both groups was that most of the ADHD participants who did not verbalize a task definition also did not evaluate their answers (4 cases). In comparison, only 1 child in the comparison group approached item 2 in this way.

Comparison of Items 1 and 2. The performance of the ADHD group appeared to change from item 1 to item 2, while the performance of the comparison group appeared to remain relatively consistent. On item 1, none of the children in the ADHD group used both task definitions and evaluations, while on item 2, 3 of these children followed this route. Moreover, on item 1, only 2 participants in the ADHD group used task definition at the beginning of the task or evaluated their partial or complete answers. On item 2, 4 children from this group used this actions, indicating that they exerted more control over the problem solving process.

These differences between both groups indicate that the participants in the comparison group were more aware of the importance of evaluating their answers and ensured that their answers were correct prior to clicking the "Done" button. Moreover, these differences in approaching the first two items suggest that participants in the comparison group often used a greater number of alternatives (i.e., task definitions, limit of the search space, and evaluation statements) in controlling their performance than did participants in the ADHD group.

Items 3 and 4.

Items 3 and 4 are more difficult than the first two items, since both the number of colors and the number of information lines are increased. Each item consists of four colors and 4 four information lines (with one information line having 2 correct colors, one line having one correct color, and two lines having no correct colors). These items can be solved rather easily if the participant limits the search space by combining information from the "2 correct" and "0 correct" lines. Thus, these items favor an approach that is based on building a systematic representation of the available information rather than "jumping into action."

Item 3. The statements made by the participants in both groups while solving item 3 are displayed in Table 10.

Six participants from the ADHD group and 7 participants from the comparison group verbalized task definitions. The increased verbalization of

Table 10

Statements Analysis for Item 3 of Crack-the-Code

	Pass/ Fail	Statements - Item 3 Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
ADHD Group								
A1	F	1. DS		4. CD	6. CD		5. EV1(+)	
A2	P			1. CD				
A3	F	1. DS		2. L1	3. CD	5.CD	4. EV1(-)	
A4	P	1. DS	2. L1 3. L2	4. AA	5. DS	6. CD		
A5	F	1. DS	2. AA	3. CD				
A6	F			1. AA 4. CD	2. DS 6. CD	3. L1 8. CD	5. EV1(+)	7. RS
A7	P	1. DS		3. CD 7. DS	4. AA 8. CD	6. L2	5. EV1(+)	2.VS
A8	F	1. DS		3.CD				2. CO 4. CO
A9	P			1. L2	2. AA	3. CD 4. DS		

(Table 10 is continued)

Table 10 (continued)

	Pass/ Fail	Statements - Item 3: Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
Comparison Gr								
B1	P			1. L1	2. CD	4. L2 6. CD	3. EV1(+) 5. EV1(-) 7. EV2(+)	
B2	F	1. DS		3. CD	6. CD		7. EV2(-)	2. CO 4. ND 5. CO 8. CO
B3	P	1. DS		2. CD	3. DS	4.CD	5. EV2(+)	
B4	P			1. AA	5. L2 6. L1	9. CD	2. EV1(+) 4. EV1(+) 7. EV1(-) 8. EV1(+) 10. EV1(+)	3. ND/L2
B5	F	1. DS		2. AA	3. CD	4. DS 5. CD		
B6	F	1. DS		2. AA	3. CD	5. CD	4. EV1(+)	
B7	F	1. DS	2. L2 3. L1	4. CD	6. CD	8. L1	5. EV1(+) 7. EV1(+) 9. EV2(-)	
B8	F	1. DS	2. L1 3. EP	4. L1	5. AA	7. IM		6. VS
B9	F	1. DS	2. L1	3. DS 8.CD	6. CD 11. L1	7. L1	4. EV1(+) 9. EV1(+)	5. ND/L2/L1 10. RS

DS = Data Stated; L1 = limit by color or by spot; L2 = limit by line; AA = add assumptions/parameters; EP = elaboration on the problem after adding information; EA = evaluation of assumptions; CD = only color and destination stated; IM = implications of a move EV1 = evaluation of a partial answer; EV2 = evaluation of a complete answer; CO = confusion; RS = regulative statements (i.e., metacognitive or evaluative statements); VS = verbalization of strategy; ND = new task defintion/all the previous types in the first task definition applied; (+) = correct; (-) = incorrect

task definitions is easy to understand given that item 3 has both more colors and more information lines than either items 1 or 2. Thus, when the participants see item 3 for the first time, it may appear overwhelmingly confusing. Four participants from both groups attempted to understand the task by stating some of the information out loud (e.g., which lines had 2, 1, or no correct). One participant from the ADHD group and 3 participants from the comparison group also verbalized their attempts to limit the search space, by either position or color (e.g., B8 and B9 attempted to decide which position would be legitimate for a color or which colors would be legitimate for a position), or in addition to this, by combining information from at least two separate lines (A4 and B7). Participant B8 elaborated on each subsequent move after limiting her search space by color (i.e., "So if the Yellow is in the wrong place in one place then I know that either the Blue or the Yellow is wrong in another."). In contrast, participant A5, made assumptions before proceeding to his first move, but this move was incorrect, thereby leading him to incorrect decisions and subsequent failure on this item.

Four of the 6 participants in the ADHD group (A1, A5, A7, and A8) who verbalized a task definition proceeded to verbalize the colors that they were about to manipulate and the positions where they would place them. The remaining 2 participants (A3 and A4) proceeded to define data for the first move after defining the task. The 3 participants in the ADHD group (A2, A6, and A9) who did not verbalize a task definition approached the task somewhat differently. A2 simply stated the position in which each of the colors would be placed, whereas participant A6 began the item by making assumptions (i.e., "I think that the correct one on this line is Blue.") and attempting to define data for each subsequent move. Finally, participant A9 used a limit by line approach to determine his first move.

Only 3 of the 7 children in the comparison group who verbalized a task definition began moving the colored chips immediately after the first task definitions (B2, B3, and B7). The other four children continued to limit the search space prior to their first manipulations. The remaining 2 children in this group began by defining data for a move (i.e., limiting the search space or making assumptions about possible positions). Both of them were able to produce correct answers. These positive performances could, however, be due to the fact that they evaluated their answers, both partial and complete ones several times. In fact, participant B4 evaluated his answers more often than other participants.

Although the first two categories (task definitions and verbalization of moves) indicated relatively small differences between both groups, considerably larger differences were observed between the groups in terms of particip[illegible] evaluation of their answers. All but 1 of the participants in the comparison group (B5) evaluated their decisions during or at the completion of the item. In contrast, only 4 participants in the ADHD group evaluated partial answers while solving the item and none of them finished their performance in evaluation of a complete answer. In terms of actual group frequencies for verbalizing evaluations, participants in the comparison group verbalized an Evaluation statement a total of 16 times (12 of which were correct), while participants in the ADHD group verbalized an Evaluation statement a total of four times (three of which were correct).

Finally, confusion was evident for only 1 participant in each group (A9 and B2), who also failed to produce a correct answer. Similarly, regulative statements were made by only 1 participant in each group, while 3 participants in the comparison group used new task definitions to arrive at the correct answer.

In sum, the main difference between both groups on item 3 once again involved the use of evaluation as a means of exerting control over one's performance. As mentioned earlier, participants in the comparison group verbalized considerably more evaluative statements than participants in the ADHD group.

In terms of correct answers on item 3, it is difficult to relate successful performances to any particular approach. It does seem, however, that the largest number of correct answers (three of the seven correct answers in both groups) were achieved by children who regulated their performance by using both task definitions and evaluations (A7, B3, B4). Two other participants (A4 and B1) were able to produce correct answers by using either task definition or evaluation. Nevertheless, 2 children, both from the ADHD group, (A2 and A9) were able to solve item 3 successfully without using task definitions or evaluating their decisions.

Item 4 Table 11 shows the statements made by the participants while they performed item 4.

Seven children from the ADHD group and 6 children from the comparison group used task definitions at the beginning of item 4. Most of these task definitions consisted of stating existing information. In the comparison group, only B7 and B8 limited their search space by color and line, respectively. In contrast, 3 children in the ADHD group used the most effective means of limiting their search space, that is, limit by line (e.g., "Blue can't go on the third space because first says two correct and then it says one correct, but then is another one with the same spot and it says zero correct, so it can't be."). Another participant from the ADHD group (A5) stated information and then made assumptions about possible moves.

Table 11

Statements Analysis for Item 4 of Crack-the-Code

	Pass/ Fail	Statements - Item 4: Task Definition		Statements - Item 4: Verbalization of Decisions and/or Moves			Statements - Item 4: Evaluation	Statements - Item 4: Other
ADHD Group								
A1	P	1. DS		2. CD	4. CD		3. EV1(+)	
A2	P			1. AA	2. L1	3. DS 4. L1		
A3	P	1. DS		2. AA	3. CD	4. L1 5. CD		
A4	P	1. DS	2. L2	3. AA	4. L2	6. L2		5. RS
A5	F	1. DS 2. AA	3. DS 4. AA	5. CD				
A6	F			1. AA	2. CD			
A7	F	1. DS	3. L2	4. DS 7. CD	5. L2 9. DS	6. DS	8. EV1(-) 11. EV1(+)	2. VS 10. RS
A8	F	1. DS	2. L2 3. DS	4. DS	6. L2	7. DS 9. AA		5. VS 8. VS
A9	F	1. DS		2. AA 4. CD	6. AA 8. CD	11. CD	7. EV1(+) 9. EV1(+) 12. EV2(-)	3. CO 5. VS 10. ND 13. CO 14. RS

(Table 11 is continued)

Table 11 (continued)

	Pass/ Fail	Task Definition	Verbalization of Decisions and/or Moves	Evaluation	Other
Comparison Gr					
B1	F		1. L1 2. CD 4. CD 6. CD	3. EV1(+) 5. EV1(-) 7. EV2(-)	
B2	F	1. DS 3.DS	4. DS 6. DS 7. CD 8. AA	5. EV1(-) 9. EV2(-)	2. CO
B3	P	1. DS	2. CD 4. CD	5. EV1(+)	3. NDa/DM1
B4	F		1. AA 3. L1 5. CD 7. CD 8. L1	2. EV2(+) 4. EV2(-) 6. EV2(+) 9. EV2(+)	
B5	P	1. DS	2. DS 3. AA 4. DS 5. AA 6. CD 8. DS 9. CD	7. EV1(+) 10. EV2(+)	
B6	F		1. DS 2. AA 3. CD	4. EV2(-)	
B7	P	1. DS 2. L1	3. L1 4. DS 5. IM 6. CD 7. DS		
B8	F	1. DS 2. L2	3. L1 4. L2 6. AA 5. L1 7. CD		
B9	F	1. DS	2. AA 3. L1 4.CD 6. DS 7. CD 8. L2 9. CD	5. EV2(+)	

DS = Data Stated; L1 = limit by color or by spot; L2 = limit by line; AA = add assumptions/parameters; EP = elaboration on the problem after adding information; EA = evaluation of assumptions; CD = only color and destination stated; IM = implications of a move EV1 = evaluation of a partial answer; EV2 = evaluation of a complete answer; CO = confusion; RS = regulative statements (i.e., metacognitive or evaluative statements); VS = verbalization of strategy; ND = new task definition/all the previous types in the first task definition applied; (+) = correct; (-) = incorrect

Two of the participants in the ADHD group who used task definitions proceeded to state colors and the destinations of these colors (A1 and A5). The remaining 5 participants in this group continued to build their representations either by making assumptions about the possible positions for colors (e.g., "That's correct so I think that the Yellow would go here.") or by defining data for a move (e.g., "They've got two correct here and there are yellows in the same spot; one says one correct and the other says two correct; I think that yellow would go to the second space."). Only 1 child in the comparison group (B3) proceeded from task definition to moving colors to their positions. Four other participants in this group proceeded from task definitions to defining data for the first move, while a fifth participant changed from task definition to assumption statements.

Both groups used an equal number of *assumptions* (i.e., seven assumptions) while atter tir g to define data for a subsequent move. The large number or assumptions made, while attempting to solve item 3, may have been due to the difficulty of this item. Moreover, the participants likely realized the difficulty of handling all of the information provided. Instead of realizing that both items allow efficient limiting of search space by combining information f· ·m different lines, they attempted to limit the search space by making a· ·umptions. These assumptions, however, were often incorrect and the number of correct performances did not increase from item 3 to item 4.

Again, as on item 3, a clear difference was observed between the two groups in terms of verbalizing *Evaluation* statements. In the ADHD group, only 3 children verbalized evaluating their partial or complete answers (and only A9 evaluated his final answer although he did so incorrectly), whereas, in the comparison group, 7 children evaluated their partial or complete answers. It would seem here that, much like item 3, the participants in the comparison group were more aware of having failed to obtain the correct answer and as a result, did not easily cease in trying different moves and alternatives in order to achieve the correct answer. It is important to emphasize, however, that nearly half of the Evaluations were erroneous; that is, the participants evaluated their answers but failed to realize that these answers violate some information lines.

Three participants in the ADHD group used regulative statements or verbalized a strategy to regulate their behavior (e.g., "I am going to look at the top row again to find the two correct"). Also, new task definitions and confusion were verbalized by only one participant in each group.

In sum, as was the case for item 3, Evaluation statements constituted the category of statements that differentiated the performance of the two groups on item 4. The participants in the comparison group seemed to regulate their performance by evaluating partial and complete answers more often than the participants in the ADHD group. No differences, however, were observed between the groups with respect to task definitions, regulative statements, or confusion statements.

Comparison of Items 3 and 4. The manner in which both groups approached item 4 appears to be similar to the manner in which they approached item 3. In terms of correct solutions obtained, however, a small difference was evident between performances on item 3 and item 4: in item 4, both the exclusive use of task definitions prior to the first move and the use of task definitions and evaluation statements lead equal numbers of participants in each group (i.e., three) to arrive at the correct answer. The seventh correct answer on this item was obtained by participant A2 in the same manner as he obtained a correct answer for item 3 (i.e., by proceeding immediately to move colors and verbalizing neither task definitions nor evaluations).

Items 5 and 6.

Items 5 and 6 include four colors and three information lines (one line containing 1 correct color and 2 lines containing no correct colors). Although items 5 and 6 have fewer information lines than items 3 and 4, previous studies have found that these items are more difficult since they often require extensive hypothesis building and testing. The major difference between the items 3 and 4, and items 5 and 6 is that for the latter items, the search space is of lesser importance, while the systematicity of hypothesis building and testing becomes central.

Item 5. Table 12 shows the statements made by both groups on item 5.

Six participants in each group verbalized task definitions on item 5. Two children from the comparison group (B2 and B7) and 1 child from the ADHD group (A2) used the best approach, limit by line, to limit the search space. Two children in the ADHD group made assumptions about which color might be correct in the "1 correct" information line and 1 participant in each group limited his or her search space according to color.

Only one participant (A1) proceeded immediately to move colors without defining the data for his moves. The other 5 participants (A3, A6, B1, B4, and B5) who did not verbalize a task definition defined data for the first move by either limiting the search space by color or making assumptions about the correct positions for a color. Two children from each group (A2, A5, B3 and B9) who employed task definitions proceeded to moves without further verbalizations, while the remaining eight participants (A4, A7, A8, A9, B2, B6, B7, and B8) proceeded from task definition to defining data for the first move. A large number of assumptions were again evident during manipulations of the chips.

Table 12

Statements Analysis for Item 5 of Crack-the-Code

		Statements - Item 5						
	Pass/ Fail	Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
ADHD Group								
A1	P			1. CD	2. AA	3. CD		
A2	P	1. DS	2. L2	4. CD	6. AA	8. AA 10. CD 13. CD	5. EV2(+) 7. EV1(+) 9. EV1(+) 11. EV1(+)	3. VS 12. CO
A3	P			1. L1	2. CD			
A4	P	2. L1		1. L1 7. L2 11. L1	3. CD 9. AA 12. CD	6. AA 10. CD	8. EV1(+) 13. EV2(+)	4. ND/AA 5. ND/L2
A5	F	1. DS	2. AA	3. CD				
A6	P			1. AA	2. CD			
A7	P	1. DS 3. DS	2. AA 4. AA	5. AA	6. CD	8. AA 10. CD	7. EV1(+)	9. CO 11. RS
A8	F	1. DS		2. L1	3. CD		4. EV2(-)	
A9	F	1. DS		2. AA	3. CD	4. L1	5. EV2(-)	

(Table 12 is continued)

Table 12 (continued)

	Pass/ Fail	Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
Comparison Gr								
B1	P			1. L1	3. AA	4. CD 5. L1	2. EV1(+)	
B2	P	1. DS	3. L2	2. AA	5. L1		6. EV2(+)	4. CO 7. CO
B3	F	1. DS		2. CD	4. CD	5. L1 6. CD	7. EV2(-)	3. CO
B4	F			1. AA	3. CD	5. L1	2. EV2(-) 4. EV2(-) 6. EV2(-)	
B5	F			1. AA	2. CD		3. EV2(-)	
B6	F	1. DS		2. DS	5. CD		3. EV1(-) 6. EV1(-)	4. CO 7. CO 8. VS
B7	F	1. DS	2. L2	3. L1	4. CD	6. CD	5. EV1(+) 7. EV2(-)	
B8	F	1 .DS	2. L1	3. AA	4. L1	6. L1		5. RS
B9	P	1. DS		2. CD	3. AA 5. CD	4. L1 7. CD	6. EV1(+) 8. EV2(+)	

DS = Data Stated; L1 = limit by color or by spot; L2 = limit by line; AA = add assumptions/parameters; EP = elaboration on the problem after adding information; EA = evaluation of assumptions; CD = only color and destination stated; IM = implications of a move EV1 = evaluation of a partial answer; EV2 = evaluation of a complete answer; CO = confusion; RS = regulative statements (i.e., metacognitive or evaluative statements); VS = verbalization of strategy; ND = new task defintion/all the previous types in the first task definition applied; (+) = correct; (-) = incorrect

However, items 5 and 6 both require the participant to make assumptions after first limiting the search space (i.e., after noticing which color is certain to be incorrect on the "1 correct" line). Thus, making assumptions is a functional approach in these items, particularly when combined with systematic evaluation of these assumptions.

All but one of the participants (B8) in the comparison group controlled their performance by evaluating partial or complete answers. The number of the participants in the ADHD group who evaluated their answers was also higher on this item, than on the previous items, indicating an adaptive change in the evaluation process. It is noteworthy that participant A2, who had solved the previous two items without evaluating his answers, applied Evaluation successfully on four occasions (i.e., once against a complete answer and three times against partial answers) and was able to achieve the correct answer. Two participants in the ADHD group who evaluated their answers correctly (A4 and A7) solved item 5 correctly, while participants A8 and A9, whose evaluation was erroneous, failed to produce a correct answer. Similarly, all 3 participants in the comparison group who used evaluation correctly (B1, B2 and B9) answered item 5 correctly, while the remaining 5 participants in this group failed to obtain a correct answer after being mislead by their erroneous evaluations. Thus, perhaps the best predictor of success on this item was the successful use of evaluations.

Four participants in the comparison group verbalized confusion while solving item 5, while only 2 participants in the ADHD group seemed to be in this situation. New task definitions were used by only 2 of the children in the ADHD group, while regulative statements were made by 1 participant in each of the groups (A7 and B8).

Generally, it seems that the majority of the participants in both groups (i.e., five participants in each group) approached this item by using both task definitions and evaluations of their decisions. Three of the children in the ADHD group, however, solved item 5 correctly by proceeding to move colors without using task definitions or evaluating their answers (A1, A3, and A6). Three children in the comparison group (B1, B4, and B5) proceeded to move colors without using task definitions at the beginning of the item but evaluated their partial or complete answers. Nevertheless, only B1 obtained a correct answer.

All of the 6 participants who evaluated their answers properly arrived at the correct answer. But, as mentioned earlier, 3 of the participants in the ADHD group obtained the correct answer only through "planning-in-action," that is, without using task definitions or evaluations. A closer examination of their performances indicated that 2 of these participants made only four moves to produce the correct answer. These participants made correct assumptions at the beginning of the task that led them to the correct answer without additional complications. The third participant made six moves and appeared to evaluate his work (i.e., he corrected one incorrect placement) during the problem solving process, although he did not verbalize the evaluation procedure.

It is also noteworthy that most of the incorrect answers produced by participants in both groups (5 cases altogether) were based on an approach that used both task definitions at the beginning of the task and evaluation statements during or at the end of the task. These evaluations were erroneous, however, and did not lead the participants to reject incorrect placements. Two additional failures in the comparison group resulted from performances involving a lack of task definitions and failed evaluations, while two other incorrect answers (one in each group) resulted when children failed to evaluate their answers in any way.

Summarizing the performance of both groups on item 5, we see that the earlier differences between both groups in their use of Evaluation are now absent. Participants in the ADHD group verbalized evaluation of both their partial and complete answers. The main difference between the groups, however, appears to be related to the influence of evaluation on the answers produced. The evaluation statements made by the participants in the ADHD group were correct the majority of the time, thus leading them to arrive at the correct answer, whereas only 3 children in the comparison group evaluated their answers correctly and produced a correct final answer as a result.

Item 6. Table 13 displays the statement analysis for both groups on item 6. On item 6, an equal number of participants from both groups used task definitions in order to limit the search space. Only participants B6 and B7 used limit by line to find the correct position of a color. Limit by color, however, was used by 2 participants in the ADHD group and 1 participant in the comparison group. Similarly, assumptions were made by 1 participant in each group.

One child from each group (A6 and B2) proceeded to move the colors without limiting the search space in any way. The remainder of the children in the comparison group defined data for a move before proceeding with the first move (3 of these 8 children had not used task definitions previously). Similarly, 5 children from the ADHD group verbalized data for a move prior to proceeding with the first move (3 of these children had not used task definitions previously). Four children in the ADHD group (A2, A5, A6, and A9) proceeded to verbalize colors and their destinations without first verbalizing any limits on the search space.

The significant difference that had been observed between both groups in their evaluation of partial and/or complete answers on items 3 and 4 was minimized on item 6. On this item, 4 children in the ADHD group and 6 children in the comparison group used evaluations. Two participants in the ADHD group (A2 and A9) and 1 participant in the comparison group (B8) evaluated their

Table 13

Statements Analysis for Item 6 of Crack-the-Code

	Pass/ Fail	Statements - Item 6: Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
ADHD Group								
A1	P			1. L1	2. CD	3. L1 4. CD		
A2	P	1. DS		2. CD	4. L1	6. CD	3. EV1(+) 5. EV1(+)	7. RS
A3	F			1. L1	2. CD	4. CD 6. CD	3. EV1(-)	5. ND/L1
A4	F	1. DS	3. L1	2. AA	4. L1			
A5	F	1. DS	2. AA	3. CD				4. RS
A6	P			1. CD				2. RS
A7	P	1. DS	2. L1	3. AA	4. L1	5. CD		6. RS
A8	F	1. DS		2. AA	3. CD 6. CD	4. L1 8. CD	5. EV1(+) 7. EV1(+)	
A9	P	1. DS		2. CD	4. L1	6. L2	3. EV1(+) 5. EV1(+)	

(Table 13 is continued)

Table 13 (continued)

		Statements - Item 6						
	Pass/ Fail	Task Definition		Verbalization of Decisions and/or Moves			Evaluation	Other
Comparison Gr								
B1	P			1. AA	2. L1			
B2	F			1. CD			2. EV2(-)	3. CO
B3	F	1. DS		2. L1	3. CD		4. EV2(-)	
B4	F			1. AA	3. CD		2. EV1(+) 4. EV2(-)	
B5	F	1. DS		2. AA	3. L1	4. CD 6. CD	5. EV1(+)	
B6	F	1. L2		2. DS	3. CD	4. L2 5. CD		6. CO 7. RS
B7	P	1. L2	2. L1 3. DS	4. AA	6. L1	7. CD 8. L2		5. CO
B8	P	1. DS	2. AA	3. L1 6. L1	5. CD 7. CD		4. EV2(+) 8. EV2(+)	
B9	F	1. DS		2. AA	3. L1	4. AA 6.CD	5. EV1(+) 7. EV2(-)	

DS = Data Stated; L1 = limit by color or by spot; L2 = limit by line; AA = add assumptions/parameters; EP = elaboration on the problem after adding information; EA = evaluation of assumptions; CD = only color and destination stated; IM = implications of a move EV1 = evaluation of a partial answer; EV2 = evaluation of a complete answer; CO = confusion; RS = regulative statements (i.e., metacognitive or evaluative statements); VS = verbalization of strategy; ND = new task defintion/all the previous types in the first task definition applied; (+) = correct; (-) = incorrect

answers correctly and also obtained the correct answer. Another participant from each group, however, failed to obtain the correct answer, although they used correct evaluations. In both instances, the evaluations were only made against partial information.

To summarize, the differences between both groups appear to be minimal for item 6, although children in the ADHD group produced again a greater number of correct answers. This may have been due to more effective evaluations, since only one of the seven evaluations verbalized by the children in the ADHD group was erroneous, compared to four erroneous evaluations verbalized by the children in the comparison group. It should be emphasized, however, that verbalization of evaluation was by no means necessary for solving this item correctly: Three of the participants who solved this item correctly (A1, A6, and B1) verbalized only their moves. Closer examination of their performances indicated that all of them solved this item with a minimal number of moves, indicating that their first assumptions were correct ones. They were thus able to limit the search space successfully.

Comparison of Items 5 and 6. Generally, the participants seemed to approach items 5 and 6 in a similar manner. Five of the 9 participants who solved item 5 correctly also solved the item 6 correctly. Task definitions were verbalized by almost all of the same participants on both items. Slight differences, for both items, however, were observed for evaluation statements, with fewer such statements occurring on item 6 for both groups.

3. Error Analysis

An error analysis was only conducted on items 3 to 6 because the overwhelming majority of the participants answered items 1 and 2 correctly. The error analysis focused on two different types of errors: (a) errors made when participants were trying to place the correct colors on the answer line (i.e., incorrect moves), and (b) errors in the final answer. Incorrect moves could be corrected later in the problem solving process, whereas the second type of error was present in the final answer when incorrect moves had not been corrected. As a result, these two types of errors are not independent of one another. Finally, careful attention was paid only to the first incorrect move made by the participant, since any subsequent mistakes were seldom independent of this first mistake. As a result, comparisons across participants would also have been difficult.

Item 3. On item 3, four children from the ADHD group made 7 incorrect moves while 6 children from the comparison group made 16 incorrect moves. Two of the seven (29%) incorrect moves in the ADHD group and six out of 16 (38%) incorrect moves in the comparison group were corrected while the participant solved the item. Moreover, the ADHD group violated the "0 correct" and the "1 correct" or the "2 correct" lines an equal number of times (twice in each case), while the comparison group violated the "0 correct" lines more often than the "1 correct" or the "2 correct" lines (five violations and three violations respectively).

A clear difference between both groups was observed for the number of errors accepted in the final answer. The ADHD group tried to avoid violating the "0 correct" lines, with only one such violation having been observed for eight violations (it should be noted that one incorrect answer line can contain several violations). In contrast, the comparison group tried to avoid violating the "1 correct" or the "2 correct" lines. That is, two violations of the "2 correct" line and two violations of the "1 correct" line were observed in 10 occurrences of violations. These differences indicate that the participants in each group, who failed to solve the items correctly, may have limited their search space in different ways. Specifically, the comparison group attended mainly to positive information (i.e., they attended to the "1 correct" and "2 correct" lines) and attempted to obtain enough correct placements based on these lines, whereas the ADHD group attended to the "0 correct" lines and attempted to avoid placing colors in the same positions as they occurred on the "0 correct" lines (i.e., in "no go" places).

Item 4. Six participants in the comparison group made a total of 22 incorrect moves on item 4, whereas 4 participants in the ADHD group made a total of only seven incorrect moves on this item. It is noteworthy that the range of incorrect moves for the comparison group was from 1 to 6, while the range of incorrect moves for the ADHD group was from 1 to 4. Four incorrect moves (57% of the incorrect moves) were corrected by the participants in the ADHD group while solving the item, while only eight incorrect moves (36% of the incorrect moves) were corrected by the comparison group. On this item, however, most of the first incorrect moves made by the participants in the comparison group involved the "1 correct" and/or the "2 correct" lines. In other words, they placed a greater number of correct colors than were indicated on the information line (i.e., four errors against three of the "0 correct" lines). The ADHD group once again displayed an equal number of violations of both "0 correct" and "1 correct" or "2 correct" lines (2 violations in each case).

Seven violations were present in their final answers given by the participants in the ADHD group and 11 violations were present in the final answers given by the participants in the comparison group. Although the number of violations were equally distributed among all four information lines for the ADHD group, the largest number of violations made by the comparison group involved the "0 correct line and the "1 correct" line (i.e., by having more than one color correct on the answer line) (four and five violations respectively). Again, this result indicates that children in the comparison group were more aware of determining the two correct chips on the "2 correct" line than not violating the remaining three information lines that contained fewer correct colors.

Item 5. Although item 5 was somewhat different from the previous two items in that it contained the same number of colors but fewer information lines, the difference between both groups in terms of the number of incorrect moves was consistent with the previous items. Eight children in the comparison group made twice as many incorrect moves as four of the participants in the ADHD group (19 and 9 incorrect moves respectively). Approximately, one third of the incorrect moves were corrected by the participants in each group (six and three corrections, respectively).

On this item, most of the initial incorrect moves (i.e., three moves) made by the children in the ADHD group violated a "0 correct" line, while most of the initial incorrect moves (i.e., six moves) made by children in the comparison group violated an "1 correct" line (6) by adding a second color as being correct on the answer line.

It is interesting to note, that the trend observed on items 3 and 4 items in regarding final answers seems is reversed for item 5. On this item, the comparison group violated the "1 correct" line (by having more than one correct color on the answer line) more often than the "0 correct" lines (five and three violations, respectively). Alternatively, the ADHD group had fewer violations of the "1 correct" line than the "0 correct" lines (two and four violations respectively). Thus, it would seem that the comparison group did not attend to violate the "1 correct" and "2 correct" lines (by determining more correct colors for those lines than the number of correct they should have), whereas the ADHD group did not attended to violate the "0 correct" lines (by placing the colors, on the answer line, in positions which were incorrect according to the information lines). It is important to remember, however, that only 3 participants in the ADHD group produced an incorrect answer on this item, compared to 6 participants in the comparison group.

Item 6. In terms of incorrect moves, the difference between both groups was smaller in item 6 than for the previous items. Five children in the ADHD group made a total of 10 incorrect moves, while 7 children in the comparison group made a total of 15 incorrect moves. The children in the ADHD group, however, corrected more of their incorrect moves than the children in the comparison group (six and four moves, respectively).

No differences were observed between both groups with regard to the type of initial incorrect moves. Because participants in the comparison group did not correct most of their incorrect moves, however, they also displayed more errors in their final answers (nine errors in the comparison group vs. four errors in the ADHD group). On this item, the violations committed by participants in the comparison group (i.e., eight violations) were divided equally between having too many colors perceived as correct on the "1 correct" line and placing a color in the same position on the answer line as it occurred on one of the "0 correct" lines. In contrast, participants in the ADHD group violated a "0 correct" line only once, a "1 correct" line three times (i.e., twice by having more than 1 color perceived as correct on the answer line and once by having no correct chips on the answer line).

Summary of the Error Analysis. Overall, the participants in the comparison group made more incorrect moves than the participants in the ADHD group. In addition, the participants in the ADHD group corrected more errors than their peers while solving an item, particularly on items 4 and 6. As a result, they had fewer errors in their final answers. Overall no differences were observed between both groups in terms of types of first incorrect moves made (i.e., whether the first violation was against a "0 correct" line or a "1 correct" or "2 correct" lines). Finally, the children in the comparison group appeared to be focused specifically on determining correct colors for the "2 correct" line for items 3 and 4, and the "1 correct" line for items 5 and 6. Particularly, on items 3 and 4 the children in the ADHD group concentrated more on the information provided in the "0 correct" lines and they attempted to avoid placing colors in similar positions on the answer line. This pattern, however, was reversed for the items 5 and 6, where the participants in the ADHD group attempted to avoid violating the "1 correct" line. The results presented in this section are discussed in the following chapter.

CHAPTER V

DISCUSSION

The main goal of this study was to examine the problem solving process on the Crack-the-Code task for children with and without ADHD. Verbal protocols provided process data, while computer protocols provided various product data. The detailed analysis of the strategies applied and the statements made by the participants while performing the task provided us with data about their thinking processes that would have been difficult to collect by other means. In what follows, the process data and the product data will be discussed in relation to the planning model that was described in chapter 1.

As mentioned earlier, this model identifies three different levels of planning: activity-planning, action-planning, and operation-planning. Crack-the-Code task is most adequately represented at the second level of planning, since it involves a well-defined problem that allows the participant to try different approaches in order to arrive at the correct answer. The model proposes four components that may be employed during the action-planning process: anticipation, representation, execution, and regulation (Das et al., in press; Parrila et al., 1994). *Anticipation* includes the ability to predict the consequences of a plan or behavior. *Representation* involves making plans and establishing subgoals in order to attain the final goal that would be otherwise too distant to achieve. *Execution* refers to the application of the plan, and *regulation* refers to the monitoring and controlling of behavior according to the plan.

The discussion of the results is presented in four main sections, each of which deals with one of the four components of the planning process. Each section begins with a discussion of the different variables included in the result section that could provide us with information about that particular component.

It then proceeds to integrate and interpret the results within this scheme. Both differences between the two groups and differences within each group are discussed. It should also be mentioned that this separation and interpretation of the data in light of the four components of the model, was done in order to enhance communication of the findings. In a planning task, where all four components interact, it is difficult to determine, in a definitive manner, which measures are associated with each specific component. The following presentation, however, attempts to associate the data with specific components of the model in order to make the data more meaningful and to facilitate the comparison of results from this and subsequent studies.

Anticipation

Anticipation is probably the most difficult component to associate with any of the time-based variables used in this study. Anticipation may be included in any mental or verbalized plan prior to or during a move (or moves) made by a participant. As a result, anticipation may be present in both First Thinking Time, which involves time spent prior to the first move, and Total Thinking Time which consists mainly of time breaks between moves. For this reason, anticipation was correlated mainly with data from the process analysis. Several of the process variables included the anticipation component either directly or indirectly. The use of the Combination strategy, for example, requires anticipation of the consequences of moves. Thus, whenever a participant used the Combination strategy we can safely assume that he or she was using this planning component. Moreover, the evaluation of assumptions that were made during task definitions may also involve anticipation (in which case anticipation may be part of First Thinking Time). Finally, it was assumed that the reasoning process included anticipation if a strategy was abandoned because the participant felt that it would lead to the placement of a color in an incorrect position.

In terms of using Combination strategies, the participants with ADHD seemed more capable of anticipating or predicting the outcome of a plan. These participants were also more proficient overall in applying the Combination strategy. Their Combination strategies were successful the majority of the time (i.e., 18 successes vs. 5 failures) and were built using more of the provided information. In contrast, the Combination search methods used by the participants in the comparison group were less effective and used less of the provided information.

Closer examination of the application of strategies indicated that although children in the comparison group displayed a larger number of incomplete strategies than children in the ADHD group (9 occurrences vs. 4 occurrences, for all of items), only one of these incomplete strategies was abandoned because the participant felt that it was leading to the placement of a color in an incorrect position. Similarly, only one such strategy was abandoned by a participant in the ADHD group for the same reason. The remainder of the applications of the incomplete strategies arose due to the participants' inability to either determine the correct position of a color (or colors) or deal with the amount of information involved in this procedure. Moreover, in terms of the assumptions made and evaluated, no significant differences were observed between both groups on any of the items.

Thus, the only differences in anticipation between both groups were found in the use of the Combination strategy: The ADHD group used better Combinations than the comparison group to arrive at the correct answer. The differences within the ADHD group, however, were substantial: Only 2 participants used the Combination strategy successfully on more than 3 items (4 items and 5 items). These participants also obtained the largest number of correct answers in the ADHD group (6 and 5 correct answers, respectively). In contrast, two participants in the ADHD group obtained either one or no correct answers for the 6 items. These two participants used mainly the Trial and Error and the Climbing search methods. Neither of these search methods, however, requires the participant to anticipate or predict the sequence of his or her plans. Consequently, the heterogeneity of the ADHD group seems to have played a significant role in terms of the general picture obtained of the differences between both groups as they relate to the anticipation component. This argument becomes even stronger when one examines more closely the performance of the comparison group with respect to applied search methods. The use of Combination as a search method was equally distributed among the participants in this group, indicating that the comparison group was more homogeneous than the ADHD group, particularly on this variable.

Representation

Of the various product measures included in this study, First Thinking Time and the Thinking Time/Dragging Time ratio are likely the most closely associated with the representation component of the planning model. The assumption underlying this association is that the greater the First Thinking Time and the higher the ratio score, the more likely the participant is to have spent time building a representation of the task and his or her plan and moves. Similarly, the use of task definitions, either at the beginning of an item or after a move (or moves), was considered indicator of representation. In terms of search methods, it was assumed that the use of Combination requires a better representation than either Trial and Error, Climbing, or Pattern. In this group of three strategies, the use of Trial and Error likely indicates that the participant failed to build a functional representation of the task. Also, several of the participants used a "false" Pattern strategy; that is, they produced an answer line that was identical to one of the information lines. These instances were also regarded as indicators of representational problems. Finally, incorrect moves made by the participants while they performed the task were also considered to be indicators of poor representation.

On all of the items, the participants in the comparison group appeared to spend more time thinking prior to making their first move (FTT) than did the participants in the ADHD group. Similarly, with the exception of item 3, the comparison group displayed higher ratio scores than the ADHD group. These group differences for the time-based variables indicate that participants in the comparison group spent more time building a representation of the task and determining what was needed in order to solve it. As discussed below, however, this may not have been the best, or even effective, way of proceeding with this task.

The comparison group not only displayed higher first thinking times but they also verbalized more task definitions and applied more strategies on items 1 and 2. On the remainder of the items, however, both groups verbalized an equal number of task definitions that were of similar quality. Thus, when task definition was most necessary, both groups used it equally often and equally well.

For applied strategies, the differences observed between both groups on item 2 were reversed on item 3. As we saw earlier, some of the children with ADHD applied the Combination search method successfully more often than the participants in the comparison group. Furthermore, on items 3 and 6, the Pattern strategy was used incorrectly (i.e., involving reproduction of one of the information lines, most commonly the "1 correct" line) by 4 and 2 children in the comparison group, respectively. In contrast, this "false" Pattern was used by only one participant with ADHD on item 4. In addition, several participants in the comparison group relied on a Trial and Error strategy to make decisions on items 3, 4, 5, and 6, whereas participants in the ADHD group applied mainly different types of Climbing strategies on these items. This group difference in the strategies applied, indicates that the participants in the comparison group built less adequate representations of the task requirements and ways in which to proceed in solving it.

Similarly, overall the comparison group made overall more incorrect moves than the ADHD group. The number of incorrect moves made by the comparison group indicates that these participants used less inclusive representations while performing the task. A closer examination of incorrect moves, however, indicates that there is greater variability among the participants in the comparison group because 3 of the participants produced more than half of the incorrect moves (i.e., 38 of the 72 incorrect moves made by this group). In contrast, the incorrect moves made by participants in the ADHD group were roughly equally distributed among the 9 participants.

In general, the above results are somewhat inconsistent. Participants in the comparison group appeared to spend more time building their representations but this activity was not very successful, as evidenced by the number of mistakes they made or the strategies they used. When the large within group differences are taken into account, however, many of the differences between both groups become very small. Perhaps the only reliable conclusion that can be drawn from this data is that there are many different ways in which to build a representation and that more of these ways were evident in the ADHD group than in the comparison group. The latter group went about the task in a more linear manner.

Execution

The application of strategies, whether correct or not, is associated with the execution of plans. The successful application of a strategy indicates that a participant's execution of a plan worked well, while an error in application implies that the execution of a plan was not functional. Moreover, a switch from a more difficult search method (i.e., Combination) to a less difficult one (i.e., Climbing) may also indicate problems in the execution of the plan.

In general, the comparison group appeared to have greater difficulty in executing plans than the ADHD group. Incomplete strategies and incorrectly applied strategies were both more frequent in the comparison group than in the ADHD group (9 vs. 6 incomplete strategies, and 7 vs. 5 application failures, respectively). Incomplete strategies that were considered to be reflective of execution problems were those in which participants were unable to determine the position of a color despite having used a strategy that could have provided this information (i.e., they gave up too quickly). Application failures, on the other hand, involved the incorrect application of a search method that ultimately violated one or more information lines. It is interesting to note that four of the application failures in the ADHD group occurred while using the Combination search method (the fifth application failure involved the Pattern search method), whereas six of the application failures in the comparison group occurred while using the Pattern search method (the seventh application failure occurred during use of the Combination method). Thus, when the ADHD group failed to apply their strategies correctly, this almost always occurred while using the most complicated method.

In terms of shifting from a more difficult to a less difficult search method, no group differences were observed overall on any of the items. Participants in the ADHD group made such a change 11 times, while participants in the comparison group made such a change 12 times while trying to solve an item. Only three of these 23 changes resulted in a participant obtaining the correct answer.

These results indicate that once execution problems are present, they are almost invariably correlated with incorrect answers for both groups. For items 3 to 6, a total of 40 performances included one or more of the previously mentioned execution difficulties. Of these 40 performances, 33 performances resulted in an incorrect answer, while only 7 performances resulted in correct answer. This indicates that the execution component, more so than any other component, was likely responsible for success on this action-planning task.

Regulation

Several variables can also be associated with Regulation. Evaluation time and evaluation statements can both indicate regulation at the end of a task. The verbalization of the evaluation of partial or complete answers during the problem solving process indicates that a participant is regulating his or her performance "on-line". In these instances, a portion of the Thinking Time reflects evaluation. Calculation of this partial time, however, is not possible because the production of statements and the timing by the computer are not entirely synchronized. For this reason, only the Evaluation Time was focused on. Also, corrections made to incorrect moves were taken to be reflective of the on-line regulation of performance, while the acceptance of incorrect answer lines at the end of the task was considered to be an indicator of poor or non-existent regulation.

Significant differences were observed between both groups on almost all measures of the regulation component. Overall, participants in the comparison group spent more time evaluating their answers at the end of the task than participants in the ADHD group. The comparison group also verbalized a greater number of evaluation statements. Specifically, during performance of the task, participants in the comparison group evaluated their partial or complete answers a total of 34 times, of which 25 evaluations (74%) were correct. The participants in the ADHD group evaluated their partial or correct answers a total of 26 times, of which 21 evaluations (81%) were correct. Both groups verbalized an equal number of evaluations of partial answers during performance of the task, while only the comparison group verbalized evaluations of complete answers during performance of the task. This difference, however, does not seem as important as compared the group difference observed in the evaluation of answers at the end of the task. Specifically, the comparison group verbalized 32 evaluations at the end of the task, 17 (i.e., 53%) of which were correct, while the ADHD group verbalized only 8 evaluations, 6 (i.e., 75%) of which were correct.

Thus, the most common form of evaluation for the ADHD group was an evaluation of partial answers during performance of the task, while the most common form of evaluation for the comparison group involved the evaluation of complete answers at the end of the task. Moreover, most of both groups' evaluations of partial answers were correct, while half of the comparison group's evaluations of complete answers were incorrect. This suggests that the approach used by the ADHD group was more functional for this task and age group.

The group differences in evaluation also appear to be correlated with the number of corrections made by each group following wrong decisions, as well as the number of incorrect answers accepted. On items 4 and 6, participants in the comparison group corrected fewer incorrect moves than participants in the ADHD group while performing the task (51% vs. 36% and 60% vs. 27%, respectively). Only on item 3, did the comparison group correct more incorrect moves than the ADHD group (38% vs. 29%, respectively). On item 5, no group differences were observed for correction of incorrect moves. In terms of accepting incorrect answers, there was a clear difference between both groups (i.e., 38 acceptances for the comparison group vs. 25 acceptances for the ADHD group) despite the fact that the participants in the comparison group seemed to evaluate their answers at the end of the item and the participants in the ADHD group appeared not to do so. This finding supports the earlier suggestion that the comparison group may have been using an approach that was not functional for this task.

Participants in the ADHD group seemed to regulate their performance in a considerably different way than participants in the comparison group. The first group used mainly on-line regulation, in that when evaluation statements were verbalized, they referred to partial answers produced during performance of the task or corrections of colors that were incorrectly placed. In contrast, the comparison group, used regulation mainly at the end of the task. It seems, however, that although the participants in the comparison group were aware of how to approach the task in terms of regulating their performance, they were not competent in using this method. It seems, therefore, that the approach chosen to regulate one's performance played a more significant role in solving correctly the task than the number of evaluations produced.

Finally, another conclusion that can be drawn from these results is that the regulation component did not seem to be associated with success on this task to the same extent as the execution component. This conclusion is only partially accurate, however, because the way in which the regulation component was measured in this study did not seem to adequately capture the regulation used by the participants with ADHD.

Limitations and Implications of the Study

The general picture obtained from the results of this study indicates that the participants in the ADHD group performed better than the participants in the comparison group on the Crack-the-Code task. Thus, the results of this study are not consistent with earlier findings that children with ADHD exhibit problems involving executive processes and the generation and application of appropriate problem solving strategies during complex cognitive tasks (Hamlett et al., 1987; Reardon & Naglieri, 1991; Tannock et al., 1993; Tant & Douglas, 1982). The results of this study suggest that children with ADHD approached the task differently than children in the comparison group. On this particular task, children with ADHD used a more functional approach than children in the comparison group.

There are several factors, however, that may have contributed to these somewhat surprising findings. First, because the ADHD group was very heterogeneous and the sample size was small, the three participants who performed best in this group may have significantly influenced the overall picture for the performance of this group. It is interesting to note that both the strongest and the weakest performances on this task were produced by children with ADHD. Closer examination of the background variables indicates that the 2 participants who obtained the largest number of correct answers on Crack-the-Code (6 correct answers and 5 correct answers) generally had higher scores on the background variables than the 2 participants who obtained the fewest number of correct answers (0 correct answers and 1 correct answer). In contrast, no similar differences were observed among the participants in the comparison group.

Secondly, although the two groups were matched on the background variables, this matching was based on their performance in grade 3 and may therefore not have provided an accurate picture of their current performance level. We do not know, for example, if all of the children ADHD were on medication when they completed the tests that were used for matching process. Their use of medication may have minimized the group differences in performance on the problem-solving task. None of the participants in the ADHD group displayed hyperactivity or attention deficits while performing the task. Instead, they were focused on the task even during the more difficult items or when dealing with an item that was similar to one that they had just solved. Thus, neither the complexity nor the repetitiveness of the items disrupted their ability to remain task focused. These results contradict earlier findings by various researchers (see for e.g., Reardon & Naglieri, 1991; Solanto & Wender, 1989; Tant and Douglas, 1982) which support that boredom emerges for the children with ADHD after repeated exposures to similar tasks and that the more complex the task, the less effective are the strategies applied by the children with ADHD.

The aforementioned differences within the ADHD group may be explained by taking into consideration the current status of Attention Deficit Hyperactivity Disorder as a diagnostic category. ADHD has become a broad category and the diagnosis of ADHD in Alberta has more than tripled in recent years (CBC News, September 11). Ritalin enhances the concentration ability of most children who take it but is perhaps over-prescribed at the present time. Classroom sizes are increasing and as a result, more children are displaying behaviors that are then assumed to be reflective of ADHD. In order to obtain the beneficial results associated with Ritalin, too many children may be diagnosed as having ADHD - children who may not meet the strict criteria for this disorder .

For example, children who are academically challenged and who succumb easily to boredom at school may exhibit symptoms of hyperactivity, inattention or fidgeting, and may therefore be wrongly included in the ADHD category. Similarly, children with learning or behavior problems often display symptoms of inattention and/or hyperactivity and are therefore frequently included in this category (Heilveil & Clark, 1990). Consequently, significant within group differences such as those found in this study are likely to be present when children with ADHD are included. In future research, the selection of participants with ADHD should include measures other than the existing medical diagnosis of ADHD so as to minimize such within group differences. Separate attention tasks and attention checklists (e.g., see Das, 1986) could be used for this purpose.

The results of this study and limitations discussed above suggest new directions for future research. The use of an action-planning task did not reveal any significant differences between children with ADHD and children without such attention deficits. Prior to drawing any conclusions about the planning abilities of children with ADHD, it is necessary to replicate this study and to administer an action-planning task in conjunction with activity-planning and operation-planning tasks that require the participant to use different approaches to problem solving. During an activity-planning task, participants must deal with real-world tasks and constraints, as well as be capable of orienting themselves toward the future. During operation-planning tasks, however, they must produce answers rapidly in accordance with task-imposed constraints, employing additional existing strategies and tactics. Therefore, the way in which children with ADHD approach an action-planning task, and the scores they achieved, may be different from the way in which they approach the other two types of tasks and the scores they obtain on them.

Finally, the development and use of other measures to assess the four components of the planning model included in the study may result in the generation of different findings. For example, the measures used in this study, did not seem to capture the regulation used by the children with ADHD. Additionally, only a few measures could be associated with anticipation. Therefore, the use of different tasks and process measures is recommended in order to provide us with a better understanding of the problem solving process for children with attention deficit hyperactivity disorder.

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APPENDIX A

Diagnostic Criteria for Attention Deficit/Hyperactivity Disorder

A. Either (1) or (2):

(1) six (or more) of the following symptoms of **inattention** have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

Inattention

(a) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities

(b) often has difficulty sustaining attention in tasks or play activities

(c) often does not seem to listen when spoken to directly

(d) often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions)

(e) often has difficulty organizing tasks and activities

(f) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)

(g) often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books or tools)

(h) is often easily distracted by extraneous stimuli

(i) is often forgetful in daily activities

(continued)

Diagnostic Criteria for Attention Deficit/Hyperactivity Disorder *(continued)*

(2) six (or more) of the following symptoms of **hyperactivity-impulsivity** have persisted for at least 6 months to a degree that is maladaptive and inconsistent with the developmental level:

Hyperactivity

(a) often fidgets with hands or feet or squirms in seat

(b) often leaves seat in classroom or in other situations in which remaining seated is expected

(c) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)

(d) often has difficulty playing or engaging in leisure activities quietly

(e) is often "on the go" or often acts as if "driven by a motor"

(f) often talks excessively

Impulsivity

(g) often blurts out answers before questions have been completed

(h) often has difficulty awaiting turn

(i) often interrupts or intrudes on others (e.g., butts into conversations or games)

B. Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before age 7 years.

(continued)

Diagnostic Criteria for Attention Deficit/Hyperactivity Disorder *(continued)*

C. Some impairment from the symptoms is present in two or more settings (e.g., at school [or work] and at home).

D. There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.

E. The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e g., Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder).

Code based on type:

314.01 Attention Deficit/Hyperactivity Disorder, Combined Type: if both Criteria A1 and A2 are met for the past 6 months

314.00 Attention Deficit/Hyperactivity Disorder, Predominantly Inattentive Type: if Criterion A1 is met but Criterion A2 is not met for the past 6 months

314.01 Attention Deficit/Hyperactivity Disorder, Predominantly Hyperactive-Impulsive Type: if Criterion A2 is met but Criterion A1 is not met for the past 6 months

APPENDIX B

Letter to Parents/Guardians

Dear Parent/Guardian:

We would like to request permission for your child to participate in a cognitive processing research project at your child's school. This research project is conducted by Timothy C. Papadopoulos under the supervision of Dr. J. P. Das and Dr. R.F. Mulcahy. We have already received permission from the Edmonton Public School Board and the Principal of your child's school to conduct the study.

Objectives

In this study, the students will be requested to complete six tasks assessing their problem solving skills. They will be asked to talk aloud while performing the tasks and their verbal responses will later be analysed. The objective of the study is to gather more information about the development of problem solving and attention-concentration skills. This basic knowledge is pertinent for the researchers in their attempts to develop more efficient teaching and remediation procedures for those children who are experiencing difficulties in different kinds of strategic thinking and problem solving tasks.

Procedure

Your child will be asked to attend one 30 minute individual session where he or she will be presented with six problem solving tasks.

Results of the Study

Results of the study and any information that you may provide us with, will be kept completely confidential. The final report will primarily present group scores. Individual names will not appear or be used at any time during the project. We will be available for consultation regarding your child's strengths and weaknesses in problem solving. Teachers will be informed of your child's results only at your request.

How to Participate

Please complete and sign the attached permission sheet and have your child return it to his/her teacher as soon as possible. If you have any questions or need further clarification, please feel free to call Mr. Timothy Papadopoulos at 492-7979 or Dr. J.P. Das at 492-4439 or Dr. R.F. Mulcahy at 492-5211 at the University of Alberta. Thank you very much in advance for considering this project.

Dr. J.P. Das
Professor
Department of Educational
Psychology

Timothy C. Papadopoulos
Master's Candidate
Department of Educational
Psychology

PERMISSION SHEET
(please return to the school)

Project: Development of Planning Skills

Researchers: Timothy C. Papadopoulos (Master's Candidate), Dept. of Educational Psychology, University of Alberta
Dr. J. P. Das and Dr. R. F. Mulcahy (Supervisors), Dept. of Educational Psychology, University of Alberta

Personal Data

Name of Child (last, first, middle) ______________________

Age (year, months) ______________________

School ______________________

Grade ______________________

Home Room Teacher ______________________

I hereby give permission for my child to participate in the above mentioned study. Also, I understand that

- this study will provide information that will help the researchers to develop better remediation methods for children with difficulties in problem solving
- all the information , including test results, will remain confidential with regard to my identity and my child's identity.
- I can ask for clarification of any aspect of the study at any point in time during and after the project regarding my child's results and their implications.
- my child will not have any physical or psychological injury in taking the tests and I am free to withdraw my consent and terminate my child's participation at any time.

______________________ ______________

Signature of Parent or Guardian **Date**