Assessment of Attention in Children

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ABSTRACT

Attention has been acknowledged as playing a central role in the processing of information. Various clinical populations such as head injured, learning disabled and "hyperactive" are thought to be particularly susceptible to difficulties in attention. Despite the fact that attention can also affect the validity and interpretation of test results, neuropsychological assessments rarely evaluate attention in an objective manner. This is primarily due to the limited availability of tests that assess attention per se.; particularly without requiring additional cognitive skills such as memory or arithmetic abilities.

The present research examined the possibility of using a popular research paradigm (Continuous Performance Test; CPT) as a clinical measure of attention for children. The specific CPT developed (i.e., CCPT) required children to attend to letters which were presented individually on a computer monitor and respond whenever a predetermined target letter occurred. The CCPT consisted of two subtests each with individual targets and each lasting for 15 minutes. The task was administered to 128 "normal" children and 25 children diagnosed with Attention Deficit Disorder (ADD).

The results of analyses on the normative sample indicated that CCPT performance improved with age and was also related to teacher ratings of school performance. CCPT performance was found to be significantly correlated with some

Wechsler Intelligence Scale for Children-Revised (WISC-R) subtests that have traditionally been found related to an "attention" factor and not significantly correlated with a WISC-R subtest which is poorly related to this "attention" factor. Analyses of data from the Conners Parent and Teacher Questionnaires indicated that CCPT performance was significantly correlated with those subscales related to attention, but not subscales related to nonattentional dimensions.

Comparison of the ADD group and a control group matched by gender, age, IQ and SES indicated that the ADD group performed significantly more poorly on the CCPT. Furthermore, clinical cut-off scores were devised which identified 73.9% of the ADD group and 4.0% of the Normative sample as "impaired". Medication that enhances attention was found to also improve CCPT performance in ADD children. Finally, analyses of both internal consistency and temporal stability provided preliminary support for adequate reliability of the CCPT.

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DEDICATION

This dissertation is dedicated to all future students who either knowingly (exhibiting masochistic tendencies) or unknowingly (evidencing naivete) choose to undertake the longest vigilance/sustained attention task known to man (or woman) - graduate school.

Chapter 1

INTRODUCTION

Impairments in attention are among the most common deficits associated with brain damage (Bigler, 1988; Lezak, 1978; Moscovitch, 1979; VanZomeren, Brouwer, & Deelman, 1984). In fact, attentional difficulties have been found in patients who had sustained minor head traumas (Rimel, Gordini, Barth, Bolt, & Jane, 1981), in patients with good recovery after head injury (Stuss et al., 1985) and even in "symptom-free" subjects years after minor concussion (Ewing, McCarthy, Gronwall, & Wrightson, 1980). Furthermore, disturbances in attention can significantly affect the validity (Ben-Yishay & Diller, 1983a) and interpretation (Ewing-Cobbs, Fletcher, & Levin, 1985) of psychological test results. Attentional abilities are also considered of primary importance in the construction of any cognitive remedial intervention program (Ben-Yishay, 1980; Ben-Yishay & Diller, 1983b; Wood, 1988). Impairments in attention have also been argued to be fundamental to the problems of learning disorders (Ross, 1976; Keogh & Margolis, 1976a) and hyperactivity (Douglas 1972; Douglas & Peters, 1979) in children. Despite the fact that attentional processes are thought to play such a critical role in these diverse areas, a review of the current assessment literature reveals a clear lack of tests available for assessment of attention per se (Lezak, 1983; Mitchell, 1983; 1985; Sweetland & Keyser, 1983). Stuss and Benson (1986) furthermore argue that there are serious deficiencies in the neuropsychological assessment of attention because there are few tests available and these have not been carefully validated.

The reason for the shortage of adequate tools to evaluate attention is likely due, at least in part, to the lack of a commonly agreed upon conceptualization of attention. It has been almost a century since William James wrote "Everyone knows what attention is" (1890), yet a universally accepted definition continues to elude us (Douglas & Peters, 1979; Posner & Rafal, 1987; Stuss & Benson, 1986; Sohlberg & Mateer, 1987; Swets & Kristofferson, 1970). The emphasized components or processes of attention vary considerably depending upon the approach taken. For example researchers studying cognitive-information processing (Eysenck, 1982; Gibson & Rader, 1979), deficits from brain injuries (VanZomeren et al., 1984; Sohlberg & Mateer, 1987), or childhood disorders (Keogh & Margolis, 1976a; Douglas & Peters, 1979) all have their own specific biases in defining attention. The current literature, in fact, suggests that attention is a multifaceted concept and that many theories have arisen in an attempt to explain it (Eysenck, 1982).

In this study a comprehensive yet parsimonious view of attention that has been classically presented from both a neuropsychological (Luria, 1973) and an information processing (Posner, 1975; Posner & Boies, 1971) perspective was adopted. This view assumes that attention consists of three separate but interrelated components or levels. The first component is alertness which refers to the basic waking state necessary for the general receptivity to incoming information. Alertness would include variations in the waking state that might be due to diurnal rhythms (i.e., tonic arousal) or alterations that would occur from the sudden presentation of external stimuli such as a warning signal (i.e., phasic arousal). The second level is selective attention or the designation of particular information for special treatment from all available stimuli. In other words, specific information is selected for processing while other available information is excluded. This differs from phasic arousal in that it does not prepare the organism to respond to any or all stimuli, but it only improves responsiveness to selected information. For example, a warning signal can affect performance by general alerting (i.e., through phasic arousal) and also by supplying relevant information about the forthcoming signal. Selective attention to a considerable degree is assumed to proceed automatically and unconsciously. Finally, there is voluntary attention which arises from the conscious effort a person invests to achieve some goal directed behaviour. Voluntary attention is limited by the amount of information that can be processed simultaneously and also by the length of time that it can be sustained. For example not only is it difficult to attend to more than one conversation at a party, but it is also demanding for radar operators to detect signals over long periods of time. These three components are not mutually exclusive and all together form a functional system for attending behaviour. For a more detailed description of this model see Posner and Rafal (1987) in addition to the above noted references.

Although obviously an oversimplification of the actual complexity involved, evidence does suggest that these three components are intimately related to the ascending reticular formation, limbic regions and frontal regions of the brain respectively (Luria, 1973). More recent evidence also suggests that the selective orienting of attention, which is also part of the selective component, appears to be associated with the parietal and midbrain regions of the brain (Posner & Rafal, 1987; Posner, Walker, Friedrich, & Rafal, 1987). There are other positions regarding the relationship between attention and neural systems. Some have stressed the special role of the right hemisphere in attending to stimuli (Brumback & Staton, 1982; Heilman & Van Den Abell, 1980), while others have argued that deficits in attention appear to be more related to anterior versus posterior site than right versus left hemisphere (Salmaso & Denes, 1982). Similarly the tripartite view of attention is not proposed to be the only acceptable theory of attentional processes. It was, however, considered to be appropriate since it provides a practical framework for the neuropsychological investigation of attention. Furthermore, this same model of attention has been used recently to understand (Posner & Rafal, 1987) and treat (Ben-Yishay, Piasetsky, & Rattok, 1987) disorders of attention due to brain injury.

Generally speaking, there are some tests available that do rely heavily on attentional processes and, therefore, may be useful for the assessment of attentional disorders. These measures are typically quite complex and performance on them can be impaired for a variety of reasons. One such test is subtracting serial sevens (Smith, 1967). This task requires the subject to start with 100 and continually subtract 7 from the preceding result (i.e., 100, 93, 86,...). This test which has little psychometric data (Lezak, 1983) also has limited relevance unless performance is grossly impaired (Smith, 1967). Additionally, the memory , arithmetic and mental tracking abilities required make interpretations of performance less than straightforward, particularly for children.

Another test that demands some mental tracking (i.e., keeping track of sequential stimuli mentally) is the Digit Span task (Wechsler, 1974; 1981). This test which requires the oral repetition of increasingly longer strings of unrelated numbers has traditionally been labeled one of the classic tests of attention (Stuss & Benson, 1986). Digit Span has been shown to be sensitive to brain damage (Costa, 1975; Weinberg, Diller, Gerstman, & Schulman, 1972), however, its sensitivity is influenced by visuo-spatial (Costa, 1975) and short-term memory (Warrington & Weiskrantz, 1973) abilities.

Another type of task that relies heavily upon attentional abilities are substitution tasks. Examples of these are Digit Symbol (Wechsler, 1981), Coding (Wechsler, 1974) and the Symbol Digit Modalities test (Smith, 1968). These tasks require the successful substitution of familiar and novel symbols. Performance on these types of tasks, however, can be significantly affected by impairments in motor speed, mental disorders, visual defects (scanning), and associative learning (Kaufmann, 1968).

The Paced Auditory Serial Addition Test (PASAT) is another "attentional" task which has been shown to be sensitive to minimal brain damage (Gronwall & Wrightson, 1974; Gronwall & Sampson, 1974), anaesthetic drugs (Seow, Roberts, Mather, & Cousins, 1981), as well as predictive of readiness to return to work following head injury (Gronwall, 1977). The PASAT, however, is quite a demanding and frustrating task which might not be appropriate for some patients who have sustained serious head injuries (Eson & Bourke, 1982). The nature of the task (i.e., rapid serial addition) also makes expeditious speech responses and arithmetic skills necessary for successful performance. These heavy demands would most likely make use of the PASAT with younger children difficult at best. In fact, norms on the PASAT are currently only available down to age 14 (Gronwall, 1977).

There are other tests which appear to require intact attentional skills such as the Trail Making test and the Stroop test (see Lezak, 1983). These "attentional measures", however, as the above noted tests are quite heterogeneous and performance on them requires many skills and abilities in addition to attention, per se.

One possibly less heterogeneous measure, with fewer task demands, used to assess the ability to sustain attention is the cancellation test. Cancellation tests are paper and pencil tasks which require the patient to search for targets (e.g., letters or numbers) in groups of nontargets. These types of tasks have been adapted successfully to the assessment of brain damaged patients (Diller, Ben-Yishay, Gerstman, Goodkin, Gordon, & Weinberg, 1974). A similar type of test developed to measure sustained attention in children is the Children's Checking Task (CCT; Keogh & Margolis, 1976b). This test requires the child to listen to a tape recorded series of numbers and check it against a similar series presented in a booklet. Although these cancellation-type tests appear to measure a more "pure" attentional process, they also require intact visual scanning and controlled rapid fine motoric responses. In fact, the sensitivity of cancellation tests for right hemisphere lesions appears to be the spatial layout of the task, which is itself sensitive to spatial neglect (Diller & Weinberg, 1977).

There are other types of tasks that require this form of sustained attention or vigilance. The terms vigilance and sustained attention are often used interchangeably and refer to the ability to attend, over a period of time (seconds to hours), to predetermined targets that appear infrequently and unpredictably (Davies & Parasuraman, 1982; Parasuraman, 1984). The study of vigilance evolved from the practical concern of deterioration over time in the performance of radar operators during World War II (Davies & Parasuraman, 1982; Warm, 1984). The basic clinical importance of vigilance has been highlighted by Lezak (1983) who suggests that sustained attention is necessary for the successful performance on any test of attention, concentration or conceptual tracking.

One well researched vigilance task which does not require significant visual scanning ability and demands minimal motoric responding is the Continuous Performance Test (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). Performance on CPT tasks has been found to be sensitive to the effects of brain damage (Kaspar, Millichap, Backus, Child, & Schulman, 1971; Mirsky & Orren, 1977; Mirsky, Primac, Ajmone-Marsan, Rosvold, & Stevens, 1960; Rosvold et al., 1956), the presence of learning disabilities (Beale, Matthew, Oliver, & Corballis, 1987; Kirchner & Knopf, 1974; Swanson, 1981), and hyperactivity (O'Dougherty, Nuechterlein, & Drew, 1984; Sostek, Buchsbaum, & Rapoport, 1980; Sykes, Douglas, & Morgenstern, 1973). CPT performance has also been found to be sensitive to the effects of stimulant medication (Strauss, Lewis, Klorman, Peloquin, Pearmutter, & Salzman, 1984; Sykes, Douglas, & Morgenstern, 1972; Tiplady, 1988), depressants (Mirsky & Cardon, 1962; Primac, Mirsky, & Rosvold, 1957; Tiplady, 1988), and aging (Davies & Davies, 1975).

The above literature, however, is not totally unequivocal since it incorporated a variety of different types of tasks each with unique stimulus and response parameters. Furthermore, most of these studies only compared summary measures and did not assess changes in performance over time. This precludes the determination if the above noted results are just due to magnitude differences (i.e., differences in level of performance) or whether they reflect actual differences in the rate of decay in sustained attention over time (i.e., whether there are differences in performance decrement). Some recent literature which monitored performance level changes over time in head injured patients (Brouwer & Wolffelaar, 1985) and hyperactive children (Prior, Sanson, Freethy, & Geffen, 1985) found no significant differences between their performances and matched controls on vigilance decrement measures. The Brouwer & van Wolffelaar study, which used an auditory vigilance task, found that although there were no significant differences in decrement rate, the control group did perform better, though not at a statistically significant level, on 28 out of a possible 30 measures than did the head injured group. The Prior et al. study, which employed a series of auditory dichotic listening tasks, similarly found that the control group performed better on 19 out of 22 measures, of which only a few reached statistical significance. It should also be noted that in both of these studies some group comparisons were made with as few as eight subjects per group. Furthermore, the Prior et al. study appears to have employed an overly difficult task because correct detection rates fell below 32% in one condition. Clearly, considering the small number of subjects used and the fact that an overwhelming majority of the variables tended toward the same direction, a reasonable case can be made against the authors' conclusions of the equivalency of the patient and control subjects' performance on these tasks. In fact, Poulton (1973) has argued that failure to show a reliable decline in vigilance during a task on a group-wise basis can result from too few subjects or too much variability in performance and, therefore, does not prove that there is no decline in performance. Additionally, it has been further argued that some types of brain damage are likely to produce attentional lapses rather than steady declines in performance on CPT type tasks (Davies & Parasuraman, 1982). Therefore, even if there is no decrease in performance over time this does not necessarily mean that no deficit in attention is present. Lower overall performance on a CPT without greater vigilance decrement may reflect fluctuations in attention and thereby provide other useful information about a subject. In summary, at least in research involving group comparisons, it appears that CPT tasks have some utility in discriminating those subjects with impairments in attention from control subjects.

In the context of this paper, research on sustained attention in "hyperactive children" is of particular importance considering the nature of the disorder. Historically, the major diagnostic emphasis for determining hyperactivity was overactivity (see Aman, 1984, for a review). From this point of view the focus was purely on the quantity of movement (Schulman, Kaspar, & Throne, 1965; Werry, 1968). More recently, however, there has been a shift toward an emphasis on attentional disturbances (Douglas, 1972; Douglas & Peters, 1979; Dykman, Ackerman, Clements, & Peters, 1971). This shift was reflected in renaming the disorder Hyperkinetic Reaction of Childhood to Attention Deficit Disorder (ADD) in the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM III, 1980). It has further been argued that disturbances in attention, rather than overactivity, should be the target of treatment (Dykman et. al., 1971; Dykman, Ackerman, & Oglesby, 1979).

Specifically, there is evidence in favor of the view that ADD children appear to have an inability to sustain the effort and control required in certain tasks and situations (Douglas & Peters, 1979). It has been contended that this inability is attributable to a defect in the self-regulated organization and facilitation of attention and in the inhibition of inappropriate responses (Douglas, Barr, O'Neill, & Britton, 1986). This difficulty may relate to a disturbance at the level of voluntary attention of the tripartite model discussed previously. If this is the case, then any valid measure of the ability to self-regulate attention should find ADD children impaired. This result has been repeatedly found on a variety of laboratory CPT tasks based on group differences (Sykes et al, 1973; Tarnowski, Prinz, & Nay, 1986; O'Dougherty et al., 1984). It has also been shown that medications found to improve attention in children (Barkley, 1977) have also improved performance on CPT tasks (Sykes Douglas, & Morgenstern, 1972; Sykes, Douglas, Weiss, & Minde, 1971). In fact, the CPT currently is considered to be one of the most highly recommended cognitive tasks for use in pediatric psychopharmacological research, particularly with ADD children (Swanson, 1985).

Diagnostic and treatment response measures for ADD children have produced a variety of tools to monitor behaviour. The Conners Parent and Teacher Rating Scales (Conners, 1969; 1970) have become two of the most widely used measures of behaviour and drug efficacy in ADD children (Aman, 1984; Barkley, 1981; Rubinstein & Brown, 1984). Behaviour rating scales of this type, however, have been criticized on methodological grounds (Loney, 1981; Sandoval, 1977) and also because they typically focus solely on deviant or inappropriate behaviours and therefore do not give a complete picture of functioning or of drug responsiveness (Conners & Barkley, 1985; Sandoval, 1977). Problems such as these have highlighted the need for reliable and objective measures of such behaviours as "concentration span", "impulsiveness", and "distractibility" (Prior & Griffin, 1985; Prout & Ingram, 1982). Clearly, on the basis of the material reviewed above, there is a need for a practical tool to assess childhood attentional processes. Such a tool might be argued to be most appropriately administered by computer as Long and Wagner (1986) point out, "Certainly, computer programs could provide a much-needed strategy for assessing vigilance, attention, and so forth" (p. 554).

One recently developed and highly publicized tool with published normative data is the Gordon Diagnostic System (GDS; Gordon & Mettelman, 1987; Gordon & McClure, 1983; 1984). This device administers a Differential Reinforcement of Low Rate Responding (DRL) task; a measure of impulsive style that has been shown to differentiate groups of ADD (hyperactive) and control children (Gordon, 1979; McClure & Gordon, 1984). The GDS also includes a version of the CPT called the Vigilance Task. This is a nine minute task which presents numbers visually and requires children to response to a particular numeric sequence (i.e., 1 followed by a 9). Despite Gordon's focus on the DRL task, a recent study by Barkley (in press) found that none of the DRL measures were drug sensitive, while most of the traditional measures (e.g., teacher ratings and behavioural observations) as well as the Vigilance Task differentiated between drug and placebo conditions. This particular Vigilance test was found to be sensitive only at high dosages of medication with ADD children (Barkley, in press). Previous research, however, indicates that vigilance tasks have been used successfully to discriminate conditions at lower dosages of medication (Sykes et al., 1971; Werry & Aman, 1975). Barkley suggests that one reason for this discrepancy might be the relatively short duration of the GDS Vigilance task (in press).

In a recent article, Gordon (1986) presents a case for why his instrument is superior to a micro-computer. In his view, the advantages of the GDS are durability, small size, and reliability in administration. However, as Milich, Pelham, & Hinshaw (1986) point out, many current micro-computers, such as the Apple II-c, are no more cumbersome than the GDS. Furthermore, since these authors have tested several hundred ADD children on computers without damage to any of the equipment, Gordon's "delicacy" argument is without supporting evidence (Milich et al., 1986). Finally, reliability of administration (e.g., would differences in required responses and displayed stimuli affect performance?) does appear to be a reasonable concern. Evidence thus far suggests that in cognitive vigilance tasks, such as the CPT, the stimulus characteristics (e.g., color, intensity, etc.) are not as critical as they are in sensory vigilance tasks, where the presence of any stimuli may be the target (Davies & Parasuraman, 1982). Although not directly studied, this might imply that in a task which requires a response to the letter X, whether this letter is blue or green is probably not critical to task performance, provided that the stimulus is above the subject's threshold. Until this issue is resolved, a CPT task that is normed on one particular type of display monitor should probably only be used on that type of monitor if one wishes to reference the results to the normative group. Furthermore, until studies suggest otherwise, the response required (e.g., button press, joy-stick manipulation, etc.) should also be consistent with the required response in a normative study. Therefore, this final point on reliability is easily overcome by utilizing standardized testing parameters.

Milich et al. (1986) also express concern about the GDS norms, which they suggest have relatively few subjects and cut off scores which are not separated by gender. Furthermore despite the fact that vigilance tests have been found to be one of the few objective measures that are dose sensitive in medication studies (Barkley, 1977), the cost of the GDS (approximately $1300 US) and its insensitivity to dosage make it less than a cost-effective tool for clinical assessment (Barkley, in press). Additionally, the inflexibility of dedicated hardware such as the GDS make it an unattractive alternative to a versatile micro-computer for the average clinic or practitioner. As Gordon recently points out, however, there are very few computer program CPT's in use and these are primarily research oriented and lack rudimentary test standardization procedures (1987a).

With respect to the previously described three levels of attention (i.e., alertness, selectiveness, and effortfulness) it appears that all of these components may play a part in some vigilance tasks such as the CPT (Davies & Parasuraman, 1982). Impairments in any of these components should, therefore, affect the performance on a CPT. Furthermore, a well designed CPT can yield numerous individual measures that might provide information to help determine the nature of an attentional disturbance. Possible raw score measures include correct responses or hits (i.e., the number of correct target detections), errors of omission (i.e., the number of target misses or the inverse of hits), errors of commission or false alarms (i.e., the number of responses to nontargets) and detection latency or reaction time (i.e., the duration of time from stimulus presentation until a correct response). Signal detection theory (Green & Swets, 1966; Swets, 1977) transformations of raw scores produce a measure of the effectiveness of discriminating the target stimuli from the background stimuli (i.e., sensitivity; D') and a measure of the degree of bias, or tendency to respond, that a subject demonstrates (i.e., response criterion or bias; B'). Finally, all of the above variables can be further analyzed to ascertain if performance deteriorates over time (i.e., to determine whether there is any vigilance decrement).

There has been little research that has examined the possible clinical relevance of these individual measures. However, variables such as hit rate and sensitivity are generally thought to be related to signal discrimination capacity (Davies & Parasuraman, 1982; Green & Swets, 1966; Swanson, 1983). This most likely involves what has been called "coming to attention" (Brown & Wynn, 1984; Keogh & Margolis, 1976a); that is, perceptual analysis, determination of salience, and focusing abilities. Commission errors and response criterion measures on the other hand, relate more to response characteristics and could be used to determine such difficulties as impulsiveness (Anderson, Halcomb, & Doyle, 1973; O'Dougherty et al., 1984; Sostek, Buchsbaum, & Rapport, 1980; Swanson, 1983). Reaction time (detection latency) measures have previously been used as a general index of the speed of information processing (Jensen & Munro, 1979; Nettelbeck, 1980; Reid & Borkowski, 1984; Sternberg, 1969) and are considered to be intimately related to attention, particularly in children (Krupski & Boyle, 1978; Rosenthal & Allen, 1978 ;Wickens, 1974). Finally, analyses of change in performance over time provides information on the ability to maintain or sustain these attentional components with the passage of time (Davies & Parasuraman, 1982; Jerison, 1977). It is felt that examination of the pattern of these individual measures may further provide valuable information on the specific nature of an attentional disturbance. For example, a child found to be significantly impaired on sensitivity may have difficulty in selective attention and might benefit from recommendations such as increasing the saliency of the important stimuli by using novel, unambiguous, and explicit information while minimizing the unimportant background stimuli. On the other hand, performance characterized by large vigilance decrements may be evidence of a disturbance in effort or voluntary attention which might respond better to initially shorter assignments which gradually lengthen with increasing ability.

Although there is some research that suggests that there are differences between visual and auditory attention (Diller & Weinberg, 1972), a review of the current literature suggests that there are no modality affects on sustained attention performance (Parasuraman, 1982). Since this issue is far from resolved clinically, it is reasonable to assume that the attentional processes measured are in the same modality as the CPT task used.

1.1 Purpose Of This Study

The goal of this research is to test the assumption that a useful tool for assessing attention, one that could be used in the neuropsychological evaluation of children, can be developed using a continuous performance measure. In other words, can a CPT task be used to measure visual attention in a practical and clinically meaningful way with individual children?

In evaluating the preliminary usefulness of this CPT measure, attempts were made to follow recommendations established in the Standards for Educational and Psychological Testing manual (American Psychological Association, 1985).

In accordance with this manual validity, although a unitary concept, is often demonstrated through construct-related, content-related and criterion-related types of evidence. Some content-related evidence, which often relies upon expert judgements about the test (i.e., CPT) being representative of the defined domain (i.e., attention), has already been presented above; for a more thorough review of continuous performance tests and attention see Davies and Parasuraman (1982).

Construct-related evidence, which primarily refers to test performance as a measure of the psychological characteristics of interest, was partially assessed by examining the internal structure of the CPT (e.g., intercorrelations of measures). CPT performance was also compared with attentional and nonattentional dimensions of established behavioural rating scales (i.e., Conners Parent and Teacher Questionnaires) and to an estimate of intelligence.

Finally, the ability of the CPT to correctly classify children with diagnosed attentional problems (i.e., ADD) and children without known difficulties in attention was assessed to provide some criterion-related evidence of validity. This was to determine if the CPT results related to the criterion of diagnosed attentional difficulties. Further criterion-related evidence was examined from the inspection of individual subject CPT results in response to medication prescribed to enhance attention.

Reliability, or the degree to which CPT performance is free from errors of measurement, was assessed by calculating both internal and test-retest reliability coefficients. This explored the consistency and stability over time of scores obtained using the CPT.

Specifically, a Computerized Continuous Performance Test (CCPT) appropriate and practical for use with children was designed and developed. The test was based on a commonly available micro-computer (Apple II-type) and would be adaptable to other commonly available personal computers. It was felt that by avoid-ing the custom-made rigid and idiosyncratic mechanical systems used by many researchers (e.g., Giacalone, 1983; O'Dougherty et al. 1984, Rapport, Dupaul, Stoner, & Jones, 1986; Zentall, 1986) the test would have widespread applicability. Furthermore, it required minimal hardware while providing standardized parameters and soundless stimulus presentations. There has been one other study found that normed a CPT task on children (Levy, 1980). Levy, however, provided no measures of changes in performance over time, did not use signal detection transformations, used uncommon parameters and a custom made set-up, and did not assess the reliability or validity of this task. This lack of a thorough CPT analysis in conjunction with unique parameters and hardware make the clinical usefulness of Levy's task questionable. The CCPT is not the first micro-computer based CPT task (see Conners, 1985; Garfinkle & Klee, 1983), but it is the first with a comprehensive attempt being made to provide a normed, valid, and reliable tool to assess attentional processes clinically with children.

Chapter 2

METHOD

2.1 Subjects

2.1.1 Normative Sample

Potential volunteer subjects for the Normative Sample were solicited via letters distributed at four elementary schools in the greater Victoria area. All of the children in grades one to five in these four schools received letters and consent forms. Out of 500 forms circulated 177 (35.4%) were returned to form the potential subject pool. Subjects were then randomly selected from the pool with attempts being made to equate the number of subjects by sex and grade. This resulted in 128 children (63 males and 65 females) being selected to participate in the study. Data for three of these subjects (all males) on the computer task were incomplete due to a power failure, an emergency bathroom requirement, and a hand positioning (i.e., resting on the keyboard cover) that resulted in inadvertent responses. Additionally, 42 of the above subjects (20 males and 22 females) were randomly selected (attempts were again made to distribute evenly across sex and grade) and retested on the computer task approximately one month (mean=28.0 days) after their initial testing.

2.1.2 Clinical Group

Subjects for the Clinical Group were solicited by asking three child psychiatrists practicing in the Victoria area to nominate subjects. All potential subjects between the ages of six and eleven nominated by the child psychiatrists had a psychiatric diagnosis of Attention Deficit Disorder (ADD) which met the criteria of the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM III, 1980; see Appendix A). DSM III was chosen over the more recent DSM III-R (American Psychiatric Association, 1987) because little research exists on the updated version at this time. Parents of these subjects were then contacted by phone and asked if they would like to volunteer to participate in the study. Those parents volunteering subsequently received letters and completed the same consent forms as the parents of the Normative Sample. Additional criteria for the subjects selected for the Clinical Group required that they were not currently receiving medication for their disorder (i.e., not within a week prior to testing) and that they had scores on the Hyperactive Index on either the Revised Conners Parent or Revised Conners Teacher Questionnaire (Goyette, Conners, and Ulrich, 1978; see Section 2.2.2) of at least 1.5 standard deviations above the mean for normal aged peers. Out of twenty five ADD clinical subjects referred and tested, one was excluded because parental permission to discontinue medication was not obtained and another clinical subject was excluded because neither of his Conners scale scores met the above criterion. This resulted in 23 subjects (20 male and 3 female) being obtained for the Clinical Group. The Conners Teacher Questionnaire was not returned for one of these subjects and the overall school performance ratings (see Section 2.2.2) were not completed by teachers of two additional clinical subjects.

Additionally three of the above subjects were retested on the computer task approximately one month after their initial testing. Three other of the above subjects were also retested while receiving medication (methylphenidate) for their disorder. The data from the latter three subjects, along with the two excluded from the Clinical Group were examined individually. Data were also obtained on a 7-year-old female who had sustained a head injury 4 months prior to assessment.

2.1.3 Control Group

A subset of the above Normative Sample was selected to form a Control Group. This sample's members were matched to the above clinical subjects individually by sex (i.e., 20 male and 3 female) and as closely as possible on age (i.e., Control mean=8.40 yrs.; Clinical mean=8.43 yrs.) and intelligence (i.e., Control mean IQ=100.3; Clinical mean IQ=96.0) All data other than sex, age and IQ were omitted from the selection of the Control Group.

2.2 Apparatus and Conditions

2.2.1 Testing Conditions

All children in the Normative Sample were tested individually and during regular school hours (i.e., 8:30 am to 2:30 pm) in a "relatively" quiet environment (e.g., medical room) located at their respective schools. The testing was performed by one of two examiners (one male and one female) who were experienced in assessing children.

All subjects in the Clinical Group were tested individually at the Jack Ledger House Child and Adolescent Psychiatric Unit of the Arbutus Society for Children.

The environment was quiet and although actual testing times were the same as the Normative Sample, most of the clinical testing was performed during weekends. The same male examiner tested all of the subjects in the Clinical Group.

2.2.2 Data Collection Materials

Parents of all subjects completed the Revised Conners Parent Questionnaire (Goyette et al., 1978). This is a normed 48 item rating scale relating to various types of child behaviour problems. Each item is scored on a 0-3 scale and items can be added to yield five factors and one index factor: Conduct Problems, Learning Problems, Psychosomatic, Impulsive-Hyperactive, Anxiety, and Hyperactive Index. Demographic information was obtained from the first two pages of the Child Behaviour Checklist (Achenbach and Edelbrock, 1983) which were also completed by parents. Based upon this information the socioeconomic status (SES) of each subject's family was quantified using the revised Blishen scales (Blishen & Carroll, 1978; Blishen & McRoberts, 1976). These scales which are based upon income level, educational status and prestige ranking provide a socioeconomic index of occupations in Canada. This index ranges from 14.4 to 96.7 and allows for groupings to be made into six socioeconomic class intervals (see Appendix J for examples). Family SES was arbitrarily based on the parent with the highest occupational ranking on these scales.

The subjects' teachers completed the Revised Conners Teacher Questionnaire (Goyette et al., 1978). This is a normed 28 item rating scale constructed similarly to the Parent Questionnaire described above. This scale yields scores on Conduct Problem, Hyperactivity and Inattentive-Passive factors and a Hyperactivity Index. Additionally, teachers completed a five point rating scale of current school performance (1. well below average, 2. below average, 3. average, 4. above average, and 5. well above average).

Intellectual estimates were made using a prorated Verbal Intelligence Quotient based upon the Information, Similarities, Arithmetic and Digit Span subtests of the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974). These specific subtests were chosen since they were considered to be particularly time efficient and objective in terms of scoring. It was reasoned that since Verbal IQ and Full Scale IQ are highly correlated with each other (r=.92; Wechsler, 1974) the prorated Verbal IQ might also provide an estimate of general intelligence. Other data coded included the testing examiner, school, and the time of task administration. It was also noted if the subjects complained while being tested on the computer task (objectively defined as talking during the task, after being instructed to remain quiet until completion of the task; see Appendix C).

2.2.3 CCPT Hardware

The CCPT was administered to all subjects on an Apple II-c micro-computer with an Apple II-c monitor. Brightness and contrast controls were set approximately on the medium setting to give a pleasant level of text illumination. A cover constructed of plasticized (polyurethane painted) cardboard was placed on top of the keyboard during test administration. This cover exposed only the space bar for subject responses and the physically distant numbers 1 and 2 and return keys for examiner program control. A green rectangular sticker (3" by 3/8") was adhered on top of the space bar and a red rectangular sticker, of the same size, was adhered to the ledge of the computer directly in front of the space bar.

2.2.4 CCPT Software

The main body of the CCPT program was written in Applesoft Basic, while the timing was handled by a 6502 processor machine language subroutine. This routine was verified as being accurate (within .2%) with a South West Technical Products Corporation Universal Digital Timer. The stimuli, defined as high resolution shapes contained in a shape table, were 12 capital letters (A,C,E,H,K,N,P,Q,S,U,X,Z). Each letter was approximately 10 millimeters in height and was displayed in a central position on the monitor. These particular letters were chosen as stimuli because they were found to require similar amounts of time to display on the screen and because they were comparable to those reported in the literature (Giacalone, 1983; Swanson, 1981). Stimuli were presented at the rate of 1.5 seconds and for a duration of .2 seconds. Although the values for rate and duration have varied considerably in the literature, these specific parameters have been found to be particularly sensitive in differentiating "hyperactive" and control groups (Sykes et al., 1971; 1972; 1973). It was on this basis that these values were chosen.

The CCPT was composed of two subtests, each of which presents, in a standardized order, 600 individual letters of which 90 (15%) are targets. This particular target percentage has also been used successfully in previous group research (Giacalone, 1983; Kupietz, 1976; Sykes et al. 1971). The sequences of letters used were previously randomized using computer generated random number lists, with the restriction that 30 targets appear in each block of 200 stimuli. This restriction was utilized to enable comparisons to be made between blocks. The actual duration of each subtest excluding practice time was exactly 15 minutes.

2.2.5 CCPT Measures

The CCPT X and AX tasks both yield a number of different measures. These two tasks could also be merged into one combined task to reduce the number of variables. Since it was unknown if the combined task would be superior or inferior to the individual tasks, analyses were performed on all three tasks (i.e., X, AX and combined) when appropriate. The measures calculated from each CCPT task administered are:

1. Hits - the number of responses made to targets.
2. False Alarms - the number of responses made to non-targets.
3. Response Time - the time in milliseconds from target presentation to response.*
4. Variability - the standard deviation of the Response Time.
5. Sensitivity - a signal detection theory measure calculated from Hits and False Alarms and ranging between 0 and 1 (see Appendix B).
6. Response Bias - a signal detection theory measure calculated from Hits and False Alarms and ranging between -1 and 1 (see Appendix B).
7. Performance Decrements - changes in any of the above measures occurring between five minute blocks.

*Note that any reaction time that was less than 180 milliseconds was considered a premature response and classified as a False Alarm. The cut-off value of 180 milliseconds was conservatively decided as a minimum for a valid response on the basis of the visual reaction time literature (see Welford, 1981).

2.2.6 Data Manipulations

Basic subject information such as subject number, birthdate, gender, group, current date and time were entered into the computer before each task was initiated. This double entry allowed for subsequent error checking by comparing the values entered for the same variables (e.g., birthdate). This basic subject information along with all CCPT data (raw and calculated scores) were then saved to 5 and 1/4 inch floppy disk. Other obtained data (e.g., WISC-R scores, Conners Questionnaires, etc.) were later merged with the CCPT data and resaved to floppy disk. Data were then transferred via an Apple compatible micro-computer which was hardwired to an IBM 3083 mainframe computer for data analysis. Random checks of several individual cases were made to ensure that the accuracy of the data was maintained throughout the data manipulations.

2.3 Procedure

For the normative sample, the parent questionnaires were sent home with instructions specifying that one parent complete the enclosed information. The teacher questionnaires were distributed and collected directly by the examiner while at that particular school. Parents of the clinically referred children completed their questionnaires during the time that their children were being assessed. They were then given a teacher questionnaire with an addressed and stamped envelope to present to their child's teacher.

During the assessment each subject was seated facing the examiner in a non-distracting environment. The Information, Similarities, Arithmetic and Digit Span subtests of the WISC-R were then administered in the proscribed manner (see Wechsler, 1974).

The subject was then seated approximately two feet away from the center of the computer monitor which was positioned at eye level. Subjects were initially tested on letter familiarity via letters presented on the screen. They were required to correctly name all 12 of the letters used before testing was initiated. Subjects unable to name all of the letters in one trial were then tested on their ability to recognize (i.e., point to) letters named for them. Testing would have been discontinued if the subjects were unable to name or recognize all 12 of the letters. No subject was found to be unable to name or recognize all of the CCPT letters.

Subjects were then instructed using standardized procedures with due regard to individual needs (see Appendix C) to rest the index finger of their dominant hand (i.e., the hand that they write with) on the red rectangular sticker on the ledge of the computer and to attend to letters that would appear on the computer screen. They were also directed to press the green button every time (but only when) they saw the designated target appear on the screen. The target in the first task was the letter X and in the second task was the letter X, if and only if, it was preceded by the letter A. These particular targets have been used in previous research (Sykes et al., 1971). Subjects were instructed to respond as rapidly as possible, although accuracy in performance was stressed. After comprehension of the task requirements was demonstrated during a practice session before each task (i.e., five consecutive correct responses; see Appendix C) testing was initiated. During the task the examiner avoided close scrutiny of the subject's performance by engaging in other unobtrusive activities (e.g., scoring previous data). This attempted to minimize possible artificial external control exerted by the presence of an examiner, which has been shown to improve performance in hyperactive (ADD) children on CPT tasks (Draeger, Prior & Sanson, 1986). A short rest period of approximately two minutes was given between the two tasks.

The order of tasks presented was invariant for all subjects and consisted of WISC-R, X-task and AX-task in that order. The WISC-R was given first to help establish rapport and to simulate a clinical assessment in which other tests would be given prior to the CCPT. The CCPT tasks were given in the same sequence to highlight interindividual differences by eliminating error variance due to order effects (Murphy and Puff, 1982) and also to obtain data that would permit the option of administering only the first subtest if necessary.

At the conclusion of the session children were allowed to choose stickers as a "reward" for their participation. On the rare occasion when children inquired about their performance, they were given accurate but vague positive feedback (e.g., "You got 80 of the X's, that's great").

Chapter 3

RESULTS

3.1 Preliminary Considerations and Observations

3.1.1 Statistics

All data were analysed using the SPSSX statistical package (SPSSX, 1986). Although the level of significance adopted for the analyses was .05, all data were examined due to the exploratory nature of the study. For example, if an overall multivariate test for an effect was found to be nonsignificant (i.e., $p>.05$) the univariate tests were nevertheless inspected. These results were interpreted with extreme caution considering the increased possibility of committing a Type I error. For all multivariate analyses the F statistic for Wilkes Lamda was used to determine significance. Exact probability levels are reported whenever possible.

3.1.2 Age versus Grade Categories

Subjects were solicited through the school system, and consequently data were obtained by grade level (1 thru 5). It might be argued, however, that chronological age is a less arbitrary category and therefore might have a more general relevance in any clinical application of the CCPT. Categories of age by year were calculated (rounding 11 months and more than 15 days up to an additional year) for all subjects. This created six age groups (6 thru 11 years); however, the 11-year-old category had only five members (2 males and 3 females). Since the mean performances of these 11-year-olds were very similar to the ten-year-old means, and a comparison group for the 11-year-old clinical subjects was desired, a decision was made to combine the ten year and 11-year-old data to form a 10/11 year-old-group. The performances of the separate 10-year-old normative group on all CCPT measures are presented in Appendix D.

3.1.3 Outliers

Visual inspection of CCPT performance scatter plots revealed the presence of some atypical scores in the normative sample. A decision was then made to remove the extreme outlying scores, which were arbitrarily defined as four or more standard deviations from the mean for that age group. It was reasoned that these cases were not typical of the sample and their inclusion would disproportionately influence group means and the subsequent analyses. Using the above criterion three cases were identified as extremely atypical with respect to their age group means. These three cases were removed from all subsequent data analyses. The reason for these deviant performances is unknown and the scores of these three subjects are presented in Appendix E. It was felt that data transformations (e.g., logarithmic) were not warranted since such a small number of cases was involved and it was desired clinically to preserve the original unadulterated meaning of the measures (e.g., number of correct responses).

3.1.4 CCPT Letter Familiarity and Practice

Of all the subjects tested only two, one from the Normative Sample and one from the Clinical Group, were unable to correctly name all of the CCPT letters on one trial. Both of these children were able to recognize letters named for them and their data appeared to be unremarkable in reference to their respective groups. Their data were therefore included with their particular group. Additionally, four subjects from each of the Normative and Clinical groups failed to meet the performance criterion for comprehension (i.e., five consecutive correct responses; see Appendix C) in their practice trials. All of these children, however, appeared to understand the task since they were able to verbalize the task requirements to the examiner and their data were retained for all analyses.

3.2 Characteristics of the Normative Sample

3.2.1 Socioeconomic Status

For the normative sample, the mean socioeconomic index was 54.49 (SD=13.75) and the mean socioeconomic class was 3.95 (SD=1.44). Table 1 presents the means and standard deviations of socioeconomic index and class for each age group (IQ which is also presented in Table 1 is discussed in Section 3.2.2).

3.2.2 Intelligence Estimate

The normative sample had a mean prorated verbal intelligence Quotient on the Wechsler Intelligence Scale for Children-Revised (WISC-R) of 109.12 (SD=10.91). The means and standard deviations of the prorated verbal IQ's for each age group are presented in Table 1.

TABLE 1

NORMATIVE SAMPLE DESCRIPTIVE DATA
Means (Standard Deviations)

Age	N	SES Index	SES Class	Verbal IQ
6	24	54.86 (14.58)	3.96 (1.63)	111.58 (10.97)
7	27	53.72 (13.50)	3.93 (1.33)	104.93 (10.65)
8	19	54.90 (12.40)	4.05 (1.31)	110.21 (12.27)
9	32	52.94 (15.48)	3.77 (1.59)	109.03 (9.73)
10-11	23	56.77 (12.54)	4.13 (1.32)	110.70 (11.06)
Total	125	54.49 (13.75)	3.95 (1.44)	109.12 (10.91)

3.2.3 Relationship between SES & IQ and Sex & Age

To determine if socioeconomic status (index) and verbal intelligence varied significantly by sex and age a multivariate analysis of variance was performed. The main effects for sex (F(2,113)=1.81, p=.167), age (F(8,226)=0.71, p=.681) and the interaction of sex by age (F(8,226)=1.24, p=.278) were all nonsignificant. It should also be noted that none of the univariate tests (i.e., examining SES and IQ separately) were found to be significant. Also through the calculation of a Pearson product-moment correlation it was determined that the correlation between IQ and SES was nonsignificant for this sample (r=.163, p=.073) on a two tailed test.

3.2.4 Relationship between SES & IQ and CCPT

Due to the continuous nature of the variables socioeconomic status (index), prorated Verbal IQ, and the CCPT measures, multiple regression analyses were used to investigate the possibility of relationships between measures. Furthermore, separate analyses were performed for SES index and prorated IQ since these were found to be not significantly correlated with each other. These analyses determined that SES index was not significantly correlated with the six performance measures of the X-task (R=.172, F(5,117)=0.71, p=.617), the AX-task (R=.189, F(5,116)=0.86, p=.510), or the combined task (R=.196, F(5,115)=0.92, p=.470). Further analyses to examine SES class using multivariate analyses of variance found that the effects for the X-task (F(30,450)=1.28, p=.150), AX-task (F(30,446)=1.10, p=.325) and combined task (F(30,442)=1.09, p=.345) were all nonsignificant.

Multiple regression analyses also indicated that prorated IQ was not correlated significantly (R=.241, F(5,118)=1.45, p=.211) with the X-task. Significant correlations with prorated IQ were found, however, for the AX-task (R=.322, F(5,117)=2.71, p=.024) and the combined task (R=.317, F(5,116)=2.60, p=.029).

Analyses were then performed to further investigate possible relationships between individual WISC-R subtest scaled scores and the CCPT. Significant intercorrelations were found between the WISC-R subtests (see Appendix F). Overall canonical correlational analyses were therefore performed to protect against type I errors. These analyses resulted in a borderline significant overall correlation between the WISC-R subtests and the X-task (F(24,398.91)=1.54, p=.052) and significant overall correlations between the subtests and the AX-task (F(24,395.42)=1.95, p=.005) and combined task (F(24,391.93)=2.14, p=.002).

Multiple regression analyses were then performed on each of the WISC-R subtests. The correlations between the six X-task measures and Information (R=.276, F(5,118)=1.95, p=.092), Similarities (R=.167, F(5,118)=0.68, p=.639), Arithmetic (R=2.72, F(5,118)=1.89, p=1.02) and Digit Span (R=.279, F(5,118)=2.00, p=.084) subtests were all nonsignificant. Multiple regressions on the AX-task measures produced nonsignificant correlations with Similarities (R=.226, F(5,117)=1.26, p=.285) and Digit Span (R=.256, F(5,117)=1.64, p=.154), and significant correlations with Information (R=.371, F(5,117)=3.73, p=.004) and Arithmetic (R=.315, F(5,117)=2.58, p=.030) subtests. Inspection of the individual CCPT measures in these significant regression analyses revealed that significant contributions were made to the Information correlation by Response Bias (T=2.71, p=.008) and False Alarms (T=2.03, p=.045). It was found that none of the other CCPT measures reached individual statistical significance (i.e., all were p>.700). Also, none of the individual CCPT measures reached accepted significance (i.e., all were p>.100) in the overall correlation of the CCPT with the Arithmetic subtest.

The combined task was found to be significantly correlated with WISC-R subtests Information ($R=.403$, $F(5,116)=4.50$, $p<.001$), Arithmetic ($R=.325$, $F(5,116)=2.75$, $p=.022$) and Digit Span ($R=.307$, $F(5,116)=2.41$, $p=.040$). Individual CCPT measures contributing significantly to the Information correlation were Response Bias ($T=3.06$, $p=.003$) and False Alarms ($T=2.14$, $p=.035$), and for the Digit Span subtest correlation the significant measure was Deviation ($T=1.98$, $p=.050$) and borderline significant for Response Time ($T=1.84$, $p=.068$). All other CCPT measures were found to be individually nonsignificant ($p>.200$). Also no individual CCPT measure on the combined task was found to be significant ($p>.100$) in the Arithmetic regression analysis. The Similarities subtest was not found to be significantly correlated ($R=.178$, $F(5,116)=0.76$, $p=.578$) with the combined task.

3.2.5 Relation between Time of Administration and CCPT

Multiple regression analyses were performed to investigate the relationship between time of task administration and CCPT performance. The resultant correlations, which were all found to be nonsignificant, were $R=.175$ ($F(5,118)=0.74$, $p=.591$) for the X-task measures, $R=.195$ ($F(5,117)=0.92$, $p=.467$) for the AX-task measures and $R=.210$ ($F(5,116)=1.08$, $p=.378$) for the combined task measures. Pearson correlation analyses also indicated that none of the individual CCPT measures were significantly ($p>.05$) correlated with time. It should be noted that the actual time the CCPT commenced ranged from 8:50 am to 2:00 pm.

3.2.6 School and Examiner Effects on CCPT

Possible effects of the examiner administering the test were assessed by multivariate analyses of variance. The examiner effect for the X-task measures was ($F(6,99)=0.91$, $p=.489$), the AX-task measures was ($F(6,98)=0.66$, $p=.678$), and the combined task measures was ($F(6,97)=0.96$, $p=.456$). These analyses also revealed that there were no significant interactions (i.e., $p>.05$) between examiner and the age or sex of the subject on task performance. Possible differences in performance between the schools sampled were also investigated. Multivariate analyses of variance found no significant differences between schools on X-task ($F(12,232)=1.34$, $p=.198$), AX-task ($F(12,230)=1.10$, $p=.361$), or on combined task ($F(12,228)=1.06$, $p=.396$) performance.

3.2.7 Subject Responses to CCPT

It was found that 18 subjects (14%) of the normative sample complained (as previously defined) during the CCPT. Multivariate analyses of variance were used to determine if this group performed differently than those without complaints on the computer tasks. The effect for complaints on the X-task measures ($F(6,117)=1.14$, $p=.345$), the AX-task measures ($F(6,116)=1.24$, $p=.293$) and the combined task measures ($F(6,115)=1.25$, $p=.285$) were all nonsignificant.

3.2.8 Relation between Age & Sex and CCPT Performance

Potential sex and age differences in task performance were also investigated by multivariate analyses of variance. On the six X-task measures significant effects were found for the sex by age interaction ($F(24,381.47)=2.28$, $p=.001$), the age effect ($F(24,381.47)=5.92$, $p<.001$) and the sex effect ($F(6,109)=4.56$, $p<.001$).

Table 2 presents the associated univariate tests. Inspection of the univariate tests indicates that the sex by age interaction is significant on the Hits measure and on the Sensitivity measure, which is largely derived from the Hits.

A series of t-tests were then performed to determine which age levels were associated with significant sex differences. The interaction for the Hits variable is displayed in Figure 1, with significant t-test differences noted. This pattern of significance over the age levels is the same for the Sensitivity measure; the data are therefore not presented. Figure 1 appears to suggest that a large part of the significant interaction might by due to the particularly poor performance of the seven year old female group.

When the analyses were repeated, excluding the seven year old group, a significant multivariate sex by age interaction ($F(18,238.07)=2.36$, $p=.002$) was still obtained; however, none of the associated univariate tests (i.e., task measures) were found to be significant ($p>1.00$) on the interaction.

Analysis of the AX-task resulted in a nonsignificant sex by age interaction ($F(24,377.98)=0.86$), $p=.656$) and significant age ($F(24,377.98)=3.20$, $p<.001$) and sex ($F(6,108)=2.68$, $p=.018$) main effects. The associated univariate statistics for the significant effects are presented in Table 3.

Analysis of the combined task resulted in a similar pattern of a nonsignificant sex by age interaction ($F(24,374.49)=1.24$, $p=.199$) and significant age ($F(24,374.49)=4.16$, $p<.001$) and sex ($F(6,107)=3.57$, $p=.003$) main effects. Associated univariate statistics for the significant effects are presented in Table 4.

Figures 2 through 7 present graphic displays of the age effects for the combined task variables, with the Response Time and Response Bias measures further broken down by sex.

TABLE 2

UNIVARIATE F TESTS FOR SEX AND AGE ON X-TASK

Effect	Variable	F(4,114)	Sig. of F
Sex by Age	Hits	4.16	.004
	False Alarms	1.31	.270
	Response Time	1.69	.157
	Variability	2.17	.077
	Sensitivity	4.20	.003
	Response Bias	0.23	.921
Age	Hits	11.22	<.001
	False Alarms	2.29	.064
	Response Time	25.48	<.001
	Variability	16.55	<.001
	Sensitivity	10.89	<.001
	Response Bias	3.60	.008
		F(1,114)	
Sex	Hits	2.78	.098
	False Alarms	3.34	.070
	Response Time	10.32	.002
	Variability	0.14	.713
	Sensitivity	2.55	.113
	Response Bias	2.85	.094

FIGURE 1

SEX INTERACTION OF HITS ON X-TASK

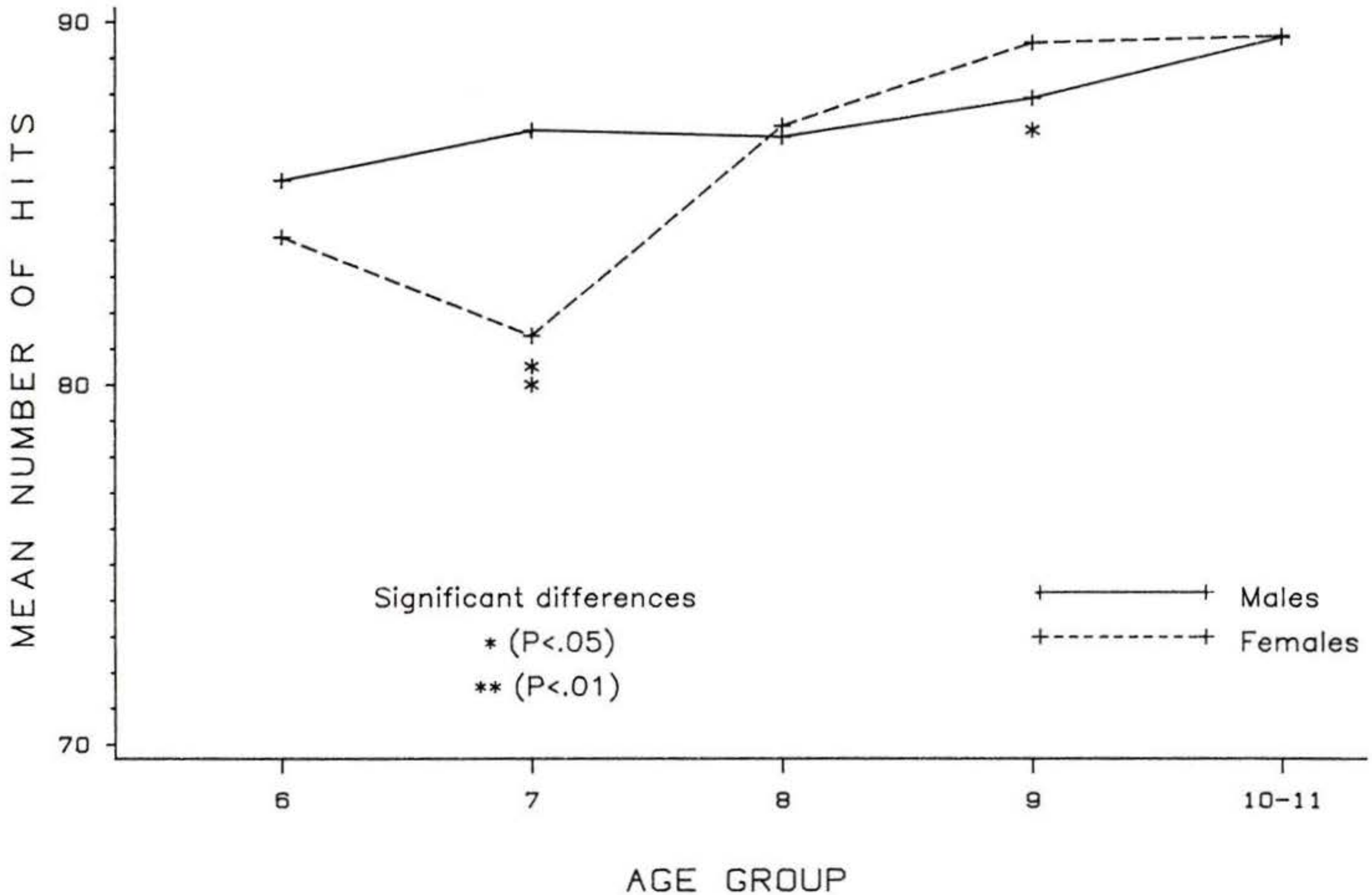


TABLE 3

UNIVARIATE F TESTS FOR SEX AND AGE ON AX-TASK

Effect	Variable	F(4,113)	Sig. of F
Age	Hits	8.21	<.001
	False Alarms	2.22	.071
	Response Time	7.84	<.001
	Variability	9.74	<.001
	Sensitivity	8.04	<.001
	Response Bias	0.84	.503
		F(1,113)	
Sex	Hits	1.66	.201
	False Alarms	0.26	.610
	Response Time	10.71	.001
	Variability	0.14	.705
	Sensitivity	1.35	.248
	Response Bias	6.39	.013

TABLE 4

UNIVARIATE F TESTS FOR SEX AND AGE ON COMBINED TASK

Effect	Variable	F(4,112)	Sig. of F
Age	Hits	10.90	<.001
	False Alarms	2.58	.041
	Response Time	17.13	<.001
	Variability	17.50	<.001
	Sensitivity	11.05	<.001
	Response Bias	1.82	.129
		F(1,112)	
Sex	Hits	2.91	.091
	False Alarms	0.77	.383
	Response Time	13.17	<.001
	Variability	0.08	.777
	Sensitivity	2.52	.115
	Response Bias	7.34	.008

FIGURE 2

MEAN HITS BY AGE ON COMBINED CCPT

(STANDARD ERROR OF MEAN INTERVALS)

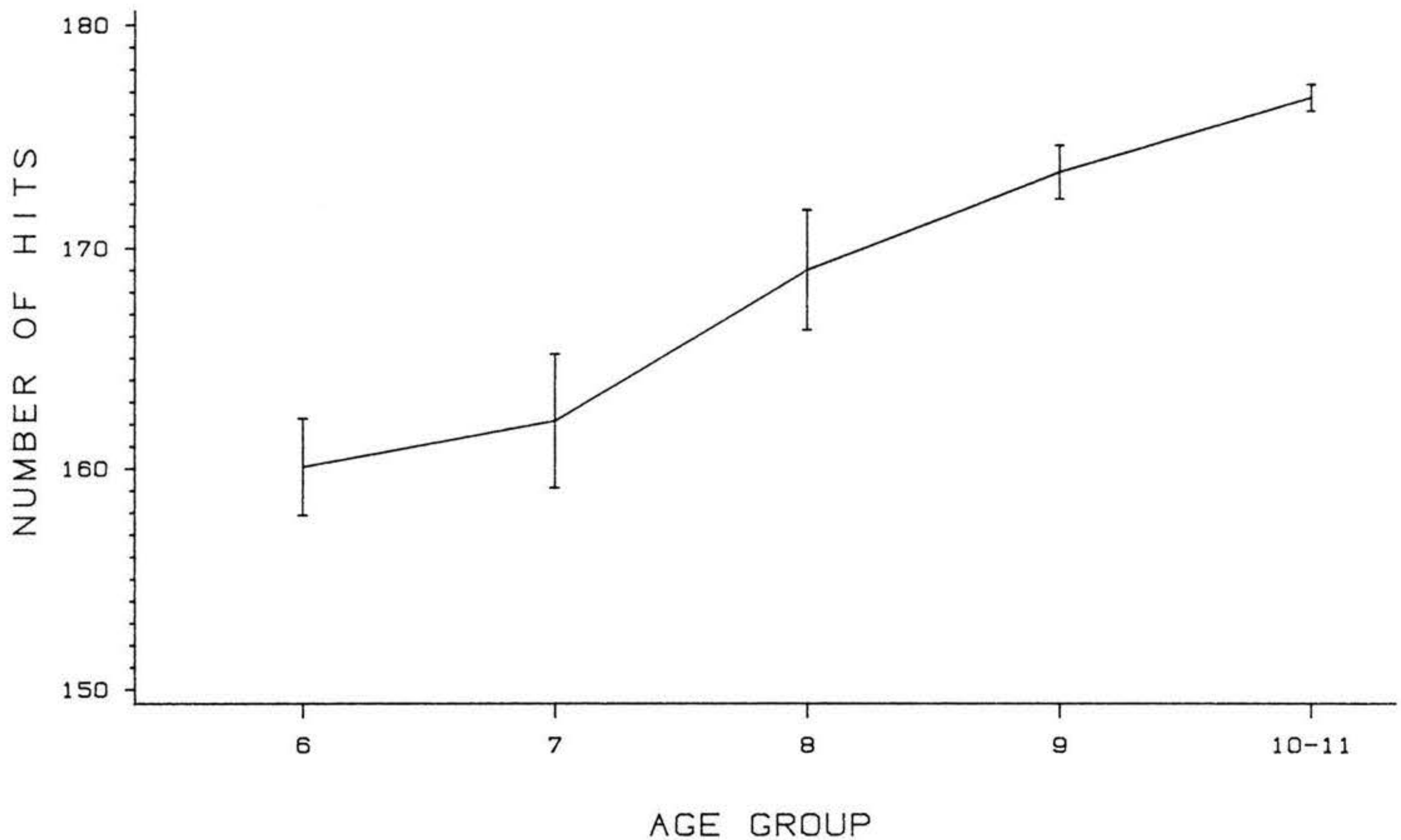


FIGURE 3

MEAN FALSE ALARMS BY AGE ON COMBINED CCPT

(STANDARD ERROR OF MEAN INTERVALS)

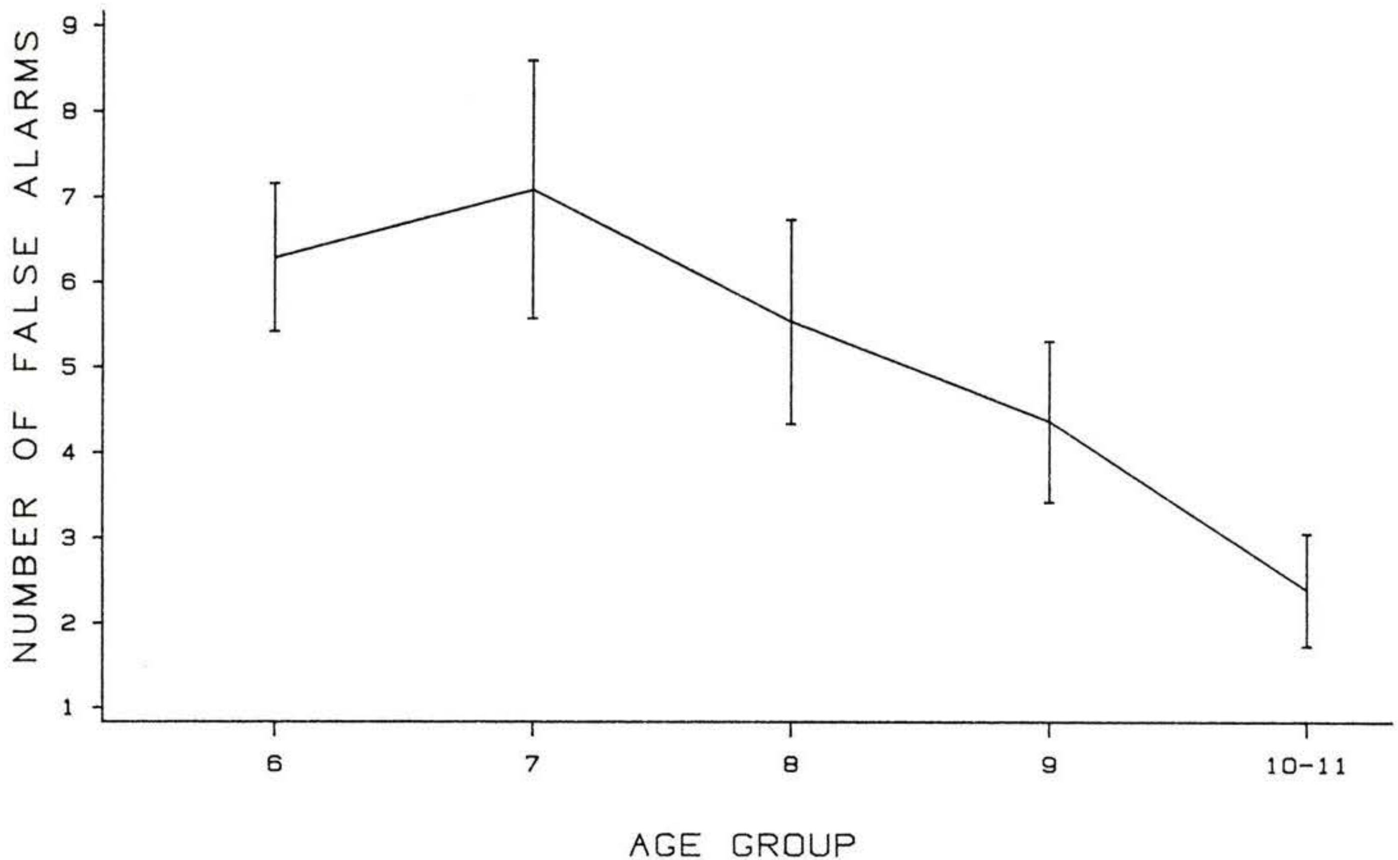


FIGURE 4

MEAN RESPONSE TIME BY AGE ON COMBINED CCPT

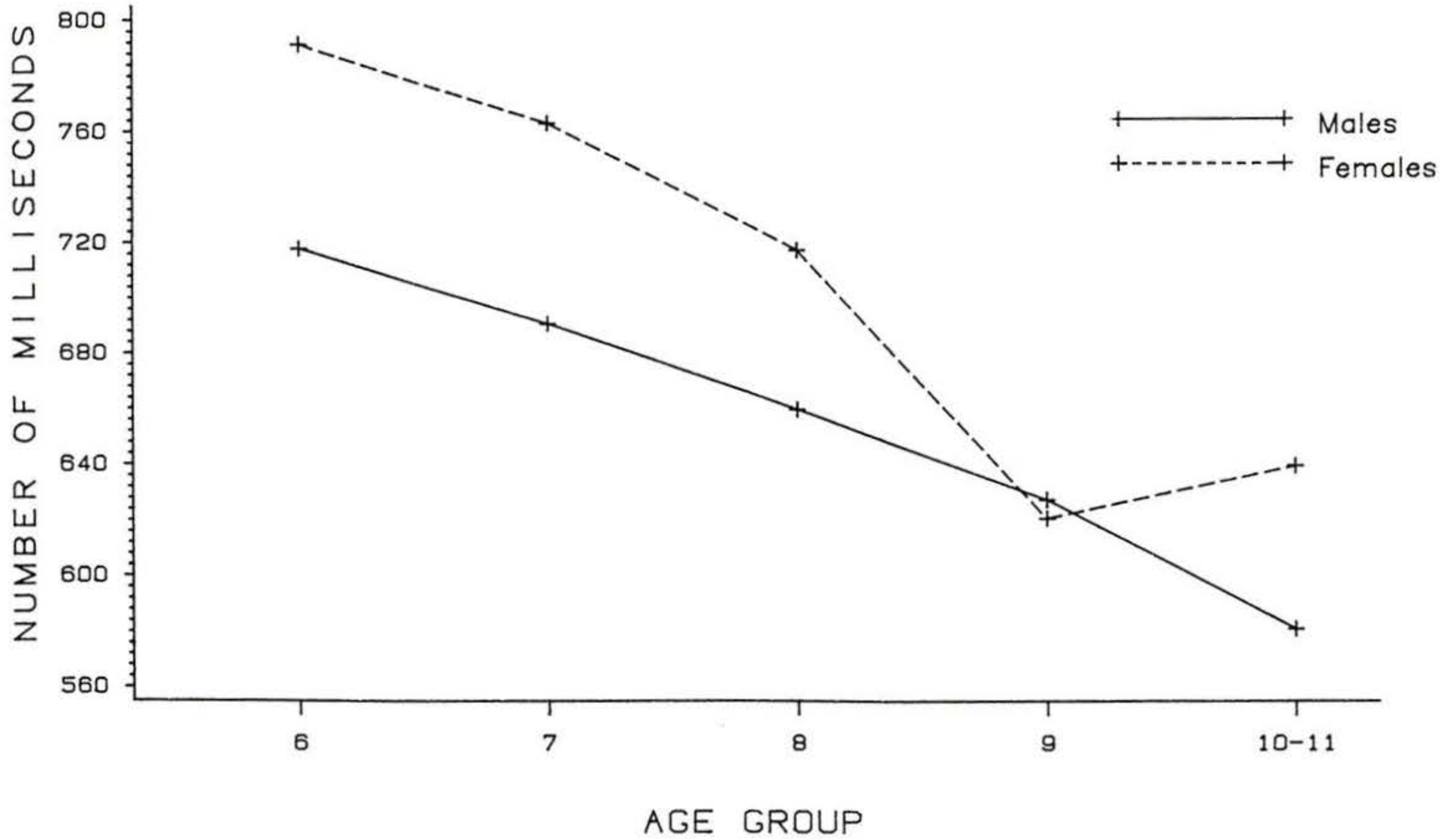


FIGURE 5

MEAN VARIABILITY BY AGE ON COMBINED CCPT

(STANDARD ERROR OF MEAN INTERVALS)

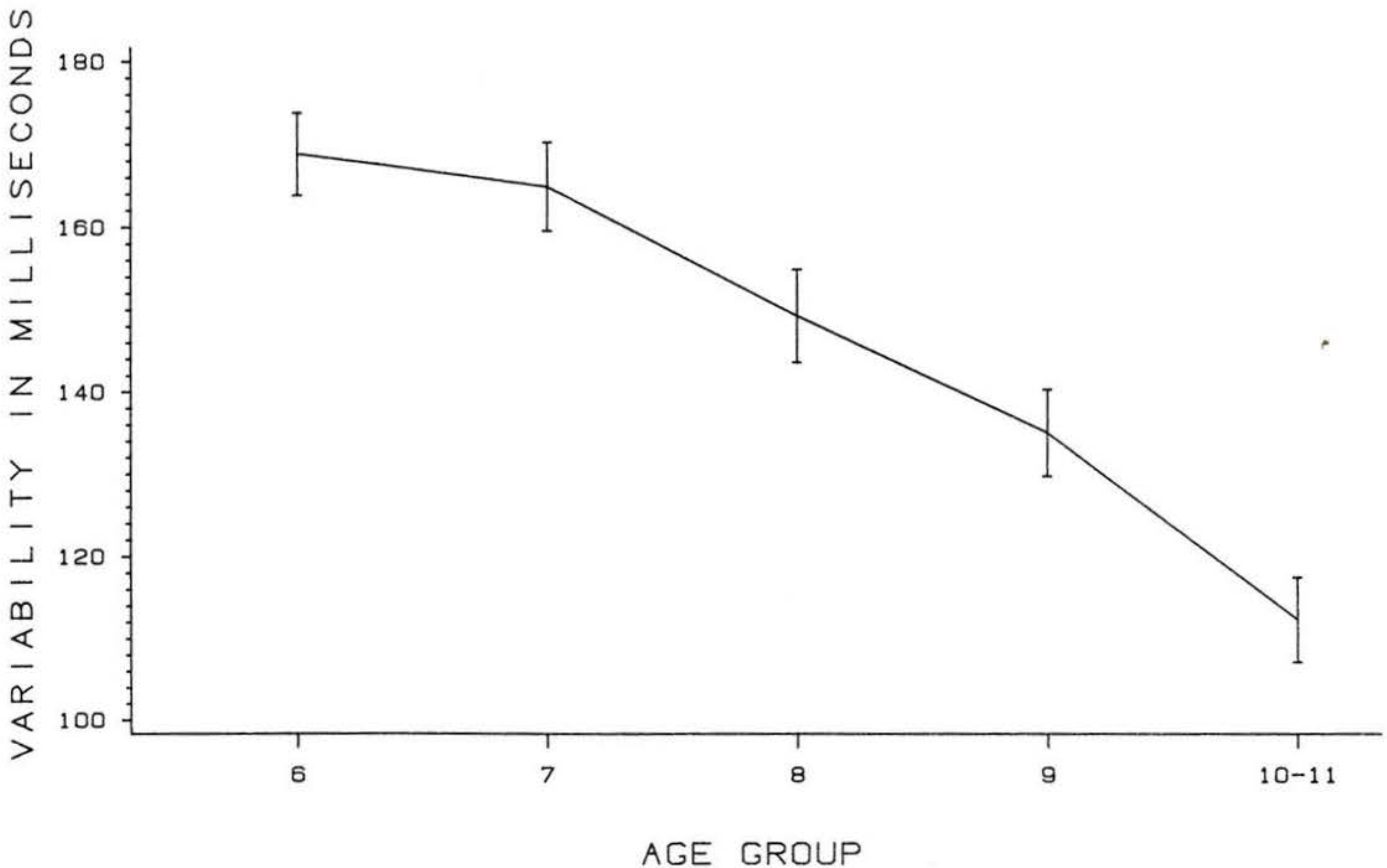


FIGURE 6

MEAN SENSITIVITY BY AGE ON COMBINED CCPT

(STANDARD ERROR OF MEAN INTERVALS)

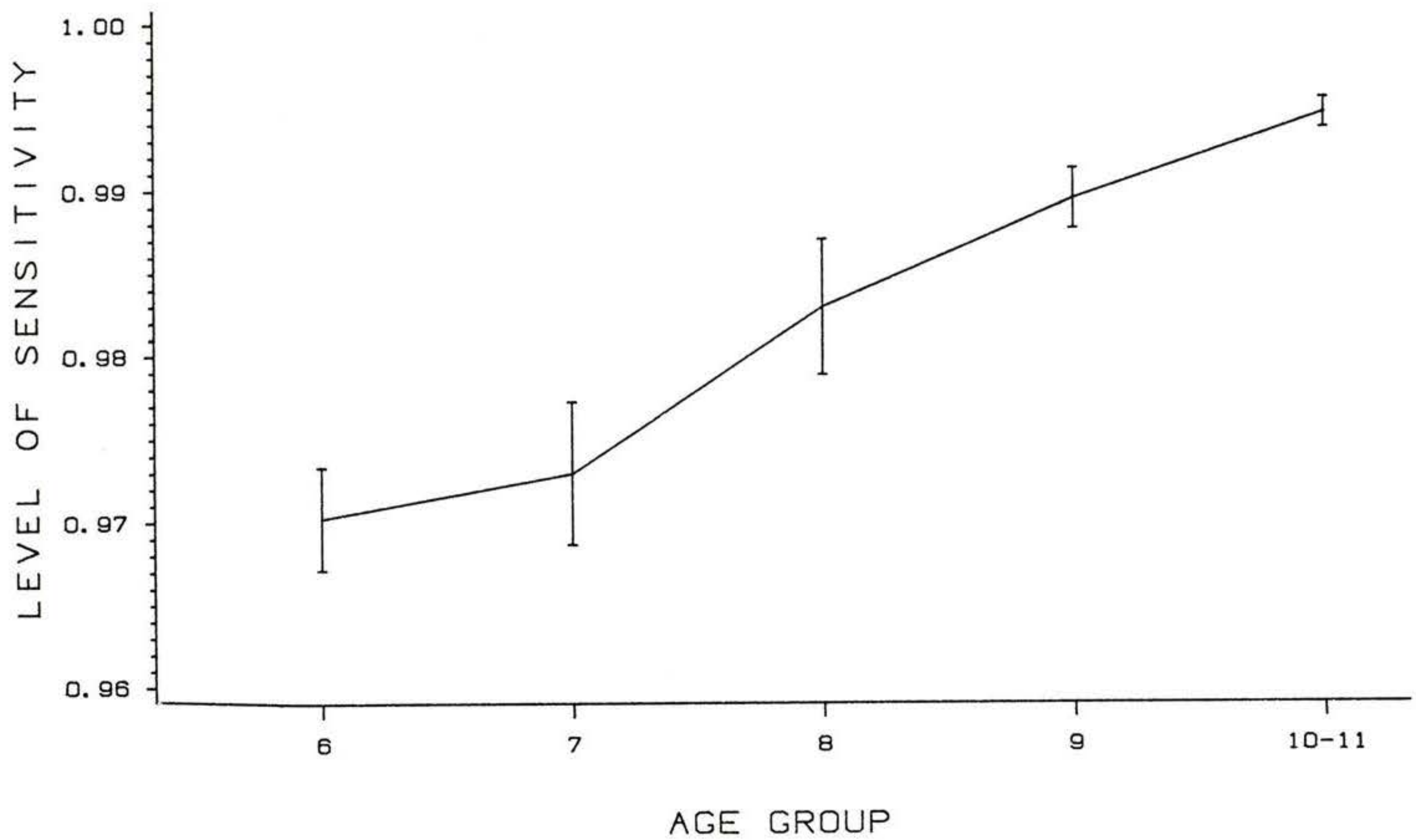
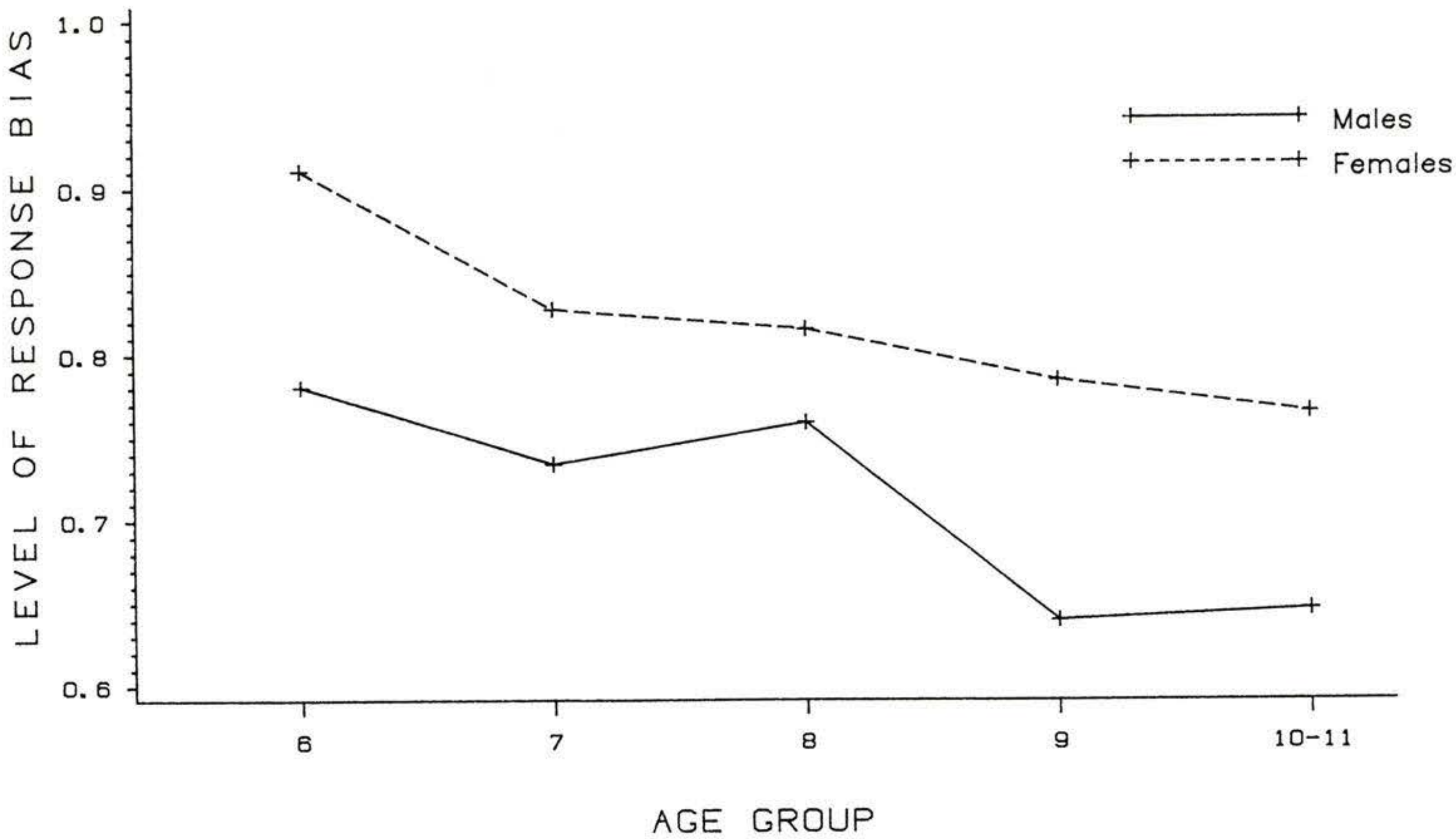


FIGURE 7

MEAN RESPONSE BIAS BY AGE ON COMBINED CCPT



Means and standard deviations for individual measures on all tasks are presented in Appendix G.

It should be noted that the pattern of significant findings on the above age by sex analyses was not altered if the 11-year-olds were treated as a separate group nor if socioeconomic index and verbal intelligence were covaried. Additionally little change was noted when grade was substituted for age level, as expected considering that age level and grade were found to have a .953 Pearson correlation coefficient.

3.2.9 Relationships between CCPT measures

Pearson correlation coefficients were calculated for the six individual measures within each task. These correlations are presented in Table 5 for the X-task and in Table 6 for the AX-task.

A canonical correlation analysis was then performed to investigate the overall correlation between the two CCPT tasks. This resulted in a significant correlation ($r=.815$, $p<.01$) being obtained between the X-task and the AX-task. The results of Pearson correlation coefficients between individual task measures are presented in Table 7.

To further investigate if the individual CCPT measures relate to one or more dimensions a principal components type of factor analysis was performed. The Sensitivity and Response Bias measures were excluded from this analysis since they were derived from linear combinations of other variables used in the analysis (i.e., Hits and False Alarms). This analysis subjected to a varimax rotation resulted in two factors with eigen values greater than one (see Table 8).

TABLE 5

INTRACORRELATIONS OF CCPT X-TASK

	Hits	False	Time	Var.	Sen.	Bias
Hits	1.000	-.154	-.496*	-.510*	.993*	-.486*
False Alarms		1.000	.024	.286*	-.247*	-.541*
Response Time			1.000	.712*	-.472*	.432*
Variability				1.000	-.513*	.202
Sensitivity					1.000	-.414*
Response Bias						1.000

* p<.01 on 2-tailed test of significance

TABLE 6

INTRACORRELATIONS OF CCPT AX-TASK

	Hits	False	Time	Var.	Sen.	Bias
Hits	1.000	-.388*	-.298*	-.517*	.996*	-.372*
False Alarms		1.000	-.003	.532*	-.468*	-.395*
Response Time			1.000	.342*	-.283*	.362*
Variability				1.000	-.541*	-.009
Sensitivity					1.000	-.317*
Response Bias						1.000

* p<.01 on 2-tailed test of significance

TABLE 7

INTERCORRELATIONS OF X AND AX TASKS

	(AX-task)					
(X-Task)	Hits	False	Time	Var.	Sen.	Bias
Hits	.627*	-.256*	-.307*	-.330*	.627*	-.186
False Alarms	-.103	.486*	-.057	.363*	-.143	-.340*
Response Time	-.525*	.154	.708*	.454*	-.512*	.348*
Variability	-.527*	.296*	.453*	.532*	-.527*	.208
Sensitivity	.619*	-.292*	-.288*	-.350*	.623*	-.151
Response Bias	-.355*	-.097	.344*	.126	-.336*	.351*

* p<.01 on 2-tailed test of significance

TABLE 8

PRINCIPAL COMPONENTS OF X AND AX TASKS

Task	Measure	Factor I (44.6% variance)	Factor II (19.6% variance)
X	Hits	-.664	-.251
	False Alarms	-.030	.804
	Response Time	.913	-.006
	Variability	.767	.327
AX	Hits	-.686	-.350
	False Alarms	.140	.840
	Response Time	.788	-.213
	Variability	.530	.598

Examination of these factors indicated that all of the task measures loaded most highly on the first factor with the exception of the False Alarm measures, and the Deviation measure of the AX-task which loaded on both factors. The measures Sensitivity and Response Bias, which were excluded from the analysis, would most appropriately (based upon their derivations and intracorrelations) be placed in the first and second factor respectively. Conceptually the first factor might be thought of as an inattentive dimension and the second as an impulsive factor.

3.2.10 Relationships between Rating Scales and CCPT tasks

Multiple regression analyses were undertaken to investigate the relationships between the Conners Questionnaires and CCPT performance. Since the individual scales derived from the Questionnaires were obtained from orthogonal solutions (Goyette et al., 1978) and intercorrelations between them have been shown to be extremely small with proper methodological considerations (Blouin, Conners, Seidel, and Blouin, in press) the analyses were performed separately for each individual scale. On the Teacher Questionnaire these analyses found significant correlations between the Hyperactive, Inattentive, and Hyperactive Index factors and CCPT performance ($p<.01$). No significant correlation, however, was found between the Conduct Problem factor and CCPT performance ($p>1.00$). Analyses of the Parent Questionnaire uncovered some significant correlations between the Learning Problem, Impulsive and Hyperactive Index factors ($p<.05$). No significant correlations were noted on the Conduct Problem, Psychosomatic, and Anxiety factors ($p>.09$). The individual correlations and levels of significance for the Teacher and Parent Questionnaires are presented in Tables 9 and 10 respectively.

TABLE 9

MULTIPLE REGRESSIONS OF TEACHER QUESTIONNAIRE AND CCPT

Teacher Factors		X-task (df=5,118)	AX-task (df=5,117)	Combined task (df=5,116)
Conduct Problems	R=	.266	.258	.263
	(p=)	(.119)	(.147)	(.135)
Hyperactive	R=	.350	.324	.382
	(p=)	(.008)	(.022)	(.002)
Inattentive	R=	.250	.362	.352
	(p=)	(.175)	(.005)	(.008)
Hyperactive Index	R=	.329	.381	.414
	(p=)	(.018)	(.002)	(<.001)

TABLE 10

MULTIPLE REGRESSIONS OF PARENT QUESTIONNAIRE AND CCPT

Parent Factors		X-task (df=5.118)	AX-task (df=5.117)	Combined task (df=5.116)
Conduct Problems	R=	.266	.191	.270
	(p=)	(.119)	(.495)	(.114)
Learning Problems	R=	.306	.204	.285
	(p=)	(.038)	(.413)	(.077)
Psychosomatic	R=	.143	.275	.261
	(p=)	(.782)	(.098)	(.141)
Impulsive	R=	.282	.283	.338
	(p=)	(.077)	(.079)	(.014)
Anxiety	R=	.191	.222	.222
	(p=)	(.490)	(.308)	(.314)
Hyperactive	R=	.270	.225	.311
	(p=)	(.106)	(.290)	(.035)

Inspection of the specific CCPT measures involved in the significant correlations indicated that only False Alarms contributed individually in a significant ($p<.05$) way.

3.2.11 School Performance Ratings

Multivariate analyses were utilized to examine the overall ratings of school performance obtained from the teachers. Although a five point scale was used, no subject in the normative sample was rated as being well below average so the analyses were based upon the remaining four points. It was found that these teacher ratings grouped subjects into categories that were significantly different on the Conner's Teacher Questionnaire overall ($F(12,307.20)=9.12$, $p<.001$) and on all four subscales individually ($p<.01$). These categories of subjects did not, however, differ overall on their ratings from the Conner's Parent Questionnaire ($F(18,322.93)=1.58$), $p=.062$). Exploratory inspection of the individual subscales of the Parent Questionnaire found significant effects on the Learning ($F(3,119)=7.33$, $p<.001$) and Hyperactive Index ($F(3,119)=4.22$, $p=.007$) factors, while the Conduct, Psychosomatic, Impulsive, and Anxiety scales were all found to be nonsignificant ($p>.200$). Furthermore these groups were found to have significantly different performances on the WISC-R subscales ($F(12,312.49)=4.05$, $p<.001$). The Information, Similarities and Arithmetic differences were significant at the .01 level, while the Digit Span subtest was significant at the .05 level. The means and standard deviations for the significant results are presented in Appendix H.

It was also found that the teacher rated groups performed significantly different on the X-task ($F(18,325.75)=1.96$, $p=.011$), AX-task ($F(18,322.93)=2.90$, $p<.001$), and the combined task ($F(18,320.10)=3.04$, $p<.001$). The significant individual measures and their means and standard deviations are presented in Table 11.

TABLE 11

SIGNIFICANT CCPT MEASURES FOR TEACHER RATED GROUPS
Means (Standard Deviations)

	Group			
	Below	Average	Above	Well Above
Variable	(n=10)	(n=54)	(n=50)	(n=10)
X-task Hits	83.70 (5.62)	87.70 (2.63)	85.72 (5.32)	88.80 (1.32)
X-task Variability	151.14 (23.58)	127.63 (30.94)	135.74 (33.19)	97.06 (31.99)
X-task Sensitivity	.980 (.016)	.992 (.007)	.986 (.015)	.995 (.003)
AX-task False Alarms	9.30 (7.26)	2.83 (3.37)	2.42 (2.32)	1.20 (2.44)
AX-task Variability	202.46 (44.86)	163.46 (39.35)	157.98 (37.94)	134.13 (54.90)
AX-task Response Bias	.592 (.330)	.795 (.211)	.815 (.190)	.788 (.105)
Combined Hits	160.90 (15.95)	170.42 (9.34)	166.54 (13.20)	175.00 (7.87)
Combined False Alarms	13.20 (9.99)	4.52 (4.49)	4.72 (4.13)	2.00 (3.30)
Combined Variability	176.80 (31.12)	144.36 (27.90)	146.86 (31.82)	115.60 (41.36)

3.2.12 CCPT Performance Decrement

X-task Analyses

Possible within task changes in performance over time were analyzed with repeated measures multivariate analyses of variance. On the X-task a significant overall interaction between age and time with task performance was obtained ($F(48,418.07)=1.84$, $p=.001$). This analysis was then analyzed to investigate the individual task performance measures. Examination of the Hits variable found another significant age by time interaction ($F(8,236)=5.40$, $p<.001$). These data were then further analyzed by age. A significant time effect was found for ages six ($F(2,22)=17.97$, $p<.001$) and seven ($F(2,25)=9.28$, $p=.001$), however, no significant time effects were found for ages eight ($F(2,17)=1.97$, $p=.170$), nine ($F(2,29)=1.00$, $p=.380$), and ten/eleven ($F(2,21)=0.98$, $p=.391$). Graphic display of this data is presented in Figure 8.

The Sensitivity measure also had a significant age by time interaction ($F(8,236)=5.06$, $p<.001$). Analysis by age indicated a similar pattern of a significant time effect for ages six ($F(2,22)=12.61$, $p<.001$) and seven ($F(2,25)=6.37$, $p=.006$), but not for ages eight ($F(2,17)=0.67$, $p=.523$), nine ($F(2,29)=0.12$, $p=.884$) and ten/eleven ($F(2,21)=2.05$, $p=.154$). These data are presented in Figure 9.

The Response Bias measure's age by time interaction was significant ($F(8,236)=2.03$, $p=.044$). Significant time effects were subsequently found for ages six ($F(2,22)=14.29$, $p<.001$), seven ($f(2,25)=4.75$, $p=.018$), eight ($F(2,17)=4.41$, $p=.029$), and nine ($F(2,29)=5.76$, $p=.008$). The time effect for Response Bias was not found to be significant ($F(2,21)=2.01$, $p=.159$) for the ten/eleven year old children. The Response Bias data are displayed in Figure 10.

FIGURE 8

MEAN HITS OVER TIME ON X-TASK

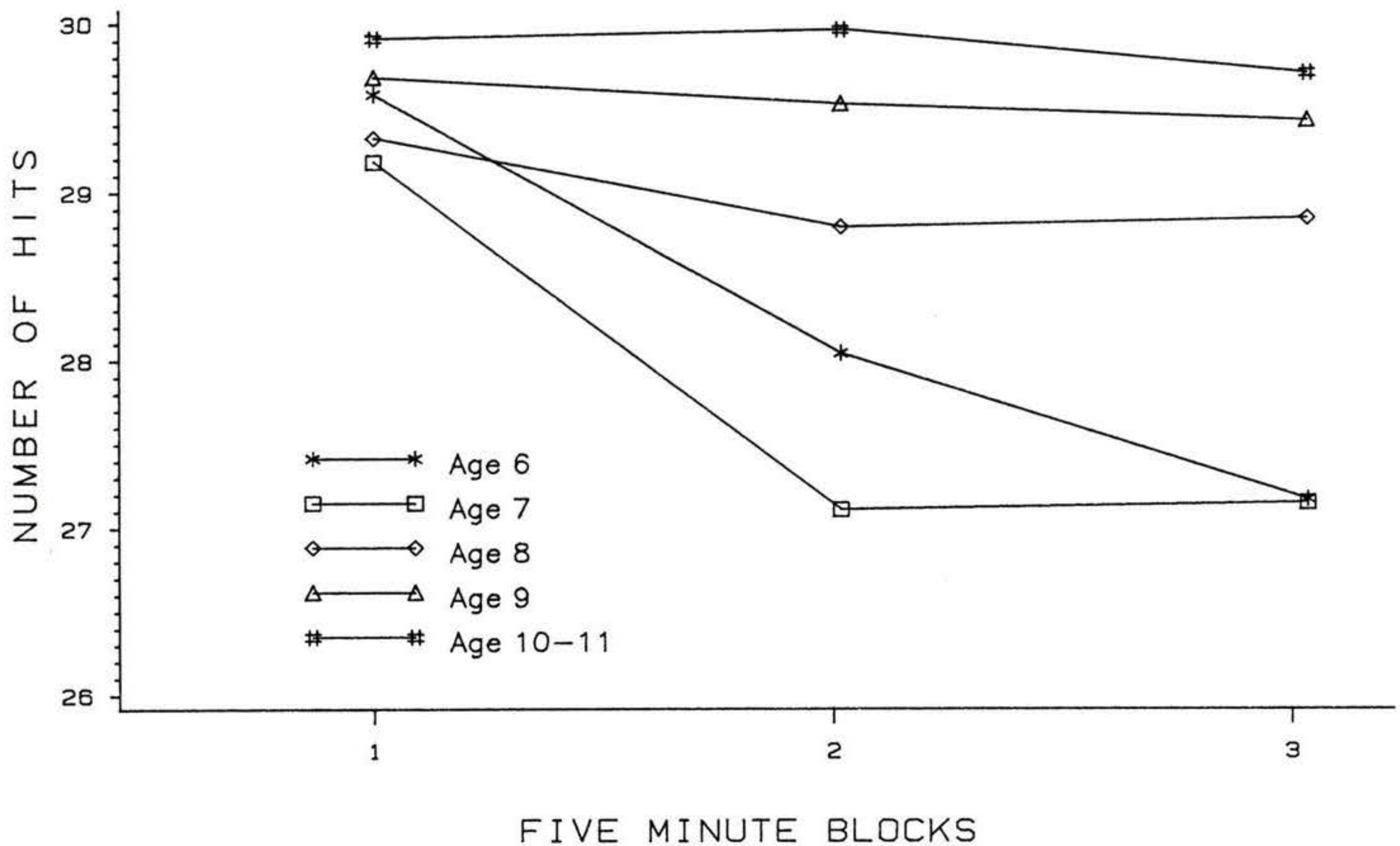


FIGURE 9

MEAN SENSITIVITY OVER TIME ON X-TASK

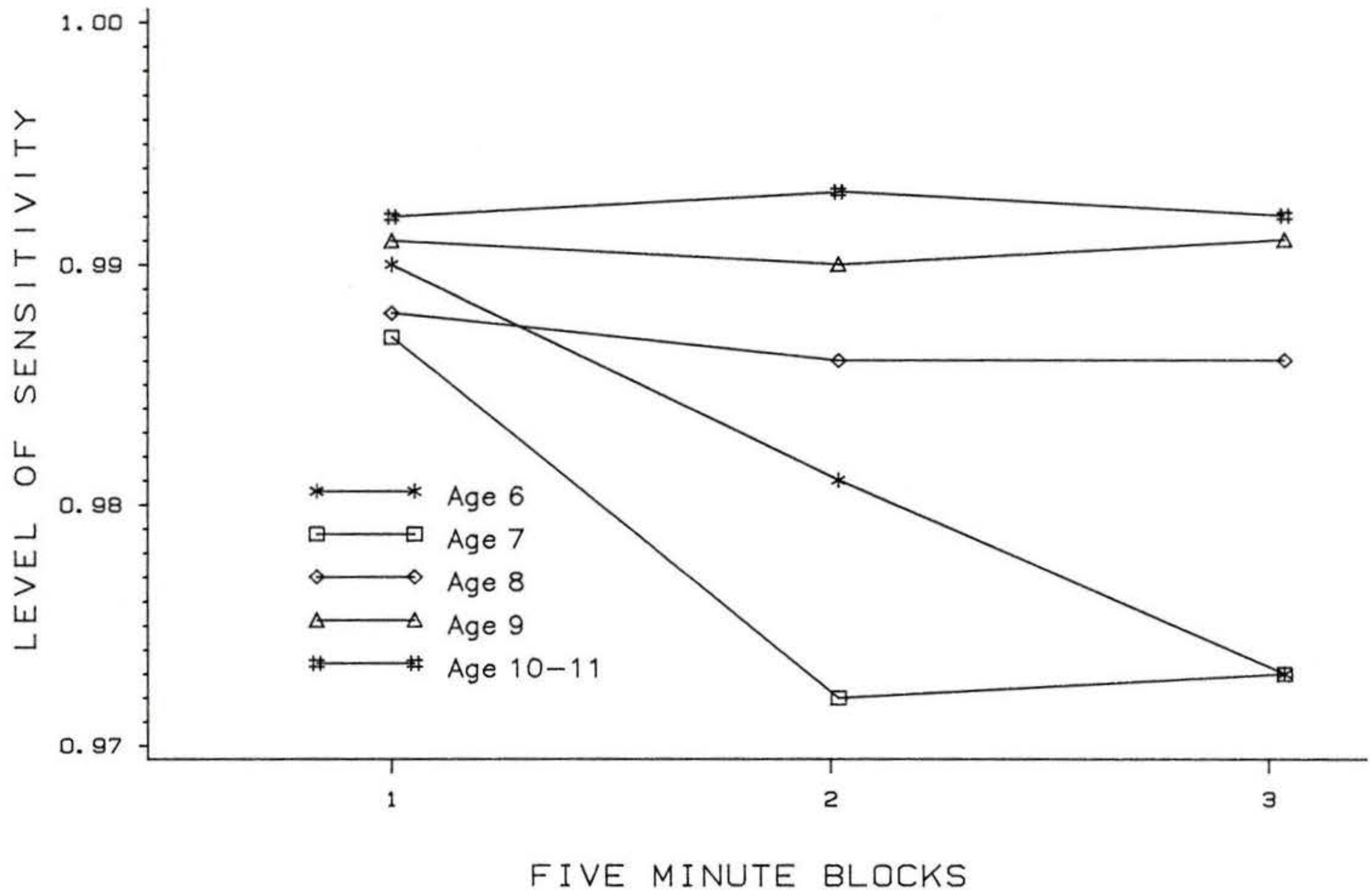
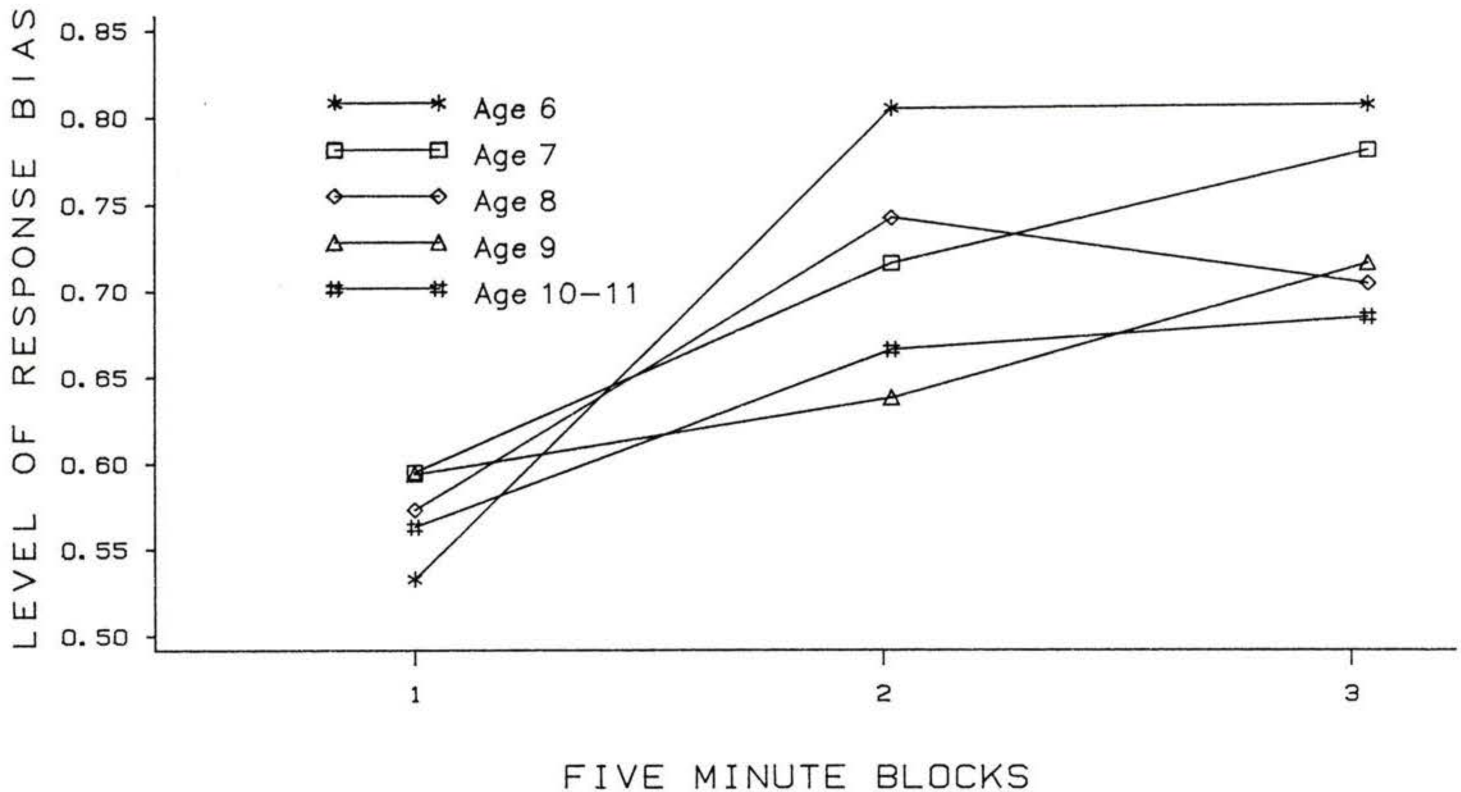


FIGURE 10

MEAN RESPONSE BIAS OVER TIME ON X-TASK



A pattern of nonsignificant age by time interactions and significant time effects were found for False Alarms ($F(8,236)=0.71$, $p=.680$; $F(2,118)=8.56$, $p<.001$) and Variability ($F(8,236)=1.28$, $p=.256$; $F(2,118)=10.42$, $p<.001$). Data for False Alarms are presented in Figure 11 and data for Variability are presented in Figure 12 (Figure 12 also includes the AX-task data which are discussed subsequently). Analysis of Response Time, which additionally included sex since it was previously shown to be significant, found no significant age by sex by time interaction ($F(8,226)=0.99$, $p=.446$), age by time interaction ($F(8,226)=1.02$, $p=.419$), nor sex by time interaction ($F(2,113)=0.54$, $p=.587$). The time effect for Response Time, however, was significant ($F(2,113)=90.18$, $p<.001$). These data are depicted in Figure 13 (Figure 13 also includes the AX-task data which are discussed subsequently).

AX-task Analyses

Analysis of performance changes over time on the AX-task resulted in an overall significant age by time interaction ($F(48,414.21)=1.47$, $p=.027$). The age by time interaction was also significant for Hits ($F(8,234)=3.00$, $p=.003$), False Alarms ($F(8,234)=2.23$, $p=.026$), and Sensitivity ($F(8,234)=3.53$, $p=.001$) on the AX-task. These results are displayed in Figures 14 through 16 respectively. For the Hits measure it was found that time was significant ($F(2,22)=7.40$, $p=.003$) for age six, but not significant for ages seven ($F(2,23)=2.49$, $p=.105$), eight ($F(2,17)=0.36$, $p=.703$), nine ($F(2,30)=0.88$, $p=.425$), and ten/eleven ($F(2,21)=0.58$, $p=.570$). Time was found to be significant in False Alarms for age six ($f(2,22)=7.83$, $p=.003$), but not for ages seven ($F(2,23)=1.68$, $p=.209$), eight ($F(2,17=2.98$, $p=.078$), nine ($F(2,30)=2.03$, $p=.149$) and ten/eleven ($F(2,21)=0.36$, $p=.702$). Sensitivity was also

FIGURE 11

MEAN FALSE ALARMS OVER TIME ON X-TASK

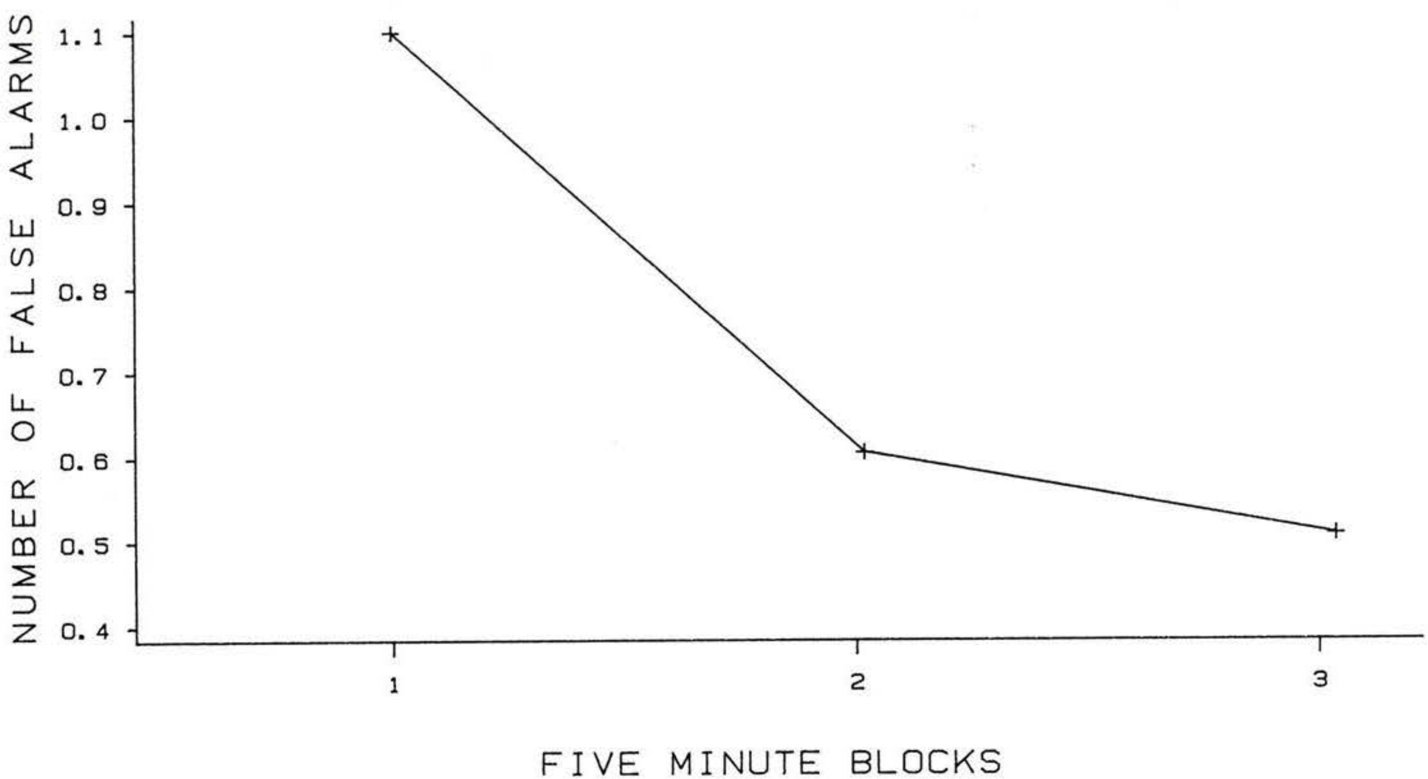


FIGURE 12

MEAN VARIABILITY OVER TIME ON CCPT TASKS

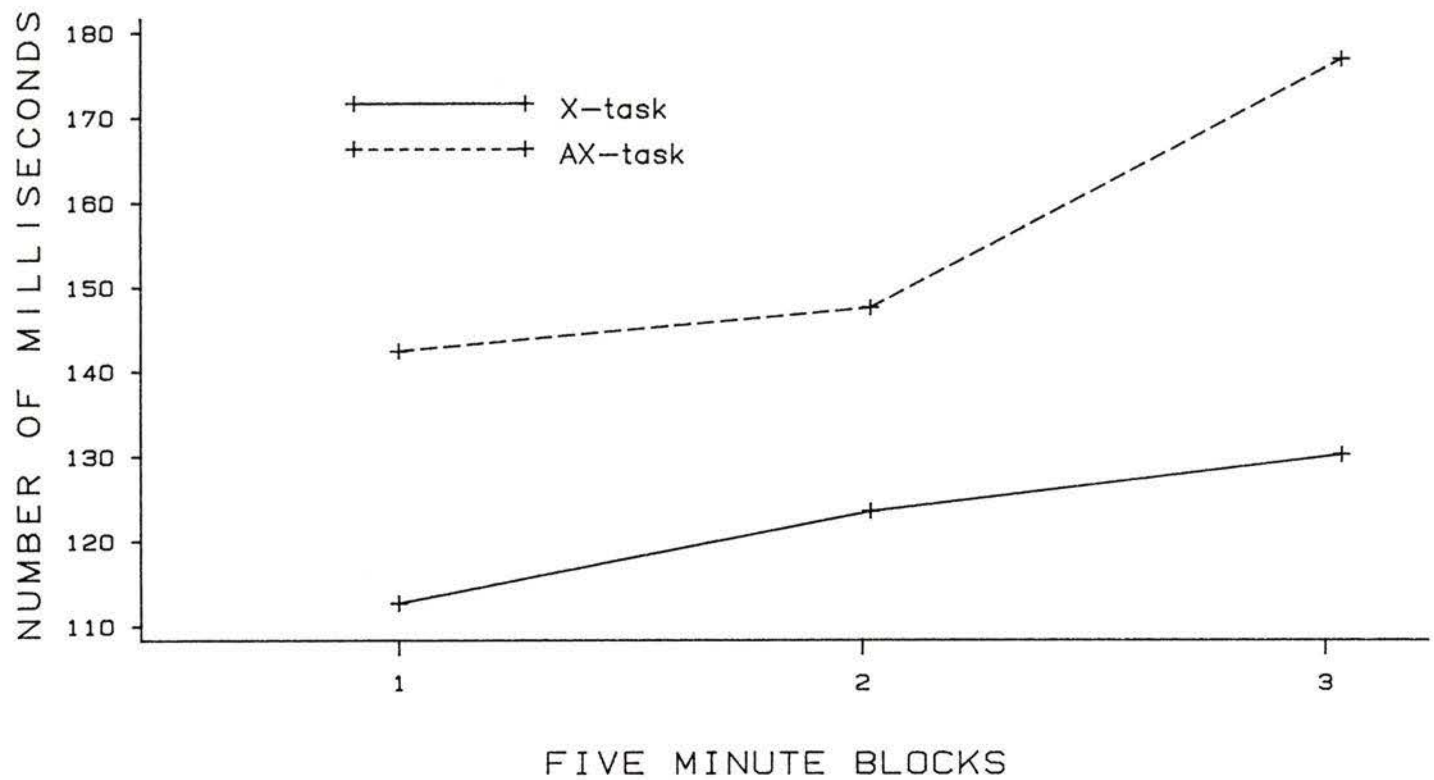
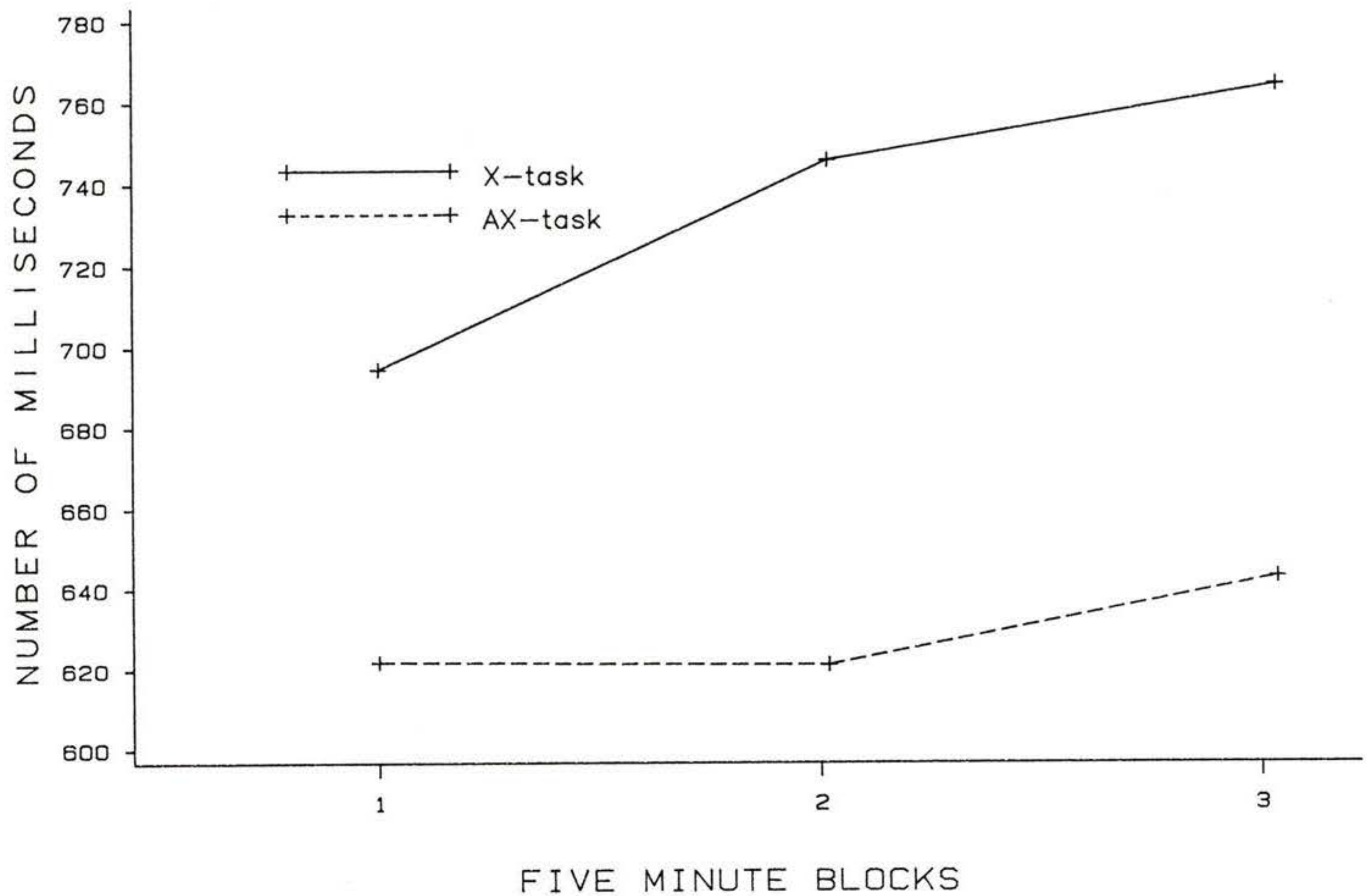


FIGURE 13

MEAN RESPONSE TIME OVER TIME ON CCPT TASKS



found to have a significant time effect for age six ($F(2,22)=8.64$, $p=.002$) but not for ages seven ($F(2,23)=2.92$, $p=.074$), eight ($F(2,17)=0.20$, $p=.820$), nine ($F(2,30)=0.75$, $p=.483$) and ten/eleven ($F(2,21)=0.89$, $p=.426$).

Variability was found to have a nonsignificant age by time interaction ($F(8,234)=0.91$, $p=.512$) and a significant effect for time ($F(2,117)=27.84$, $p<.001$). This effect is displayed in Figure 12. Response Time was found to have nonsignificant age by sex by time ($F(8,224)=0.98$, $p=.451$), age by time ($F(8,224)=1.37$, $p=.212$), and sex by time ($F(2,112)=1.06$, $p=.350$) interactions and a significant main effect of time ($F(2,112)=11.82$, $p<.001$). These data are displayed in Figure 13. Response Bias was also found to have nonsignificant age by sex by time ($F(8,224)=0.30$, $p=.966$), age by time ($F(8,224)=1.09$, $p=.370$), and sex by time ($F(2,112)=1.43$, $p=.244$) interactions and a significant main effect of time ($F(2,112)=5.97$, $p=.003$). This effect is depicted in Figure 17.

FIGURE 14

MEAN HITS OVER TIME ON AX-TASK

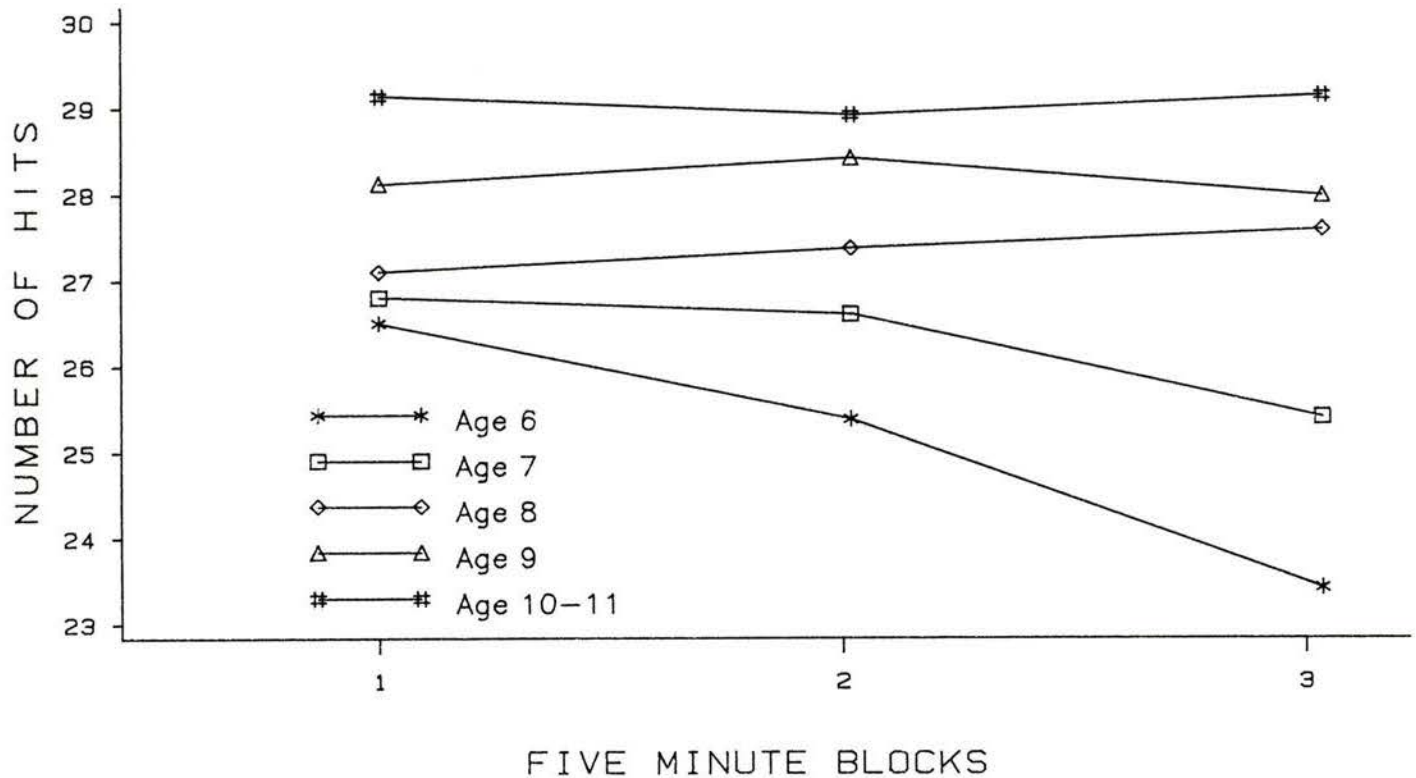


FIGURE 15

MEAN FALSE ALARMS OVER TIME ON AX-TASK

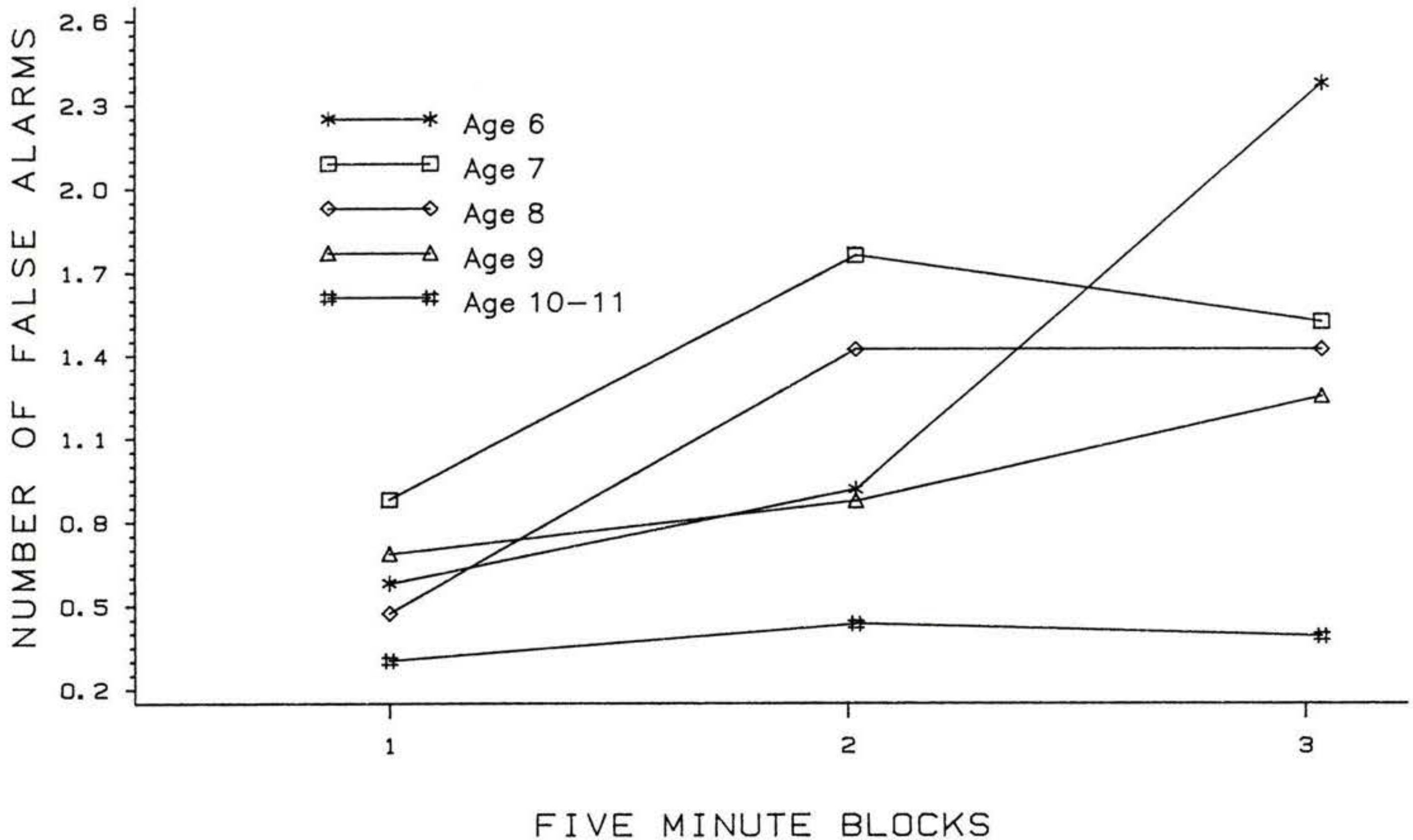


FIGURE 16

MEAN SENSITIVITY OVER TIME ON AX-TASK

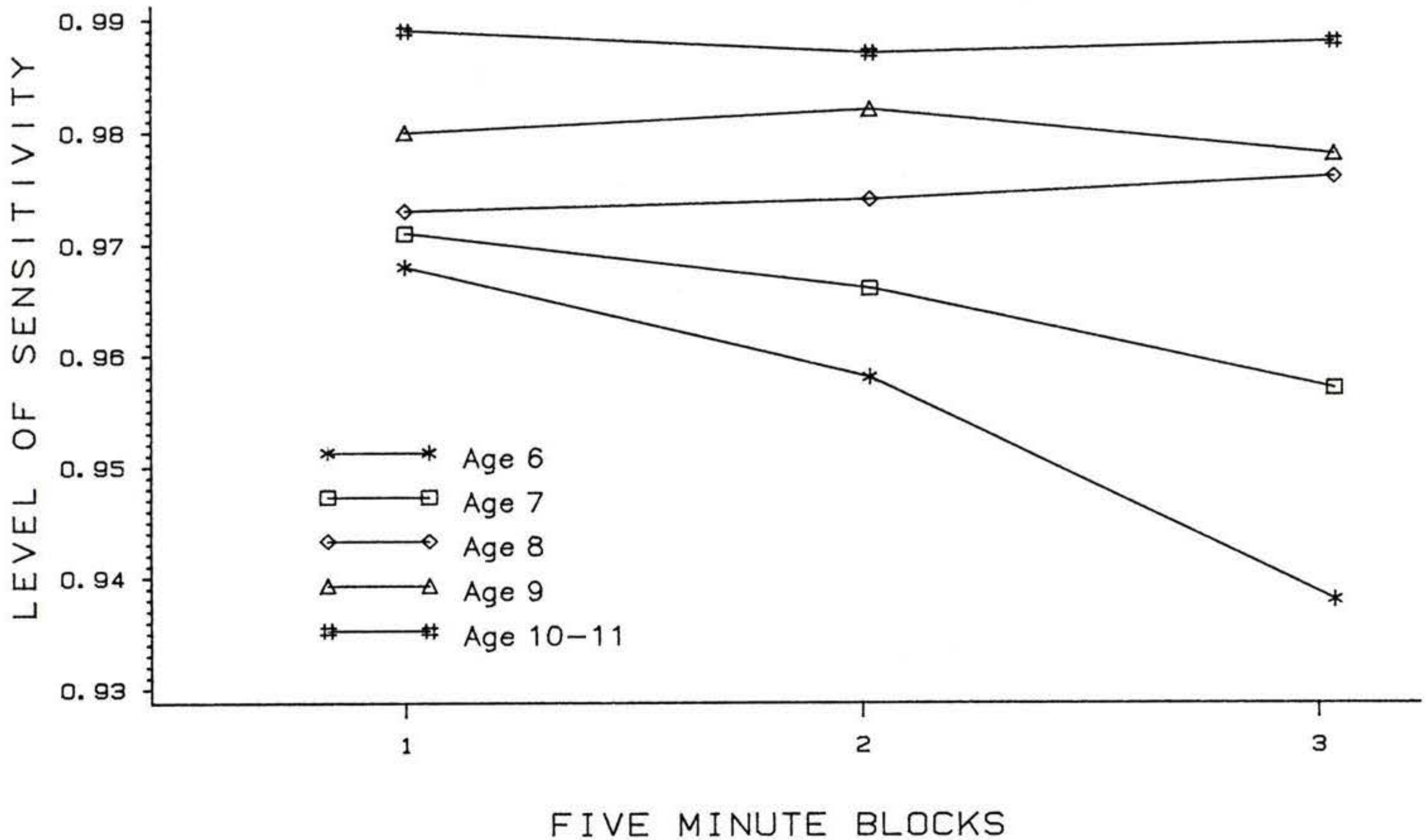
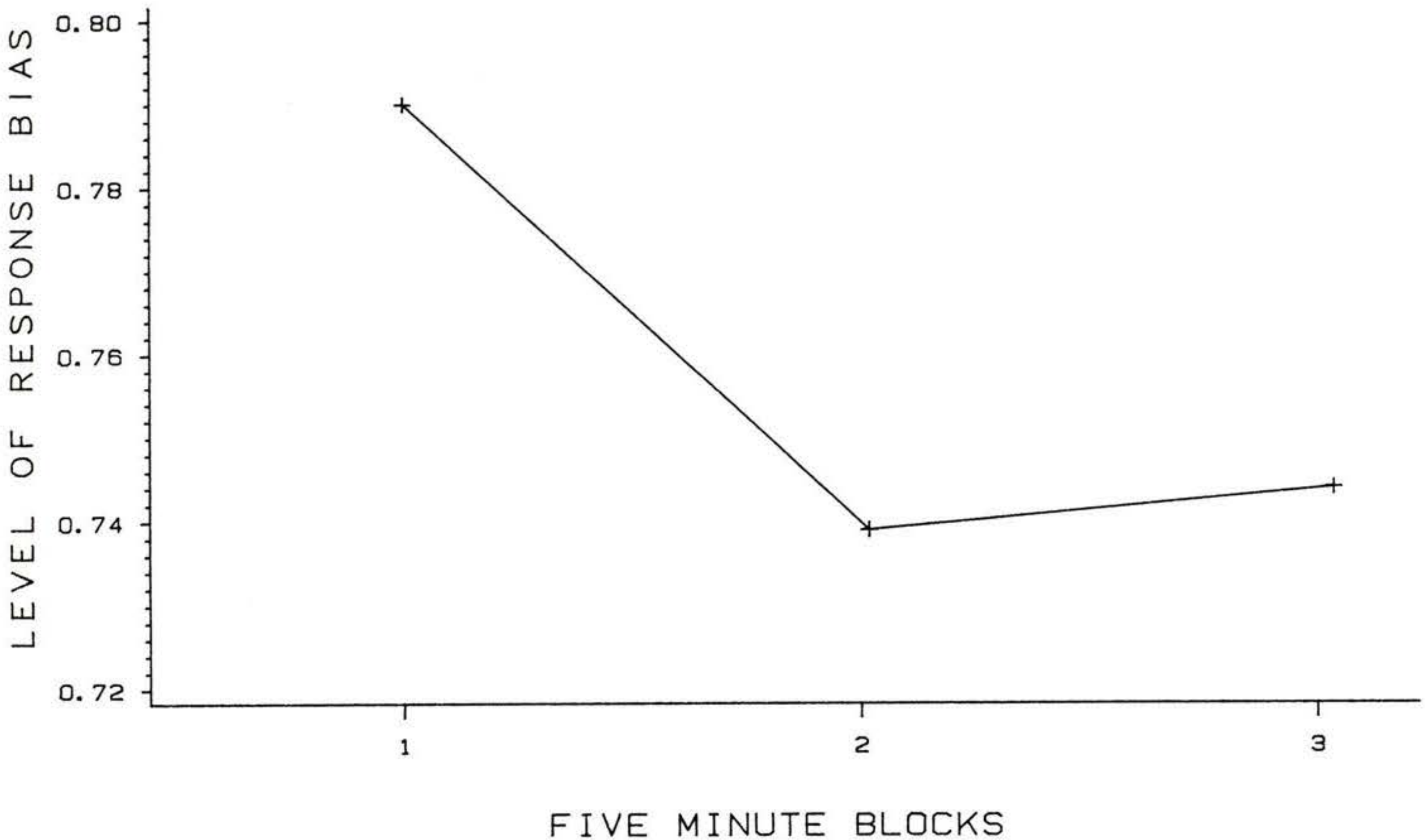


FIGURE 17

MEAN RESPONSE BIAS OVER TIME ON AX-TASK



3.3 Characteristics of the Clinical Group

3.3.1 Clinical Group Descriptive Data

For the Clinical Group, the mean socioeconomic index was 43.53 (SD=13.67) and mean socioeconomic class was 2.81 (SD=1.40). The Clinical group also had a mean prorated verbal IQ on the WISC-R of 96.00 (SD=14.40).

3.3.2 Relation between Questionnaires and Tasks

Since the Clinical Group size was relatively small, it was felt that it would be inappropriate to use multivariate techniques to analyse these data (i.e., to use canonical correlations and multiple regressions). Therefore, Pearson correlation coefficients were calculated between the Teacher and Parent Questionnaire factors and the individual CCPT measures for the X-, AX- and combined tasks. Only three of these correlations were found to be significant ($p<.05$). Considering the small sample size, another 11 of these comparisons were thought to be of exploratory interest ($p<.10$). All of the above correlations and their levels of significance are presented in Table 12.

TABLE 12

SIGNIFICANT CORRELATIONS BETWEEN QUESTIONNAIRE FACTORS AND CCPT
(Clinical Group)

N	Teacher Factor	CCPT Measure	r	p
22	Conduct Problem	X-Variability	.517	.014
	Inattentive	X-Response Time	-.508	.016
	Inattentive	X-Response Bias	-.403	.063
	Inattentive	Com-Response Bias	-.376	.084

N	Parent Factor	CCPT Measure	r	p
23	Conduct Problem	X-Variability	.517	.012
	Impulsive	X-False Alarms	.389	.066
	Impulsive	X-Variability	.387	.068
	impulsive	AX-False Alarms	.375	.078
	Impulsive	Com-False Alarms	.409	.053
	Anxiety	X-False Alarms	-.403	.056
	Hyperactive Index	X-Hits	-.355	.096
	Hyperactive Index	X-Response Bias	-.395	.062
	Hyperactive Index	AX-Response Bias	-.359	.093
	Hyperactive Index	Com-Response Bias	-.380	.074

3.3.3 School Performance Ratings

Overall current school performance ratings by teachers were obtained for 20 of the Clinical Group. Three members (15%) were rated well below average, six (30%) were rated below average, nine (45%) were rated average, one (5%) was rated above average and one member (5%) was rated well above average.

3.4 Comparisons of Clinical Subjects and Matched Controls

3.4.1 Demographics

To test if the Clinical and Control Groups were adequately matched by prorated verbal intelligence and age, a multivariate analysis of variance was performed. This resulted in a nonsignificant multivariate group effect ($F(2,43)=0.72$, $p=.493$) and nonsignificant univariate effects for age ($F(1,44)=.004$), $p=.947$) and intelligence ($F(1,44)=1.46$, $p=.233$). Although the groups were not matched with respect to socioeconomic index, further analysis using a t-test indicated that the groups were not significantly different on this measure ($T(42)=1.47$, $p=.150$).

3.4.2 Subject Responses to CCPT

It was found that 60.9% (n=14) of the Clinical Group complained during the CCPT. Only 30.4% of the control group, on the other hand, complained during the computer task. This difference was found to be statistically significant (Chi-sq(1)=4.29, $p=.038$).

3.4.3 Questionnaire Ratings

Comparison of the Clinical and Control Groups using multivariate analyses of variance indicated that they were rated significantly different on the Conner's Teacher Questionnaire ($F(4,40)=5.31$, $p=.002$). Inspection of the univariate F tests revealed that the Clinical group was rated significantly higher on the Conduct ($F(1,43)=5.91$, $p=.019$), Hyperactive ($F(1,43)=13.36$, $p=.001$), Inattentive ($F(1,43)=21.06$, $p<.001$), and Hyperactive Index ($F(1,43)=19.98$, $p<.001$) factors. The Clinical group was also rated significantly higher on the Conner's Parent Questionnaire ($F(6,39)=13.74$, $p<.001$). Examination of the individual factors found the Clinical group to have significantly higher ratings on the Conduct ($F(1,44)=38.34$, $p<.001$), Learning ($F(1,44)=35.68$, $p<.001$), Impulsive ($F(1,44)=52.07$, $p<.001$) and Hyperactive Index ($F(1,44)=73.75$, $p<.001$) factors. They were also found to differ on the Psychosomatic factor ($F(1,44)=7.01$, $p=.011$), but not on the Anxiety factor ($F(1,44)=0.88$, $p=.355$).

3.4.4 School Performance Rating Comparisons

Five members (28.7%) of the control group were rated below average, ten (43.5%) were rated average and eight subjects (34.8%) were rated above average by their teachers on overall school performance. This distribution appears to be significantly different (Chi-sq(4)=9.42, $p=.051$) from the Clinical Group distribution, which was previously described (see Section 3.3.3). In general, it appears that the controls were rated slightly higher than the Clinical subjects.

3.4.5 CCPT Performance

The two groups were then compared on their CCPT performance which resulted in significant multivariate group effects for the X-task ($F(6,39)=3.64$, $p=.006$), the AX-task ($F(6,39)=4.96$, $p=.001$) and the combined task ($F(6,39)=4.70$, $p=.001$). The associated univariate F tests are presented in Table 13 for the X- and AX-tasks.

On the combined task the univariate tests demonstrated the same pattern of significance as the individual tasks and are therefore not presented. The means and standard deviations for the X- and AX-tasks are presented in Table 14. From Table 14 it appears that the groups differ on the standard deviations of their performances in addition to their means. These differences in variability were found to be significant on Bartlett-Box homogeneity of variance tests ($p<.05$) for all variables except the X-task Response Time and the AX-task Response Bias.

TABLE 13

UNIVARIATE F TESTS FOR CLINICAL VERSUS CONTROL GROUPS

X-TASK

Variable	F(1,44)	Sig. of F
Hits	11.50	.001
False Alarms	5.77	.021
Response Time	2.07	.157
Variability	12.00	.001
Sensitivity	6.51	.014
Response Bias	2.40	.129

AX-TASK

Variable	F(1,44)	Sig. of F
Hits	15.48	<.001
False Alarms	10.82	.002
Response Time	0.81	.373
Variability	6.86	.012
Sensitivity	9.21	.004
Response Bias	2.43	.126

TABLE 14

CCPT PERFORMANCES OF CLINICAL AND CONTROL GROUPS

X-TASK

Variable	Control Group Mean (S.D.)	Clinical Group Mean (S.D.)
Hits	86.96 (3.66)	72.13 (20.65)
False Alarms	2.35 (2.93)	28.78 (52.69)
Response Time	738.09 (99.68)	790.53 (143.48)
Variability	132.34 (35.51)	183.85 (61.82)
Sensitivity	.990 (.011)	.899 (.169)
Response Bias	.675 (.221)	.537 (.366)

AX-TASK

Variable	Control Group Mean (S.D.)	Clinical Group Mean (S.D.)
Hits	83.35 (7.20)	61.70 (25.39)
False Alarms	4.04 (6.15)	29.44 (36.50)
Response Time	640.67 (95.46)	680.97 (192.51)
Variability	173.92 (45.13)	221.24 (73.96)
Sensitivity	.979 (.023)	.856 (.192)
Response Bias	.689 (.322)	.516 (.425)

3.4.6 CCPT Performance Decrement

The two "matched" groups were then compared with respect to changes in their task performance over time. On the X-task the interaction between group and time was not significant ($F(12,33)=1.80$, $p=.089$), but an overall significant time effect was noted ($F(12,33)=6.97$, $p<.001$). Exploratory analyses of individual task variables resulted in significant group by time interactions for Hits ($F(2,43)=3.34$, $p=.045$) and Variability ($F(2,43)=4.50$, $p=.017$). Data for Hits and Variability are displayed in Figures 18 and 19 respectively.

Analysis by group found significant time effects for Controls ($F(2,21)=4.46$, $p=.022$) and Clinical subjects ($F(2,21)=7.74$, $p=.003$) on Hits. For Variability the Controls were found to have a nonsignificant time effect ($F(2,21)=0.83$, $p=.449$) while the Clinical subjects had a significant effect for time ($F(2,21)=6.46$, $p=.006$). For the remaining X-task variables the pattern of group by time interaction and time effects respectively were ($F(2,43)=1.57$, $p=.220$; $F(2,43)=0.58$, $p=.563$) for False Alarms, ($F(2,43)=1.81$, $p=.176$; $F(2,43)=39.96$, $p<.001$) for Response Time, ($F(2,43)=1.22$, $p=.306$; $F(2,43)=2.02$, $p=.145$) for Sensitivity, and ($F(F2,43)=0.30$, $p=.740$; $F(2,43)=7.56$, $p=.002$) for Response Bias.

On the AX-task the overall interaction of group by time was significant ($F(12,33)=2.79$, $p=.010$). A significant group by time interaction was also found for the variable Hits ($F(2,43)=6.29$, $p=.004$). These data are presented in Figure 20.

Analysis by group found the Controls to have a nonsignificant time effect ($F(2,21)=0.49$, $p=.619$) and the Clinical subjects to have a highly significant effect for time ($F(2,21)=10.20$, $p=.001$). The remaining AX-task variable patterns for the group by time interaction and the time effect respectively were ($F(2,43)=0.13$,

FIGURE 18
MATCHED GROUPS OVER TIME FOR HITS
(X-TASK)

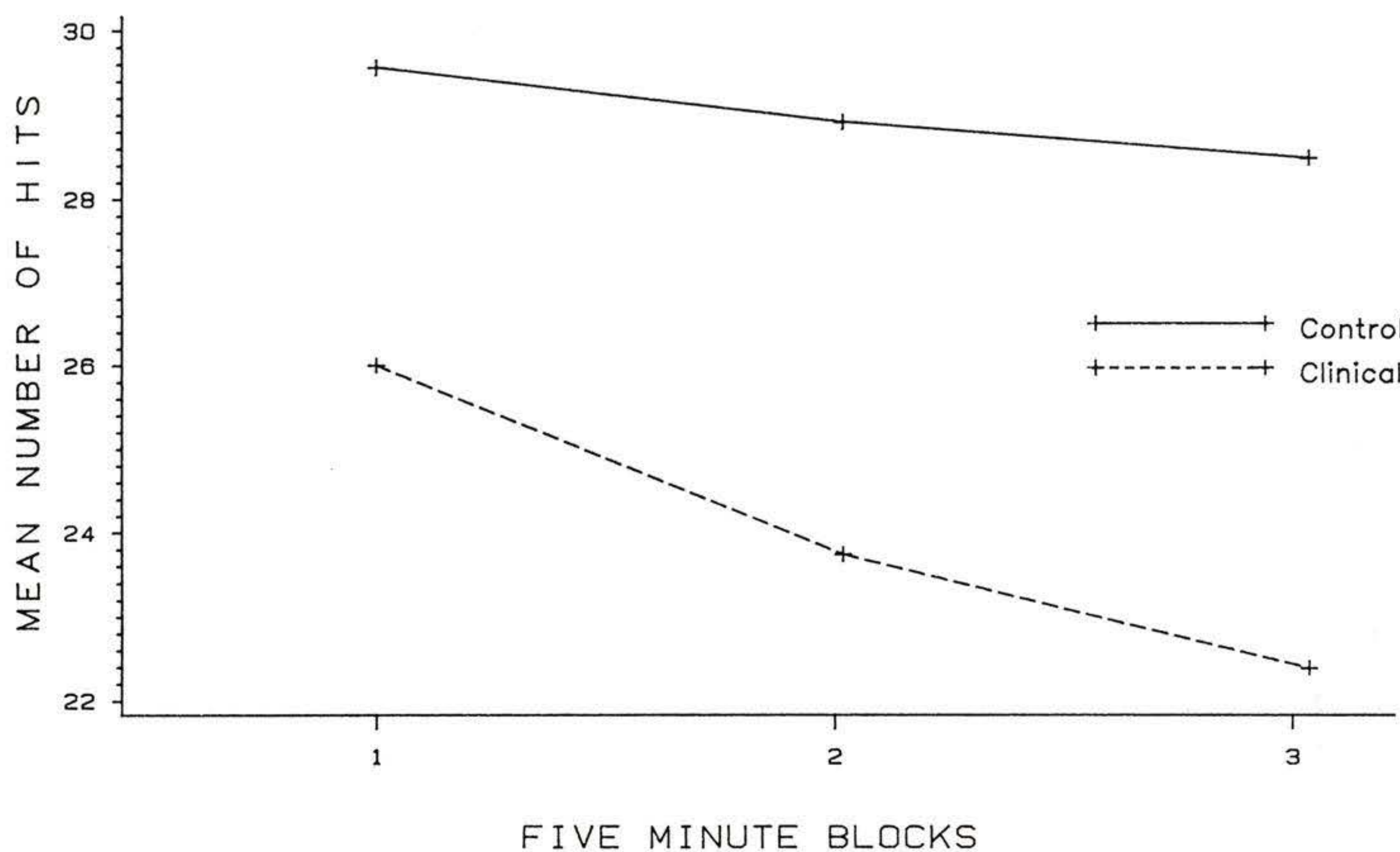


FIGURE 19

MATCHED GROUPS OVER TIME FOR VARIABILITY (X-TASK)

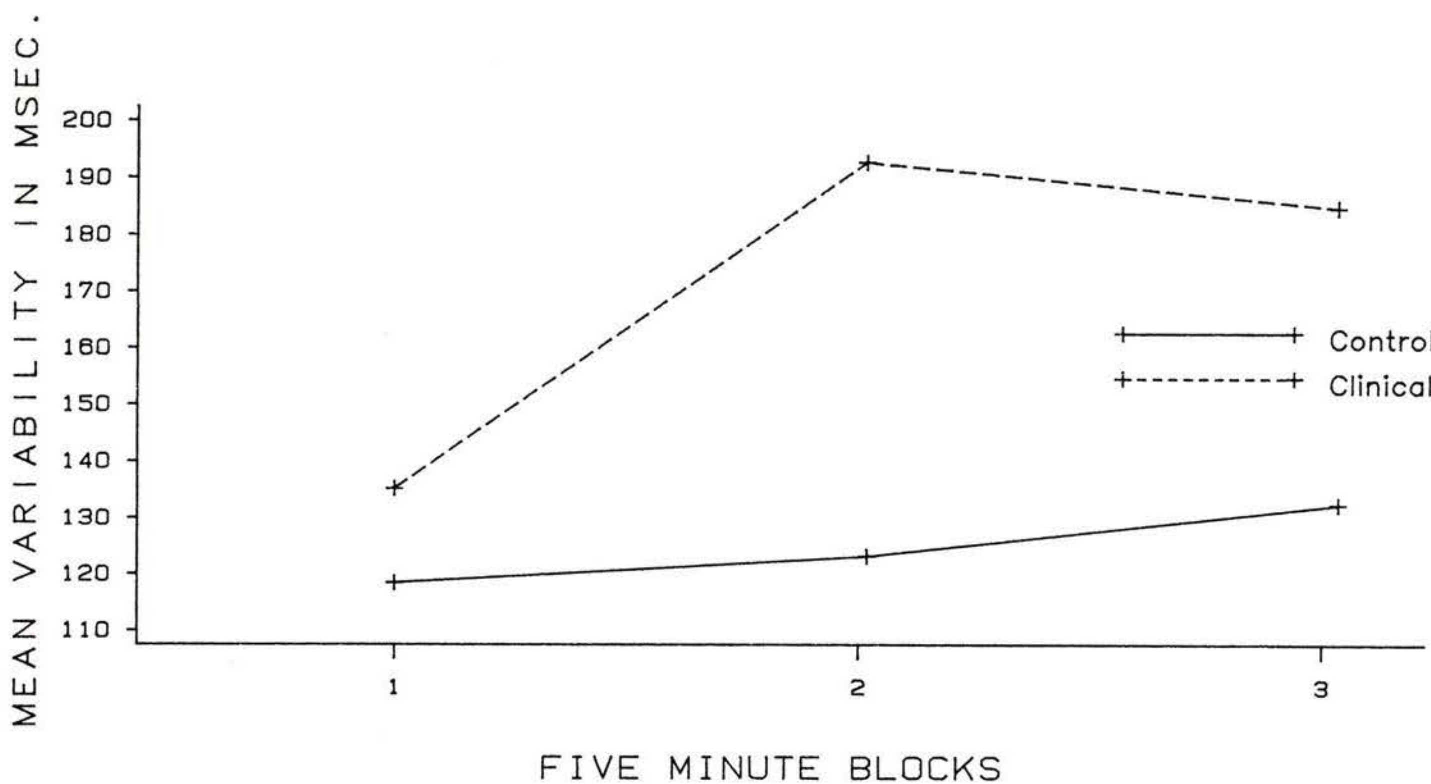
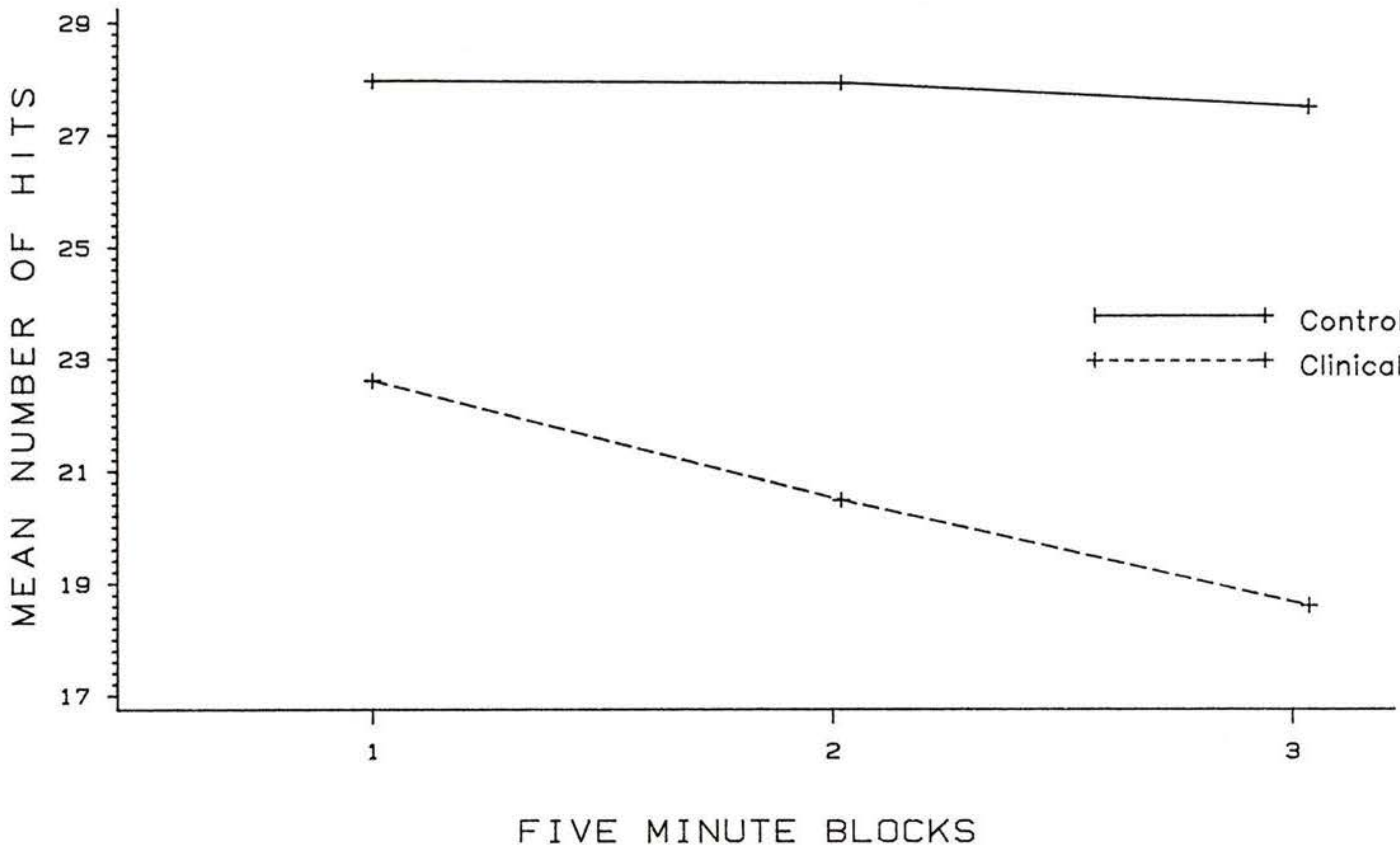


FIGURE 20

MATCHED GROUPS OVER TIME FOR HITS
(AX-TASK)



p=.878; (F(2,43)=0.05, p=.955) for False Alarms, (F(2,43)=2.20, p=.123; F(2,43)=0.19, p=.824) for Response Time, (F(2,43)=0.36, p=.696; F(2,43)=3.44, p=.041) for Variability, (F(2,43)=0.20, p=.821; F(2,43)=0.51, p=.603) for Sensitivity, and (F(2,43)=1.09, p=.346; F(2,43)=3.68, p=.033) for Response Bias.

3.5 Individual Assessment of Clinical Subjects and Normals

3.5.1 Discriminate Function Analyses

To determine the optimal potential to predict whether clinical subjects and normals could be distinguished on an individual basis, a series of discriminate function analyses were utilized. Since it was found that most of the CCPT measures were significantly related to age separate analyses were performed by age level. Also, although the group comparisons suggested that some of the CCPT measures distinguished groups better than others all six measures of each task were used to optimize the predictions and because all measures are always readily available. It should also be observed that although some of the CCPT variables were found to be significantly different by sex (e.g., Response Time), the number of subjects involved was felt to be too small to further break down the analyses by gender. This may have resulted in some loss of power in the ability to distinguish between the two groups.

The results of the analyses suggested that the X-, AX- and combined tasks were able to correctly classify around 90 percent of the subjects as clinical or normal. Tables 15 and 16 present the individual age and total classification rates for each task separately. It is noteworthy that these analyses did not include the three outlying cases and therefore the classification rates would be slightly lower if they had been included.

TABLE 15

DISCRIMINANT FUNCTION CLASSIFICATION FOR X AND AX TASKS

X-task

Age	Correct Norm Percent (n)	Correct Clinical Percent (n)	Correct Overall Percent (n)
6	100.0 (24)	75.0 (3)	96.4 (27)
7	92.6 (25)	55.6 (5)	83.3 (30)
8	94.7 (18)	100.0 (2)	95.2 (20)
9	93.5 (29)	33.3 (1)	88.2 (20)
10-11	95.7 (22)	60.0 (3)	89.3 (25)
Total	95.2 (118)	60.9 (14)	89.8 (132)

AX-task

Age	Correct Norm Percent (n)	Correct Clinical Percent (n)	Correct Overall Percent (n)
6	95.8 (23)	75.0 (3)	92.9 (26)
7	92.0 (23)	55.6 (5)	82.4 (28)
8	94.7 (18)	50.0 (1)	90.5 (19)
9	93.8 (30)	66.7 (2)	91.4 (32)
10-11	100.0 (23)	80.0 (4)	96.4 (27)
Total	95.1 (117)	65.2 (15)	90.4 (132)

TABLE 16

DISCRIMINANT FUNCTION CLASSIFICATION FOR COMBINED TASK

Age	Correct Norm Percent (n)	Correct Clinical Percent (n)	Correct Overall Percent (n)
6	95.8 (23)	100.0 (4)	96.4 (27)
7	88.0 (22)	66.7 (6)	82.4 (28)
8	94.7 (18)	50.0 (1)	90.5 (19)
9	93.5 (29)	66.7 (2)	91.2 (31)
10-11	100.0 (23)	80.0 (4)	96.4 (27)
Total	94.3 (115)	73.9 (17)	91.0 (132)

3.5.2 Clinical Investigations

It should be noted that before this phase was initiated, the three previously defined outlying cases were returned to the normative group. The rational for this decision was that these cases were collected with the normative sample and no good reason was found to exclude them from this aspect of the study.

In order to evaluate the practical usefulness of the CCPT, specific criteria had to be established that would maximize identification of Clinical Subjects and minimize the selection of the Normative subjects. Since restrictions were not placed on the Normative Sample, however, it might be argued that some of the children in this sample could be expected to have significant attentional problems. Based upon accepted prevalency rates (see Barkley, 1981) a conservative estimate of approximately five percent of the normative sample might be suspected as having significant attentional problems. Therefore, an a priori decision was made that the clinical cutoff criteria of the CCPT would not identify more than five percent of the Normative Sample.

The first step undertaken was reduction of the 18 resulting measures (i.e., 6 measures by 3 tasks). Based upon the Discriminant function analyses the combined task, which had the highest overall correct classification rate, appeared to be a reasonable starting point. The specific measures Hits and False Alarms were examined first since they have traditionally been used in CPT research and also because they are readily interpretable. Table 17 presents data on the number of subjects identified using cutoff points for these two measures at two, three and four standard deviations from respective age group means.

TABLE 17

CLINICAL DISCRIMINATION USING HITS AND FALSE ALARMS COMBINED CCPT

Standard Deviation	CCPT Measure	#Identified Normative (unique)*	#Identified Clinical (unique)*
2	Hits	7 (7)	9 (9)
	False Alarms	7 (5)	15 (7)
	Total	(12)	(16)
3	Hits	4 (4)	8 (8)
	False Alarms	5 (5)	13 (7)
	Total	(9)	(15)
4	Hits	1 (1)	7 (7)
	False Alarms	2 (2)	12 (7)
	Total	(3)	(14)

*Unique refers to subjects not already identified at that particular standard deviation.

Arbitrarily using four standard deviations as a cutoff for extremely atypical scores, these two measures alone identified 60.8% (n=14) of the Clinical Group and 2.4% (n=3) of the Normative Sample. Using the same criteria the X-task identified 43.5% (n=10) and 1.6% (n=2) and the AX-task identified 56.5% (n=13) and 3.2% (n=4) of the Clinical and Normative groups respectively. The four standard deviation cutoff appeared to be appropriate seeing that it was the first criterion employed where the percentage identified was within the previously accepted range for the normative sample.

The next step undertaken was to evaluate the possible additional usefulness of the two signal detection theory measures Sensitivity and Response Bias, which were calculated from Hits and False Alarms. As seen in Table 18 the signal detection theory measures did select similar numbers of subjects, however, no unique (i.e., not already identified) Clinical subjects were identified. A similar pattern was noted for the X- and AX-tasks.

It was concluded that although they may be of theoretical interest these signal detection measures in addition to being more difficult to interpret clinically added nothing more than the raw measures and were therefore redundant. These two variables were then discarded from further analysis.

The timed measures Response Time and Variability were investigated next. As noted in Table 19 the Deviation measure added no unique clinical subjects at any criteria. Response Time, on the other hand, contributed some Clinical subjects that had not been already identified. It also appears from Table 19 that these measures, particularly Response Time, lose their sensitivity (i.e., ability to identify subjects) rapidly with increasing standard deviations. This most likely is

TABLE 18

CLINICAL DISCRIMINATION USING SENSITIVITY AND RESPONSE BIAS COMBINED CCPT

Standard Deviation	CCPT Measure	#Identified Normative (unique)*	#Identified Clinical (unique)*
2	Sensitivity	7 (0)	11 (0)
	Response Bias	6 (5)	7 (0)
	Total	(5)	(0)
3	Sensitivity	5 (0)	9 (0)
	Response Bias	0 (0)	3 (0)
	Total	(0)	(0)
4	Sensitivity	2 (1)	8 (0)
	Response Bias	0 (0)	0 (0)
	Total	(1)	(0)

*Unique refers to subjects not already identified in Table 17 at that particular standard deviation.

related to the distributions of these measures (i.e., being more normally distributed than previously discussed CCPT measures). It appeared reasonable to discard the Deviation measure, but retain the Response Time at its most sensitive criterion (i.e., two standard deviation cutoff).

The resulting combined task with three measures (i.e., Hits, False Alarms and Response Time) identified 73.9% (n=17) of the Clinical Group and 4.0% (n=5) of the Normative Sample. Using the same three measures and criteria the identification percentages for the X-task were 56.5% (n=13) and 3.2% (n=4) and for the AX-task were 69.6% (n=16) and 4.8% (n=6) for the Clinical and Normative groups respectively. It should also be noted that all Clinical subjects identified on the AX-task and all except one that were identified on the X-task were also detected on the combined task. The clinical cutoff scores and standard error of measurements for each age group on the combined CCPT are presented in Table 20.

TABLE 19

CLINICAL DISCRIMINATION USING VARIABILITY AND RESPONSE TIME COMBINED CCPT

Standard Deviation	CCPT Measure	#Identified Normative (unique)*	#Identified Clinical (unique)*
2	Variability	6 (2)	8 (0)
	Response Time	3 (2)	7 (2)
	Total	(4)	(2)
3	Variability	1 (0)	5 (0)
	Response Time	0 (0)	2 (1)
	Total	(0)	(1)
4	Variability	0 (0)	3 (0)
	Response Time	0 (0)	0 (0)
	Total	(0)	(0)

*Unique refers to subjects not already identified in Table 18 at that particular standard deviation.

TABLE 20

COMBINED CCPT CLINICAL CUTOFF SCORES

Age	Hits (standard error)*	False Alarms (standard error)*		Response Time (standard error)*
6	<117.12 (3.08)	>23.29 (2.88)	male	>911.70 (7.50)
			female	>913.25 (12.01)
7	<101.60 (2.14)	>37.24 (2.25)	male	>891.98 (17.42)
			female	>891.21 (16.66)
8	<121.56 (2.76)	>26.53 (2.83)	male	787.73 (12.48)
			female	>860.60 (16.32)
9	<146.78 (1.46)	>25.24 (1.90)	male	>782.69 (8.68)
			female	>764.72 (6.03)
10-11	<165.34 (1.78)	>15.03 (1.22)	male	>727.61 (8.36)
			female	>800.00 (9.82)

*standard error refers to Standard Error of Measurment

3.5.3 Conners Questionnaire Results

Normative Sample

Seventeen subjects (13.6%) in the Normative Sample obtained Hyperactive Index scores on the Conners Parent or Teacher Questionnaire that were at least 1.5 standard deviations above the norm for same aged peers. Twelve of these subjects' scores were obtained solely on the Teacher Questionnaire, two were obtained only on the Parent Questionnaire and three subjects had scores above the 1.5 standard deviation criterion on both questionnaires. If the cutoff score was increased to at least 2.0 standard deviations above norm, 13 (10.4%) of the normative sample obtained Index scores that were beyond this criterion. This corresponds to nine, two and two for the number of subjects above the 2.0 standard deviation criterion on the Teacher Questionnaire, Parent Questionnaire and on both respectively.

Five subjects (four males) of the Normative Sample obtained scores on the CCPT within the clinical range (see Section 3.5.2). Three of these subjects (all male) obtained Hyperactivity Index scores of at least 1.5 standard deviations above norm on either the Conners Teacher or Parent Questionnaire. The other two subjects' Questionnaire scores were within one standard deviation of the norm. The above results did not change if a 2.0 standard deviation cutoff value was adopted for the Questionnaires.

Clinical Group

Of the 23 members of the Clinical Group, 11 obtained Hyperactivity Index scores on both the Conners Parent and Teacher Questionnaires that were at least 1.5 standard deviations above the norm for same aged peers. Eight members of the Clinical Group had scores above this criterion only on the Parent Questionnaire and four subjects only acquired above criterion scores on the Teacher Questionnaire. There appeared to be no particular pattern across these three "groups" with respect to CCPT performance. Out of the 11 subjects with both Questionnaires elevated, seven were within the "clinical" range on CCPT performance. Seven of the eight subjects with elevated Parent Questionnaires had "clinical" range scores on their CCPT performance and of the four with elevated Teacher Questionnaires three were within the "clinical" range.

Twenty members of the Clinical Group obtained Hyperactivity Index scores that were at least 2.0 standard deviations above norm. Four of the eight subjects who received scores on both Questionnaires above this criterion were within the "clinical" CCPT range. All of the eight subjects with scores on the Parent Questionnaire and the four subjects with scores on the Teacher questionnaire that were greater than this criterion were within the "clinical" range on their CCPT performance. One subject in the Clinical Group whose performance on the CCPT was within the "clinical" range did not obtain a score at least 2.0 standard deviations above the norm on either of his Conners Questionnaires.

3.6 Reliability of CCPT Measures

3.6.1 Internal Consistency

Internal reliability was assessed by first dividing the X- and AX-tasks into equivalent halves using an odd-even methodology for target and nontarget trials (i.e., placing odd trials in one half and even trials in the other half). The combined CCPT "halves" were calculated by aggregating the even trials from the X- and

AX-tasks and aggregating the odd trials from the two tasks. The resulting halves were then correlated with each other (Pearson product-moment) and corrected for the reduced number of items used (Spearman-Brown correction formula). This yielded overall coefficients that ranged from .591 to .984 for the combined normative sample. The individual coefficients for the combined and specific age groups are presented in Table 21 for the X-task, Table 22 for the AX-task and Table 23 for the Combined task. Internal reliability coefficients are also presented for the combined clinical sample in these Tables.

TABLE 21

INTERNAL RELIABILITY COEFFICIENTS FOR X-TASK
(95% Confidence Intervals)

Group	Hits	False Alarms	Response Time (m/f)*
Age 6 (n=24)	.555 (.197-.782)	.464 (.080-.731)	.979 (.994/.947) (.951-.991)
Age 7 (n=27)	.891 (.774-.950)	.858 (.711-.934)	.950 (.959/.916) (.892-.977)
Age 8 (n=19)	.922 (.804-.970)	.600 (.197-.828)	.956 (.951/.962) (.888-.983)
Age 9 (n=31)	.621 (.345-.800)	.778 (.604-.888)	.973 (.970/.984) (.945-.987)
Age 10-11 (n=23)	.709 (.422-.867)	.628 (.291-.828)	.984 (.980/.981) (.962-.993)
Total (n=124)	.863 (.811-.902)	.748 (.658-.818)	.982 (.982/.981) (974-.987)
Clinical (n=23)	.985 (.964-.994)	.996 (.990->.995)	.946 (.874-.977)

*(m/f) refers to male & female scores which are provided when relevant

TABLE 21 (Continued)

INTERNAL RELIABILITY COEFFICIENTS FOR X-TASK
(95% Confidence Intervals)

Group	Variability	Sensitivity	Response Bias
Age 6 (n=24)	.609 (.273-.814)	.516 (.139-.762)	.509 (.129-.757)
Age 7 (n=27)	.503 (.149-.740)	.893 (.778-.951)	.612 (.282-.811)
Age 8 (n=19)	.309 (.000-.670)	.941 (.851-.978)	.560 (.139-.808)
Age 9 (n=31)	.826 (.664-.914)	.728 (.500-.862)	.464 (.129-.701)
Age 10-11 (n=23)	.744 (.478-.885)	.817 (.611-.920)	.656 (.336-.840)
Total (n=124)	.748 (.658-.818)	.865 (.814-.903)	.591 (.462-.696)
Clinical (n=23)	.798 (.578-.910)	.984 (.962-.993)	.769 (.523-.898)

TABLE 22

INTERNAL RELIABILITY COEFFICIENTS FOR AX-TASK
(95% Confidence Intervals)

Group	Hits	False Alarms	Response Time (m/f)*
Age 6 (n=24)	.927 (.837-.968)	.528 (.159-.770)	.957 (.966/.949) (.902-.982)
Age 7 (n=25)	.959 (.909-.982)	.937 (.862-.972)	.940 (.932/.941) (.867-.974)
Age 8 (n=19)	.914 (.786-.967)	.743 (.438-.896)	.946 (.969/.883) (.862-.979)
Age 9 (n=32)	.920 (.840-960)	.790 (.611-.894)	.987 (.990/.990) (.973-.994)
Age 10-11 (n=23)	.667 (.354-.846)	.666 (.345-.846)	.982 (.983/.978) (.957-.992)
Total (n=123)	.943 (.920-.960)	.805 (.731-.859)	.970 (.965/.970) (.957-.979)
Clinical (n=23)	.979 (.951-.991)	.988 (.972-.995)	.983 (.960-.993)

*(m/f) refers to male & female scores which are provided when relevant

TABLE 22 (Continued)

INTERNAL RELIABILITY COEFFICIENTS FOR AX-TASK
(95% Confidence Intervals)

Group	Variability	Sensitivity	Response Bias (m/f)*
Age 6 (n=24)	.654 (.336-.837)	.930 (.843-.970)	.728 (.716/.265) (.462-.874)
Age 7 (n=25)	.477 (.100-.735)	.995 (.900-.980)	.848 (.994/.685) (.680-.932)
Age 8 (n=19)	.671 (.310-.862)	.934 (.834-.975)	.363 (.493/.262) (.000-.701)
Age 9 (n=32)	.676 (.430-.831)	.923 (.846-.962)	.893 (.855/.964) (.790-.947)
Age 10-11 (n=23)	.725 (.446-.876)	.641 (.310-.834)	.581 (.609/.525) (.226-.800)
Total (n=123)	.728 (.635-.766)	.946 (.923-.962)	.765 (.769/.724) (.650-.831)
Clinical (n=23)	.832 (.641-.926)	.987 (.969-.994)	.953 (.890-.980)

*(m/f) refers to male & female scores which are provided when relevant

TABLE 23

INTERNAL RELIABILITY COEFFICIENTS FOR COMBINED TASK (95% Confidence Intervals)

Group	Hits	False Alarms	Response Time (m/f)*
Age 6 (n=24)	.918 (.818-.964)	.541 (.178-.774)	.984 (.994/.961) (.963-.993)
Age 7 (n=25)	.980 (.954-.991)	.911 (.808-.960)	.956 (.970/.932) (.902-.981)
Age 8 (n=19)	.946 (.862-.979)	.710 (.380-.881)	.959 (.962/.948) (.894-.984)
Age 9 (n=31)	.952 (.902-.977)	.868 (.740-.935)	.985 (.987/.993) (.969-.993)
Age 10-11 (n=23)	.610 (.264-.818)	.851 (.675-.935)	.987 (.987/.985) (.969-.994)
Total (n=122)	.960 (.944-.972)	.826 (.762-.876)	.984 (.984/.981) (.977-.989)
Clinical (n=23)	.987 (.969-.994)	.998 (.995->.995)	.977 (.946-.990)

*(m/f) refers to male & female scores which are provided when relevant

TABLE 23 (Continued)

INTERNAL RELIABILITY COEFFICIENTS FOR COMBINED TASK
(95% Confidence Intervals)

Group	Variability	Sensitivity	Response Bias (m/f)*
Age 6 (n=24)	.619 (.291-.818)	.882 (.744-.948)	.826 (.823/.647) (.635-.922)
Age 7 (n=25)	.525 (.159-.762)	.970 (.932-.987)	.853 (.927/.789) (.691-.933)
Age 8 (n=19)	.574 (.159-.814)	.939 (.846-.977)	.556 (.520/.645) (.139-.808)
Age 9 (n=31)	.859 (.726-.930)	.960 (.919-.981)	.819 (.790/.907) (.653-.909)
Age 10-11 (n=23)	.738 (.470-.881)	.742 (.478-.883)	.675 (.746/.607) (.363-.851)
Total (n=122)	.807 (.735-.862)	.952 (.932-.966)	.792 (.780/.777) (.716-.851)
Clinical (n=23)	.731 (.454-.879)	.990 (.976->.995)	.967 (.923-.986)

*(m/f) refers to male & female scores which are provided when relevant

3.6.2 Test-retest Consistency

Test-retest reliability coefficients based upon Pearson product-moment correlations were calculated for the 42 normative subjects tested twice on the CCPT. These correlations for the X, AX and combined tasks are presented in Table 24. This Table also presents coefficients for the summed total of the 42 Normative subjects and the three Clinical subjects on the combined task. Estimates of the potential test-retest reliability coefficients for Clinical subjects based upon a correction for curtailment (i.e., differences in the variance of the two populations; McNemar, 1969) are presented in Appendix I.

TABLE 24

TEST-RETEST RELIABILITY COEFFICIENTS FOR CCPT TASKS (95% Confidence Intervals)

Group	Hits	False Alarms	Response Time (m/f)*
Normative X-task (n=42)	.453 (.168-.664)	.326 (.020-.572)	.765 (.760/.728) (.598-.867)
Normative AX-task (n=42)	.687 (.485-.821)	.470 (.197-.675)	.769 (.747/.746) (.604-.869)
Normative Combined task (n=42)	.771 (.611-.872)	.398 (.110-.629)	.822 (.782/.800) (.691-.902)
Normative & Clinical Combined task (n=45)	.793 (.653-.881)	.539 (.291-.716)	.824 (.701-.900)

*(m/f) refers to male & female scores which are provided when relevant

TABLE 24 (Continued)

TEST-RETEST RELIABILITY COEFFICIENTS FOR CCPT TASKS (95% Confidence Intervals)

Group	Variability	Sensitivity	Response Bias (m/f)*
Normative X-task (n=42)	.539 (.282-.726)	.451 (.168-.664)	.321 (.020-.572)
Normative AX-task (n=42)	.647 (.430-.793)	.695 (.493-.824)	.248 (.045/.424) (.000-.515)
Normative Combined task (n=42)	.733 (.551-.848)	.773 (.611-.872)	.325 (.227/.324) (.020-.572)
Normative & Clinical Combined task (n=45)	.733 (.558-.846)	.787 (.641-.879)	.420 (.139-.635)

*(m/f) refers to male & female scores which are provided when relevant

3.7 Individual Case Data

3.7.1 Clinical Subjects Not Meeting Defined Criteria

As previously remarked two of the subjects tested for the Clinical Group failed to meet the defined clinical criteria. The first of these subjects was receiving medication (methylphenidate) which reportedly greatly improved his condition. Since this subject was, at the time of testing, performing adequately in school and at home his mother and psychiatrist decided not to discontinue his medication at that time. Data were, therefore, not obtained on this subject while unmedicated. The second of these subjects failed to obtain a rating of 1.5 standard deviations or above on either of his Conners Teacher or Parent Questionnaires. Neither of these two cases were identified by the CCPT using the criteria noted above.

3.7.2 Medication Trials

As previously mentioned three of the subjects in the Clinical Group were also seen while receiving medication (methylphenidate) that was prescribed for their disorder. The results of this testing will be discussed for each of the three subjects individually. Based upon the clinical investigations in Section 3.5.2, subject performance was evaluated using the three previously selected CCPT measures (i.e., Hits, False Alarms and Response Time) of the Combined task.

The first subject, T.N., was a male age 9 years and 11 months. He was initially assessed while receiving medication and was then retested after seven days without receiving medication. In addition to the CCPT the Digit Span subtest of the WISC-R was also administered on both occasions. T.N.'s scaled score on the Digit Span subtest was 6 when he was receiving medication and 5 when he was not. This small difference most likely represents normal variability over time and was not considered clinically significant. Similarly T.N.'s Response Time on the CCPT was slightly shorter on medication (673.04 msec.) than off medication (702.17 msec.), a difference felt to be quite small considering the Normative standard deviation obtained at this age level (see Appendix G). T.N.'s performance change on the Hits measure, however, appeared to be quite significant and is presented in Figure 21 along with the clinical cutoff (i.e., four standard deviation cutoff) for his age group. The False Alarm data for T.N. also appeared to vary somewhat between medication conditions and are presented in Figure 22.

The second subject, A.W., was a 7 year, 9 month old female. She was initially assessed while "on" medication and then reassessed after 14 days of not receiving medication. In addition to the CCPT and Digit Span tests, the Conners Parent and Teacher Questionnaires were completed on both occasions. Unfortunately it was not possible to obtain "blind" rating on these checklists (i.e., both the parents and teacher were aware of the conditions). A.W.'s scaled scores on the Digit Span test did not significantly vary for "on" medication (8) to "off" medication (9). Her Teacher Questionnaire Hyperactivity Index also appeared to change little from when receiving medication (3.65 s.d. above norm) to when not receiving medication (3.43 s.d. above norm). On the other hand, her Parent Questionnaire Hyperactive Index changed from 2.32 s.d. above norm while "on" medication to 0.60 s.d. above norm while "off" medication. A.W.'s CCPT scores were all slightly better while "on" medication, however, both sets of scores were well within the non-clinical range for her age (see Table 25).

FIGURE 21

HITS FOR T. N. ON COMBINED CCPT

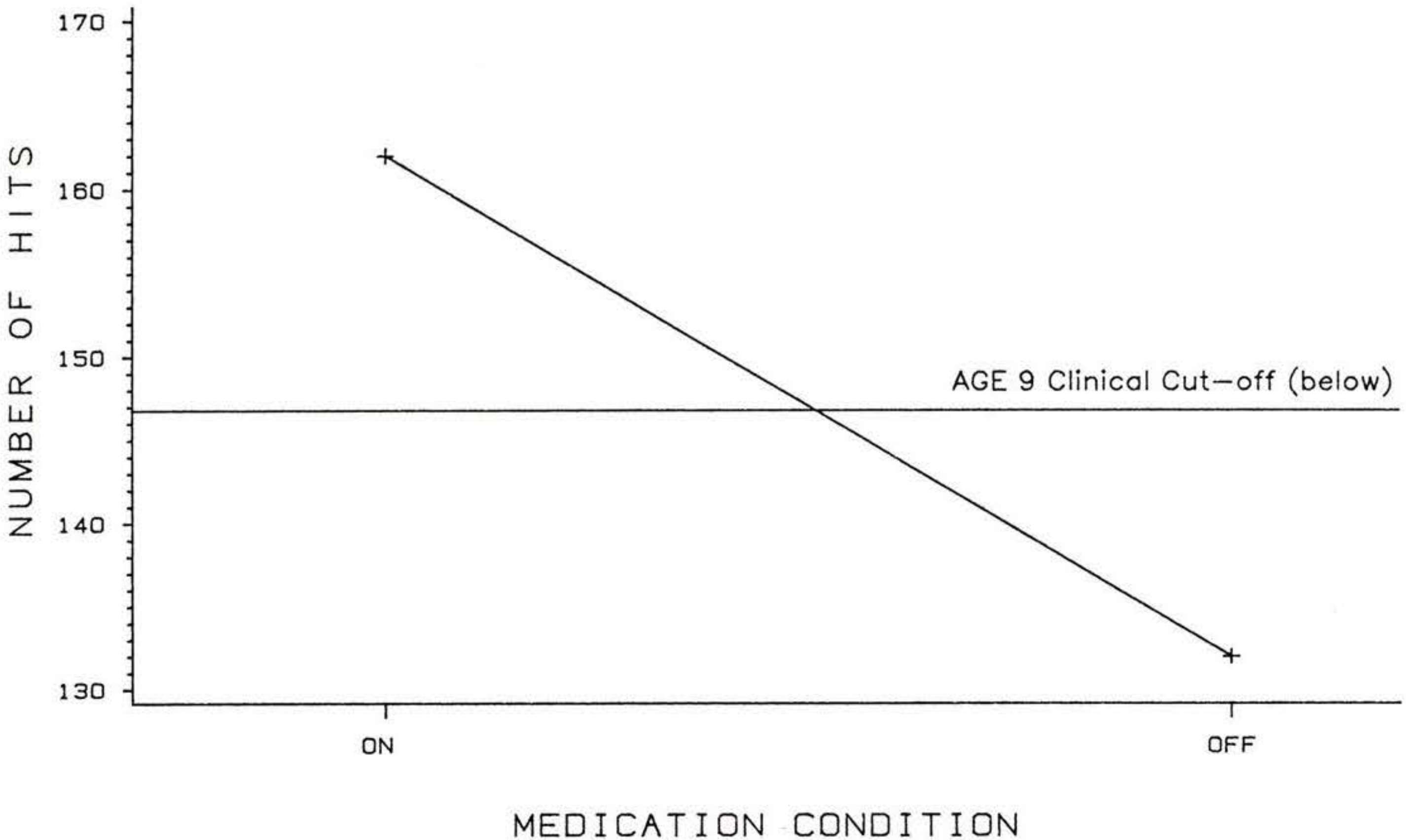


FIGURE 22

FALSE ALARMS FOR T. N. ON COMBINED CCPT

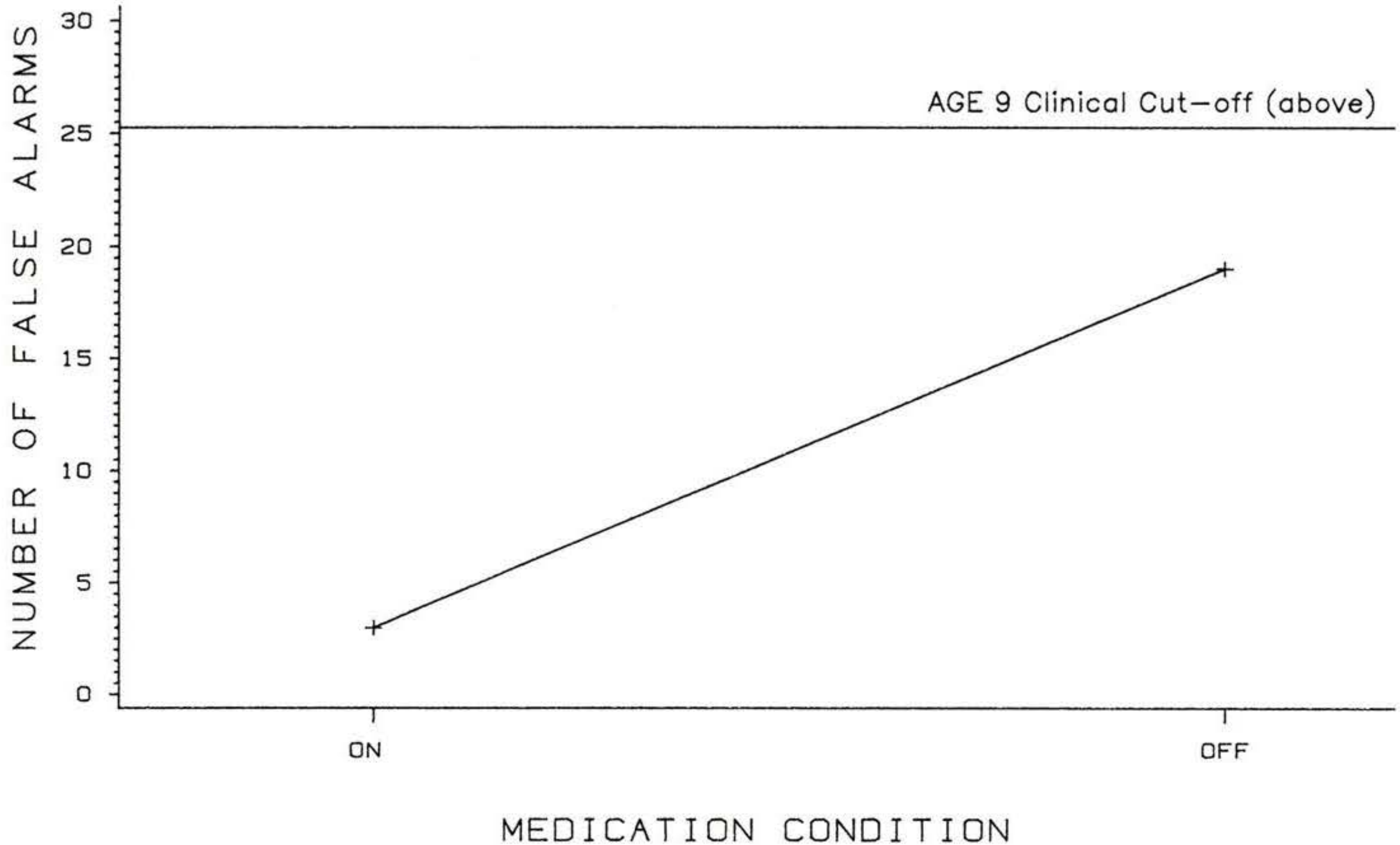


TABLE 25

CCPT PERFORMANCE FOR A.W.

Measure	On med.	Off med.	7 year cutoff
Hits	178	153	<101.60
False Alarms	2	13	>37.24
Response Time	604.98	714.63	>891.21

The last Clinical subject, K.C., was an 11 year 1 month old male. K.C. was seen on three separate occasions, the first while receiving medication, then again after 7 days of not receiving medication, and finally 7 days after his medication was reintroduced. The CCPT, Digit Span and Conners Parent and Teacher Questionnaires were obtained during all three conditions. Again the Digit Span scaled scores, which were 5 while initially "on", 6 when "off" and 7 when "on" again, did not appear to be influenced by medication condition. The Conners Questionnaires which again were not completed by "blind" raters, however, demonstrated significant differences between conditions. The Teacher Questionnaire Hyperactivity Index scores were 0.97 s.d. above norm while "on", 2.51 s.d. above norm while "off", and 0.11 s.d. above norm when "on" again. The Parent Questionnaire Hyperactivity scores were 1.45 s.d. above norm, 4.64 s.d. above norm and 0.55 s.d. above norm for "on", "off" and "on" medication respectively. On the CCPT K.C.'s Response Time scores of 486.27, 518.32 and 564.97 did not appear to vary significantly by medication condition and were all well below the clinical cutoff of 727.61 msec. for his age range. K.C.'s number of Hits on the CCPT appeared to be somewhat related to condition (see Figure 23) although these scores were also all within the non-clinical range. Finally, K.C.'s False Alarms appeared to be significantly related to medication condition as demonstrated in Figure 24.

FIGURE 23

HITS FOR K. C. ON COMBINED CCPT

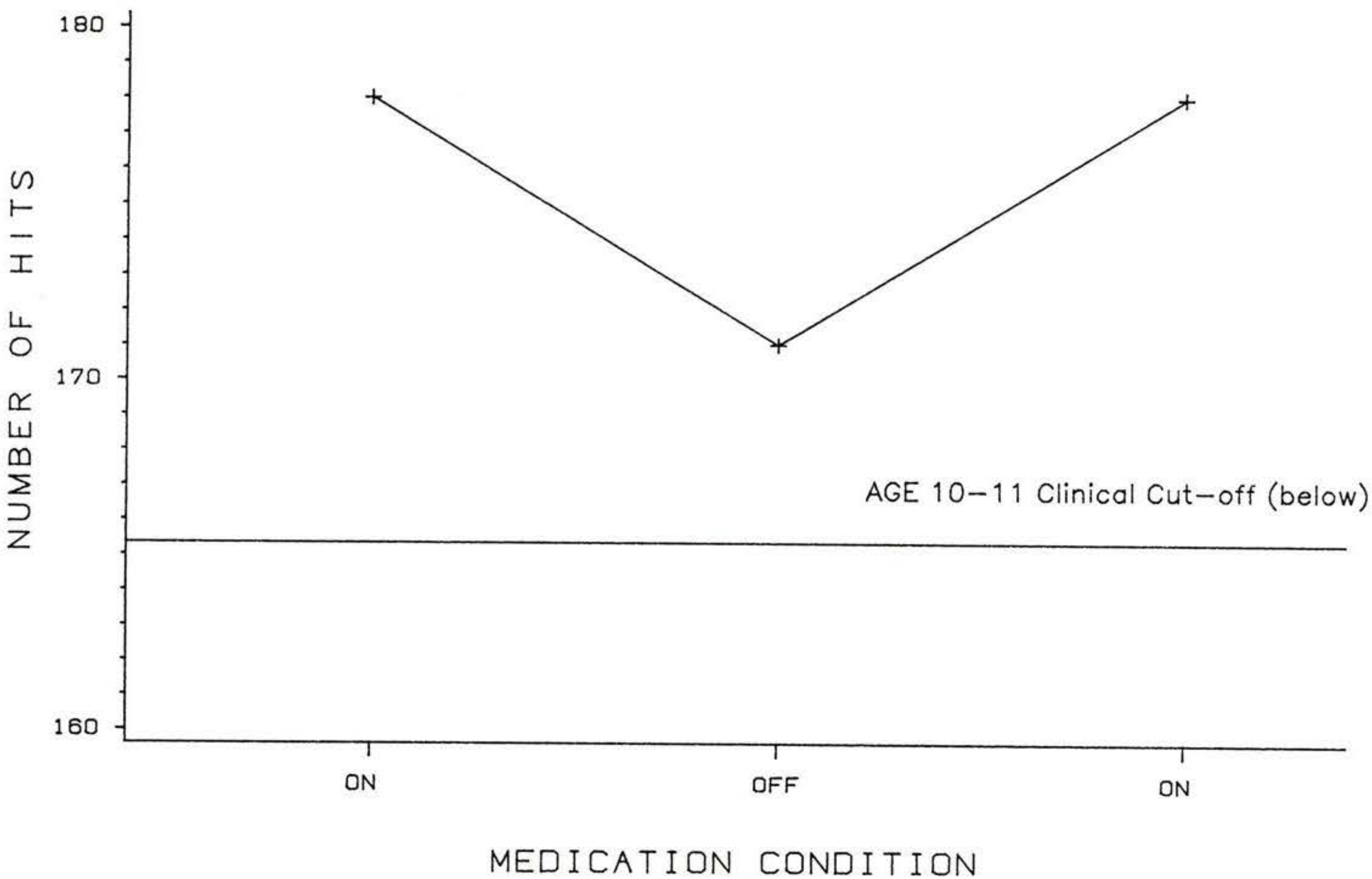
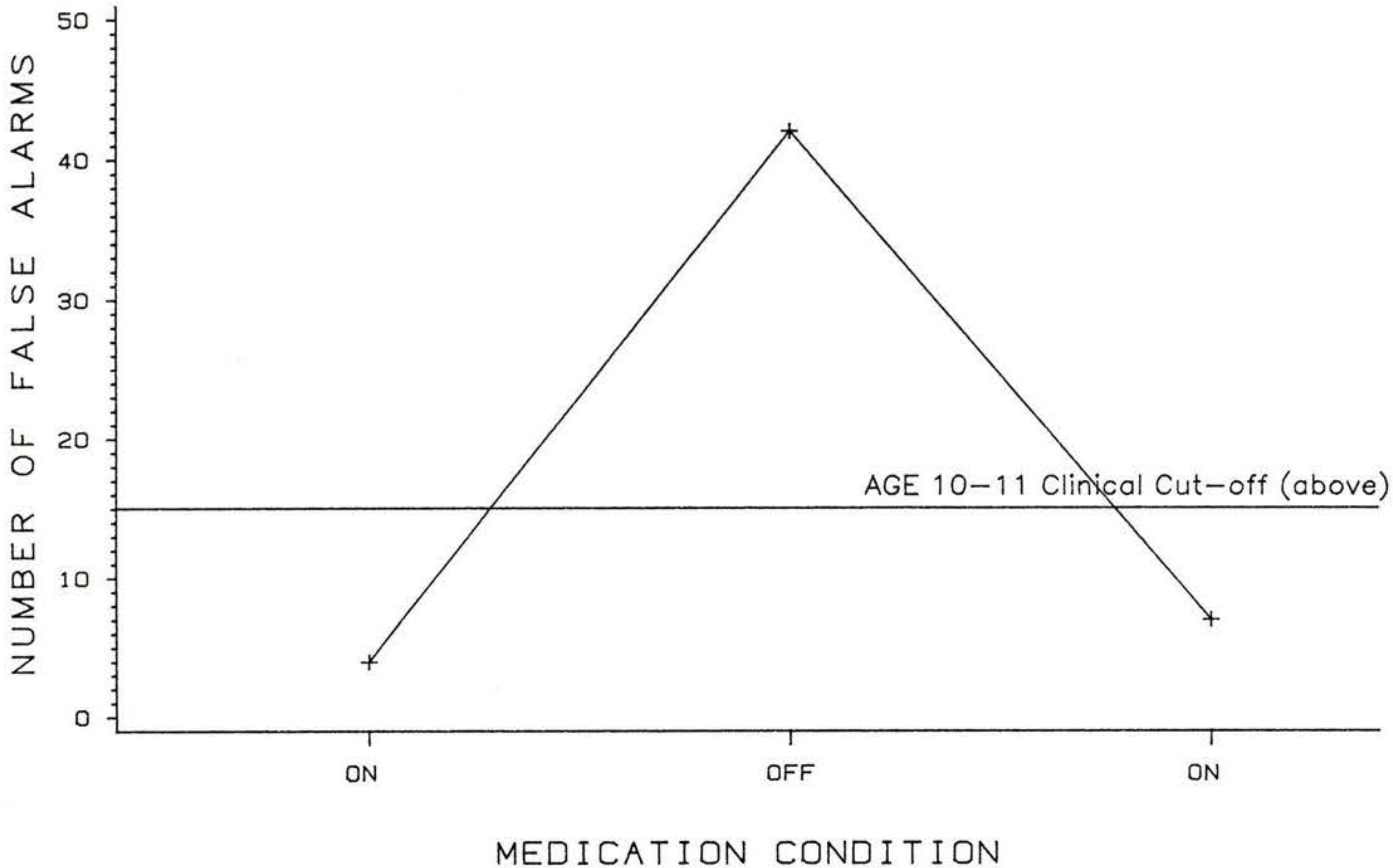


FIGURE 24

FALSE ALARMS FOR K. C. ON COMBINED CCPT



3.7.3 Head Injured Case

Individual data were also obtained on a 7 year 4 month old female who had sustained a closed head injury as a result of a motor vehicle accident which occurred four months prior to her assessment. At that time her WISC-R Full Scale IQ was 103 and a complete neuropsychological examination found her to have many strengths including above average language and academic abilities. S.B.'s main difficulties appeared to be in fine motor coordination, although a variable performance on some memory tests did suggest that she might have some attentional difficulties. S.B.'s number of Hits (144) and False Alarms (19) were both within the 7 year old clinical cutoff values of 101.60 and 37.24 respectively. Her Response Time of 939.98 msec., however, was above the 891.21 msec. clinical cutoff value.

Chapter 4

DISCUSSION

The primary goal of the present study was to accumulate data necessary to make a preliminary assessment of the potential utility of a CPT task (i.e., the CCPT) for the individual assessment of attention in children. The subsequent discussion evaluates this goal and presents implications for future research.

4.1 Subject Samples

The Normative Sample obtained for the study appeared to have a slightly higher than average socioeconomic status. The implications of this, however, are probably not consequential considering the insignificant relationship observed between SES and CCPT performance. The mean prorated verbal IQ of the Normative Sample was also slightly higher (mean=109, s.d.=11) than expected for an estimate of IQ (mean=100, s.d.=15) based upon the U.S.A. national normative sample (Wechsler, 1974). This discrepancy could reflect the limitations in estimating IQ based upon the prorating procedure used or actual differences between the Victoria and U.S.A. samples. Considering the finding of Holmes (1981) of mean Full Scale IQ on the WISC-R of 108 (s.d.=12) for similar aged British Columbian children, the above discrepancy most likely reflects actual differences between the Victoria and U.S.A. samples. The prorating procedure used could therefore be assumed to provide a reasonable estimate of IQ. Further evidence that SES and estimated IQ were reliable findings were the consistencies observed for both of these variables across both age and sex.

The clinical group's mean SES and prorated verbal IQ appeared to be lower than the Normative Sample's SES and IQ means. This finding is consistent with the literature which indicates that clinical groups typically have lower IQ scores (Schachar, Rutter, & Smith, 1981) and come from lower SES families (Barkley, 1981).

4.2 Construct-Related Evidence of Validity

4.2.1 Prorated Verbal IQ

The finding of significant correlations between estimated IQ and CCPT performance was not unexpected, particularly considering the four subtests chosen to prorate. Based upon prior factor analytic studies, the subtests Arithmetic and Digit Span have high loadings, Information a moderate loading, and Similarities a low loading on a factor that has been labelled "Freedom from Distractibility" which is assumed to be related to attention (see Sattler, 1988). Based upon this research one might argue that Arithmetic, Digit Span and Information should be significantly correlated with a measure of attention, but Similarities would not; the exact result that was obtained with respect to the combined CCPT. It should be noted, however, that this Freedom from Distractibility factor is argued by some to be poorly understood and its label might be an oversimplification of its actual meaning (Ownby & Matthews, 1985; Stewart & Moely, 1983).

4.2.2 Developmental and Gender Data

In general it was found that overall performance on the CCPT tasks improves with age. Significant developmental trends have also been reported on CPT type tasks in the literature (see Levy, 1980; Murphy-Berman & Wright, 1987; Sykes et al., 1973). This developmental trend might be considered a necessary prerequisite considering that a review of different types of attention tasks by Davies, Jones, and Taylor (1984) concluded that, the ability to attend clearly improves with age in children.

Further developmental trends were noted in CCPT performance changes over time. On several of the CCPT measures (i.e., X-task Hits, Sensitivity and Response Bias; AX-task Hits, Sensitivity and False Alarms) it was found that the younger children's performance decreased more rapidly than older children's performance with the passage of time. Few studies have addressed this issue (e.g., Gayle & Lynn, 1972) and this result, as far as can be determined, has not been previously reported in the literature. Whether differences in performance decrement reflect the continual development of voluntary attention cannot presently be answered. It is known, however, that the frontal regions of the brain are relatively slow to develop and maturation continues well into puberty and possibly beyond (Stuss & Benson, 1986). Performance on other CCPT measures (i.e., X-task False Alarms, Variability and Response Time; AX-task Variability, Response Time and Response Bias) did deteriorate over time, but not differentially by age. These two findings together suggest that although CCPT measures were found to be highly correlated they are not necessarily redundant and may assess different aspects of the same phenomenon (attention). Furthermore, the results of decrements in performance over time are consistent with theories of sustained attention (Parasuraman, 1984) and provides additional evidence that the CCPT actually measures this construct.

The majority of the CCPT measures were not found to significantly vary by gender. This result is also consistent with the CPT literature (see Gordon, 1987a; Levy, 1980), although Murphy-Berman and Wright (1987) did find that boys had a higher score on their false alarm measure (i.e., boys were more impulsive). A similar result on the CCPT was the significantly lower Response Biases (i.e., higher impulsivity) obtained by males on the AX and combined tasks. The robustness of this finding, however, is unknown considering that CCPT False Alarms did not vary by sex and the current literature does not seem to provide further data on this issue. Whether or not these two independent findings of greater male impulsiveness are reliable may have to await further research before being generally accepted.

The other CCPT measure which was found to vary by gender was Response Time which in general was found to be shorter for males than for females. The only other study found which examined the relationship between Response Time and sex on a CPT did not, however, find a significant difference between the sexes (Levy, 1980). This finding is particularly surprising considering that it is generally reported in the literature that males have shorter reaction times than females (see Welford, 1980). The reason for males responding faster is most likely not due to sex differences in attention, but as Welford (1980) theorizes is due to basic genetic differences between the sexes and may relate to relative brain size. Regardless of the reason, the reliability of this finding on the CCPT (i.e., on all three tasks) indicates that separate comparison scores should be used for males and females.

There were also no significant differences found in CCPT performance decrements between males and females. This result is generally supported by the vigilance literature (see Davies & Parasuraman, 1982).

4.2.3 Conners Questionnaire Data

Further construct-related evidence is provided by the obtained correlations between the CCPT and the Conners Questionnaires. Significant correlations were obtained between all individual scales which could be argued to relate to attention on both the Teacher (Hyperactive, Inattentive and Hyperactive Index) and the Parent (Learning Problems, Impulsive and Hyperactive Index) Questionnaires. On the other hand, no significant correlations were obtained between CCPT performance and the Questionnaire scales which appear related to nonattentional dimensions for the Teacher (Conduct Problems) and for the Parent (Conduct Problems, Psychosomatic and Anxiety) Questionnaires. The above finding is particularly interesting considering the current controversy existing between literature questioning the independence between Hyperactivity and Conduct Disorder (e.g., Draeger et al., 1986; Koriath, Gualtieri, VanBourgondien, Quade, & Werry, 1985; Quay, 1979) and literature supporting this distinction (Blouin et al., in press; Hinshaw, 1987; Milich, Loney, & Landau, 1982). The present study would appear to support the theoretical distinction between these two dimensions at least in a normative sample.

The Clinical Group evidence is less clear concerning the Conners Questionnaires; this is felt to be primarily due to the small number of subjects. If one adopts a less conservative criterion for accepted significance (e.g., $p<.10$) in consideration of the small number of subjects, some suggestive evidence emerges. Specifically, the Inattentive factor of the Teacher Questionnaire and the Impulsive and Hyperactive Index factors of the Parent Questionnaire are the only scales correlated with multiple CCPT measures. Interestingly the Conduct Problem factor of both Questionnaires was significantly correlated with the same CCPT measure (X-task Variability). Whether this suggests that the above noted distinction between Conduct Disorder and Hyperactivity might be less clear in a clinical population is unknown and will also have to be addressed in future research with larger numbers of subjects.

4.2.4 CCPT Structure

Intracorrelations and intercorrelations between CCPT measures provided some support that these measures assess a single, or at least related, construct(s). The principal components analysis, furthermore, suggested that the CCPT might actually be measuring two dimensions, an inattentive factor and an impulsivity factor. Whether or not these two factors have clinical significance or utility for individual children will have to be investigated in future research. The lack of acceptable measures of these dimensions, however, will make validation of this interpretation difficult. One approach might be the construction of a rating scale based upon items from DSM III (American Psychiatric Association, 1980) that at least conceptually appear to differentiate these factors. Subsequently these ratings could be compared with CCPT performance scores in an attempt to resolve this issue.

4.2.5 School Performance Ratings

Assuming that attention is as important for learning as argued in the literature (see Piontkowski & Calfee, 1979; Trabasso & Bower, 1968; Torgesen, 1981), any measure of this construct should also in some way relate to school learning. This also addresses the issue of "ecological" validity or, in other words, is there a relation between actual environmental data (e.g., school performance) and CCPT scores. The results of the teacher ratings of overall school performance provide some information concerning these issues. On all of the CCPT measures found to be significantly different by performance group rating, the group that was rated as being below average performed at a lower level than the groups rated average or above. This finding provides preliminary evidence that the construct measured by the CCPT is related to overall school performance, and if this construct is attention, is consistent with the literature referenced above.

4.3 Criterion-Related Evidence of Validity

4.3.1 Group Comparison Data

Examination of the Clinical and Control groups which were matched by gender and not statistically different with respect to age, prorated verbal IQ and SES revealed striking differences in terms of their CCPT performance. A majority of the CCPT measures were found to be significantly different in both magnitude and variability for the two groups with the clinical group performing less well and more variably. The Clinical Group's performance also appeared to deteriorate over time at a significantly more rapid rate on some of the CCPT measures (i.e., X-task Hits and Variability; AX-task Hits). The above noted differences obtained in performance magnitude were felt to be significant despite the nonhomogeneity of variances observed. This was because considerable evidence exists that indicates marked skewness, departures from normal kurtosis and extreme differences in variance do not notably disrupt the F test for judging significance in analyses of variance (McNemar, 1969). Furthermore, many of the statistical differences obtained were highly significant ($p<.01$) so that the risk of making a Type I Error was felt to be quite low. Significant group differences between children with diagnosed attentional difficulties and children undiagnosed with these problems would be expected on any test assumed to measure attention. The present findings are consistent with this notion and replicate prior group research reported in the literature (Sykes et al., 1973; Tarnowski et al., 1986; O'Dougherty et al., 1984).

Furthermore, the group differences obtained in the rate of performance decrement might suggest that children diagnosed with ADD have some difficulty at the level of voluntary attention. This would be consistent with the view that these children have deficits in the self-regulation and internal control of attention (Douglas & Peters, 1979; Douglas et al., 1986). This is also congruent with evidence of frontal region dysfunction in ADD children obtained in studies of cerebral blood flow (Lou, Henriksen, & Bruhn, 1984) and neuropsychological test results (Chelune, Ferguson, Koon, & Dickey, 1986).

4.3.2 Individual Clinical Data

Perhaps a more conclusive and practical source of criterion-related evidence concerns not group but individual subject data. Using the clinically derived cut off scores, the CCPT was found to identify as "impaired" 73.9% and 4.0% of the Clinical and Normative groups respectively. In assessing this performance regarding correct classification two relevant issues first need to be highlighted.

The first issue concerns the diagnostic category of ADD. There exist many difficulties in diagnosing ADD such as the availability of few objective measures to assess the specified symptoms (Cantwell & Baker, 1987; Dulcan, 1986). Furthermore, difficulties in aetiological specificity (e.g., organic versus environmental), distinguishable symptomatology (e.g., distinction between ADD, Learning Disabilities and Conduct Disorder) and specific treatment response (e.g., treatments effective for ADD are also effective in normals, delinquents and learning disabled) have led some investigators to question the validity and reliability of the ADD category itself (Prior & Sanson, 1986; Rubinstein & Brown, 1984). Finally, the diagnosis of ADD has been argued to require information from a variety of sources and should never rely upon a single measure (Gordon, 1987a; Milich et al., 1986).

The second concern pertains to estimates of the prevalency of ADD which have varied widely in the literature (e.g., 2%-20%), although most investigators accept between 3% and 5% as reasonable estimates for school aged children (Barkley, 1981).

Considering the above issues and the fact that the proposed purpose of the CCPT was to assess attention not diagnose ADD, the conclusion that the 26.1% of

Clinical subjects and the 4.0% of the Normative subjects represent false negatives and false positives respectively may be an over simplification.

The ability of the CCPT to identify the majority of children with known attentional difficulties was therefore felt to be acceptable for an exploratory test. Furthermore, this discriminating ability provides direct evidence for both the validity and practical usefulness of this device. Incidentally, of the five members of the Normative Sample identified by the CCPT four were males. This result is also consistent with the reported estimates for male to female ratios, which range from 3:1 to 9:1 for ADD (Barkley, 1981).

A final point regarding the individual clinical data concerns the differences between these data and the group analyses. One example of this is provided by the CCPT measure Response Time. Although not found to significantly vary between the matched groups, Response Time was found to be useful for identifying Clinical subjects. This result is most likely related to increases in sensitivity that occur in this measure when within age group comparisons are made. In other words, combining various age ranges into groups increases the variability of measures, which are known to change by age, and may mask more subtle but reliable within age differences between the groups. It might also be suggested that for the same reason (i.e., combining different ages into groups) the Prior et al. study (1985) and a more recent study by Schachar, Logan, Wachsmuth and Chajczyk (1988) failed to find significant differences in performance decrement between ADD and control groups. The present finding of some significant decrement differences between these groups, despite a similar combination of age levels, might reflect an increase in statistical power due to a larger number of subjects being utilized in the current research, although differences in task parameters between the studies cannot be ruled out. To assess this position it would be necessary to collect enough Clinical and Control subjects to also analyze group differences within specific ages. This would increase the sensitivity and theoretically might uncover differences in Response Time and additional differences in performance decrements over time on other CCPT measures.

4.3.3 Medication Trial Data

Current research is in agreement that methylphenidate medication is effective, at least in the short-term, for the amelioration of the attentional difficulties seen in ADD children (Douglas et al., 1986; Evans, Gualtieri, & Hicks, 1986; Rapport et al., 1986), although the mechanism(s) of this therapeutic action remain poorly understood (Dulcan, 1986; Solanto, 1986). The finding that all three of the subjects receiving methylphenidate demonstrated some improvement on the CCPT is consistent with the above research and provides further support for the validity of the CCPT.

Specifically, the medication result with two of the children was quite striking with one CCPT measure in each case apparently "normalizing" (i.e., crossing the clinical cut off score) when receiving methylphenidate. The third child's performance both "on" and "off" medication were within the nonclinical range. This result is also particularly interesting since the child's psychiatrist, parents and teacher all agreed that a discontinuation of her medication appeared warranted <u>independently</u> of the CCPT results. At last report this final child is functioning adequately both at home and at school without medication.

Another interesting finding was the insensitivity of Digit Span, which appears to be related to attention (Lezak, 1983; Sattler, 1988), in comparison with the CCPT to the medication conditions. The insensitivity of Digit Span to methylphenidate has been found previously (Sebrechts et al., 1986) and is one of the reasons that vigilance tasks are more highly recommended to assess the attentional effects of drugs (Tiplady, 1988).

A final point with respect to these medication trials concerns the objectivity of the CCPT. If placebo's are not readily available, as in the present study, and raters are not "blind" (e.g., when teachers dispense medication) the usefulness of subjective rating scales is felt to be severely compromised. The use of objective assessment devices such as the CCPT is felt to be a minimum requirement for the clinical assessment of treatment efficacy, particularly when knowledge of the conditions cannot be controlled.

4.3.4 Data on Head Injured Subject

A neuropsychological assessment conducted post trauma in this case suggested the possible presence of some attentional difficulties. The CCPT result supported this position and provided preliminary evidence that this task may be an appropriate test for children who have sustained head injuries and potentially may be applicable for other neuropsychological populations. These conclusions, however, will have to await further data before acceptance.

4.4 Reliability

4.4.1 Internal Consistency

Due to the atypical test design of the CCPT (i.e., target trials randomly distributed within nontarget trials) measures of interitem consistency such as coefficient alpha appeared inappropriate (see Anastasi, 1982). It therefore appeared most suitable to estimate the internal reliability by using a split-half procedure. Since it was assumed that items near the end of the task would be more difficult than items near the beginning, an assumption that was supported by the above noted performance decrements, and odd-even division of items was used. The resulting reliability coefficients were quite variable between tasks, measures and age levels. In general, the combined CCPT appeared to be more reliable than either the X or AX task individually. It furthermore appeared that the restricted range obtained on the majority of CCPT variables reduced the resulting reliability coefficients. Evidence of this was provided by the general increases observed in the coefficients when the measures were more variable (e.g., when combining age levels and when examining Clinical subjects). In general for most tests of cognitive abilities a reliability coefficient of at least .80 is considered acceptable (Anastasi, 1982; Sattler, 1988). Therefore, on the combined CCPT the overall reliabilities of the selected clinical measures Hits (.960), False Alarms (.826) and Response Time (.984) all appear to be of acceptable reliability. For the Clinical Group, which performed more variably, all three of these coefficients were greater than .970. Although the combined CCPT appeared to be quite reliable, particularly with Clinical subjects, its consistency was quite variable in "normal" children within specific age level. The implications of this are that the CCPT would be most appropriate in distinguishing between normal and abnormal performance and not in making fine gradations within a normal population.

4.4.2 Test-retest Consistency

Further reliability data were obtained by re-examing some of the subjects to determine the temporal stability of the obtained scores. The resulting reliability coefficients were lower than the internal reliability coefficients as expected considering the variety of possible differences between the two circumstances. The results indicated that again, in general, the combined task was more reliable than either the X or AX task individually. Despite the combining of age level the restricted range of scores obtained by the Normative subjects again made the reliability coefficients more difficult to interpret. Evidence of this is provided by the general increases noted in the reliability coefficients if the data from just three Clinical subjects were added to the normative test-retest data. The obtained test-retest reliability coefficients, furthermore, appear to be comparable with those reported for the WISC-R individual subtests which ranged from .55 to .85 on similar aged children (Wechsler, 1974). Estimates of the potential test-retest reliability coefficients for a clinical population were computed to further demonstrate the effects of restricted range. The estimated coefficients were believed to be overly optimistic, however, it was felt that acceptable levels of test-retest reliability appear obtainable on the CCPT, at least for children with significant attentional difficulties.

4.4.3 Examiner Data

The lack of an effect on subject performance being obtained for the examiner administering the CCPT suggests that potential measurement error due to the examiner is most likely negligible. This result was not unexpected considering that the examiner's involvement in the CCPT is minimal and the computer administration of the task is quite standardized.

4.5 Other Considerations

4.5.1 Generalization Data

Some preliminary evidence that the obtained CCPT data are generalizable (i.e., could be replicated elsewhere) were provided by the finding that CCPT performance did not significantly vary between the schools tested. Future research will have to investigate if these findings could be extended to more dissimilar samples (e.g., outside the Victoria region). A further issue concerns the fact that only 35.4% of the Normative Sample solicited actually volunteered to participate in the study. This obtained group, therefore, did not represent a truly random sample of children from the schools that participated. The limitations of this are at present uncertain, however, according to teacher reports the extremes interms of ability, in both directions, were well represented by the subjects selected to participate. Additionally, the conservative approach taken to determine the cut off scores probably further minimized the effects of this sampling bias.

4.5.2 Practical Issues

There probably is little clinical need to consider IQ when interpreting CCPT results despite some significant correlations between prorated verbal IQ and CCPT performance being obtained. This is argued because, at most, less than 11% of the CCPT variance can be attributed to prorated verbal IQ (i.e., the square of the largest correlation <.322> obtained between CCPT task and IQ).

It also appeared appropriate to assess time of day effects for the CCPT since some cognitive abilities such as short term memory appear to change from morning to afternoon testing (Baddeley, Hatter, Scott, & Snashall, 1970; Folkard & Monk, 1979). The lack of a significant effect being found for the time of task administration suggest that little consideration need also be given to administration time when interpreting CCPT performance.

It should be noted, however, that the lack of practical significance demonstrated for IQ, time and SES apply only for the restricted values observed. In other words, for IQ and SES slightly above average and for administration times between 8:50am and 2:00pm. The effects upon performance of administering the CCPT to subjects significantly lower than average in IQ or SES and during times outside the tested range are at present unknown.

4.5.3 Subjects Responses

The finding of a greater percentage of subjects complaining during the CCPT in the Clinical Group than in the Normative Sample was not an unexpected result. In fact, since the proposed construct being measured (i.e., attention) is the same construct that the Clinical subjects were diagnosed as deficient in, one might expect that the CCPT would also be subjectively more difficult for this group.

What was surprising was that clinical impressions of attitude toward the CCPT often were not reflected in subject performance. This impression was supported by lack of a significant difference being obtained between complainers and non-complainers in the Normative Sample. One major difficulty with this analysis concerns defining complaining. For example the statement "How much longer is this?" could either reflect genuine inquisitiveness or simply frustration with the task. In an attempt to avoid subjective ratings a liberal definition of complaining (i.e., talking when instructed not to) was adopted. This definition may have increased the number of complainers and obscured the differences between "actual" complainers and noncomplainers performances. Nonetheless, the Clinical and Normative subjects in general appeared motivated to perform well on the CCPT and the lack of a relation between complaints and performance might suggest that motivation did not appear to be a significant factor in their performance.

4.6 Concluding Remarks

Preliminary validity and reliability evidence obtained suggest that the CCPT holds much potential as a practical measure of attention in children. Some of these results, however, in addition to being preliminary are outright exploratory and need to be replicated before being generally accepted. Pursuit of this research appears to be warranted considering that a recent survey of child psychologists indicated that few relied upon direct assessment of attentional and impulsive characteristics which was argued by Rosenberg and Beck (1986) to reflect an unfamiliarity with potential tests and a gap between recent research findings and current clinical practice. This same issue is addressed by Gordon

(1987b) as he states "Laboratory measures have had a long history in ADD research and a very short one in actual clinical practice" (p.54).

In addition to replication, future research should concentrate on both increasing the number and extending the age range for the Normative Sample. The implication that increases in sustained attention occur at age 11, at least in observational studies (Milich, 1984), further highlights this latter need. The collection of additional Normative subjects could also be used to evaluate the appropriateness of the present norms and clinical cutoff scores, and allow comparison with alternative types of scaling (e.g., percentiles) to be made with respect to sensitivity. Also the accumulation of CCPT data on samples of neuropsychological populations (e.g., head injured), both with and without attentional difficulties, would provide further information on the appropriateness of including this instrument in the general neuropsychological assessment of children. It may in the future also prove useful to obtain normative and clinical data on adult populations.

Another line of research would be to further explore the relations and distinctions between attention and impulsivity. A recent article by Halperin et al. (1988) suggests that some types of CPT errors might relate more to impulsivity and others more to inattention. Their data, although theoretically interesting were obtained from a group of variously aged normal children and the practical usefulness of their implications for individual children, who commit relatively few errors, is questionable. Even in the group comparisons for this study multivariate analyses were not possible due to the presence of many empty cells (i.e., most subjects did not make all types of errors). The distinction between attention and impulsivity might not be clear cut, however, considering that some authors suggest that impulsivity can be a failure to maintain attention (Kinsbourne & Caplan, 1979). Theoretical and practical differentiation of attention and impulsivity appears to merit further research since they were conceptualized as separate dimensions in the diagnosis of ADD (DSM III; American Psychiatric Association, 1980). More recently, however, this notion has been abandoned in favor of a unidimensional view in the diagnosis of Attention Deficit Hyperactivity Disorder (ADHD; DSM III-R; American Psychiatric Association, 1987). It should be noted that this unidimensional definition of ADHD has already received sharp criticism (Lahey et al., 1988). Nevertheless, future research should examine this issue further and also clarify if the CCPT actually provides information on one or two dimensions. This matter may be particularly relevant for neuropsychological populations in which impulsivity is not infrequently encountered (see Lezak, 1983).

Finally results obtained on the CCPT should at present be inspected with extreme caution. Additionally, the conservative approach employed for determining the clinical cutoff scores may have reduced the CCPT's sensitivity for less than extreme attentional difficulties. For reasons such as these it is suggested that CCPT results only be interpreted within a general neuropsychological evaluation. The CCPT should be utilized as an additional information source and not as a diagnostic instrument. Qualitative examination of the CCPT results might also provide relevant clinical information with respect to issues such as degree of attentional difficulty and length of attention span. It is hoped that information provided by the CCPT will contribute to the understanding and assessment of disorders of attention, the field which Geschwind (1982) dubbed "a frontier in neuropsychology" (p. 173).

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APPENDIX A

DEFINITION OF ATTENTION DEFICIT DISORDER

314.01 Attention Deficit Disorder with Hyperactivity

Diagnostic criteria for Attention Deficit Disorder with Hyperactivity

The child displays, for his or her mental and chronological age, signs of developmentally inappropriate inattention, impulsivity, and hyperactivity. The signs must be reported by adults in the child's environment, such as parents and teachers. Because the symptoms are typically variable, they may not be observed directly by the clinician. When the reports of teachers and parents conflict, primary consideration should be given to the teacher reports because of greater familiarity with age-appropriate norms. Symptoms typically worsen in situations that require self-application, as in the classroom. Signs of the disorder may be absent when the child is in a new or a one-to-one situation.

The number of symptoms specified is for children between the ages of eight and ten, the peak age range for referral. In younger children, more severe forms of the symptoms and a greater number of symptoms are usually present. The opposite is true of older children.

A. Inattention. At least three of the following:

1. often fails to finish things he or she starts

2. often doesn't seem to listen

3. easily distracted

4. has difficulty concentrating on school work or other tasks requiring sustained attention

5. has difficulty sticking to a play activity

B. Impulsivity. At least three of the following:

1. often acts before thinking

2. shifts excessively from one activity to another

3. had difficulty organizing work (this not being due to cognitive impairment)

4. needs a lot of supervision

5. frequently calls out in class

6. has difficulty awaiting turn in games or group situations

C. Hyperactivity. At least two of the following:

1. runs about or climbs on things excessively

2. has difficulty sitting still or fidgets excessively

3. has difficulty staying seated

4. moves about excessively during sleep

5. is always "on the go" or acts as if "driven by a motor"

D. Onset before the age of seven.

E. Duration of at least six months.

APPENDIX B

FORMULAE FOR SIGNAL DETECTION THEORY MEASURES

*Sensitivity = .5+((y-x)(1+y-x))/(4y(1-x))
*Response Bias = (y(1-y)-x(1-x))/(y(1-y)+x(1-x))

y = proportion of target trials to which subject responds (i.e. Hits/possible Hits)

x = proportion of nontarget trials to which subjects responds (i.e., False Alarms/possible False Alarms)

** If y=1, y was estimated at 2 to the (-1/t) power
** If x=0, x was estimated at 1-(2 to the (-1/t) power.

t = number of trials on which relevant stimulus type (target or nontarget) occurred.

* (see Grier, 1971)
** (see Davies & Parasuraman, 1982)

F. Not due to Schizophrenia, Affective Disorder, or Severe or Profound Mental Retardation.

314.00 Attention Deficit Disorder without Hyperactivity

Diagnostic criteria for Attention Deficit Disorder without Hyperactivity

The criteria for this disorder are the same as those for Attention Deficit Disorder with Hyperactivity except that the individual never had signs of hyperactivity (criterion C).

314.80 Attention Deficit Disorder, Residual Type

Diagnostic criteria for Attention Deficit Disorder, Residual Type

A. The individual once met the criteria for Attention Deficit Disorder with Hyperactivity. This information may come from the individual or from others, such as family members.

(from DSM III; American Psychiatric Association, 1980)

APPENDIX C

CCPT ADMINISTRATION INSTRUCTIONS

After asking the subject if they need to use the restroom, seat them comfortably with their dominant hand (what they write with) and arm resting on the table top at approximately two inches below their elbow. Position screen at eye level and approximately two feet from their head. Examiner should sit on the subject's right side if possible. The following instructions can be modified if necessary.

<u>X-task</u>

Select X-task (1) on menu and input the subject information. While the computer is "thinking" gently cover the keyboard.

"Now you're going to do something on the computer which is like a game of attention. Sometimes you will have to push this green button here (point) and other times you will have to keep your finger on this red area here" (point). "You will always use this finger" (point to dominant hand index finger).

(Display shapes). "First I want you to tell me the names of all of the letters here on the screen; start with this one" (point to the letter 'A' and allow the subject to read on or continue to point sequentially at all of the letters. If there are any letters misread or unknown note this and then call out the letters in the following order "Z,C,H,N,A,X,E,Q,P,K,U,S" requiring the subject to correctly point to the letter named. If they are unable to correctly identify all letters discontinue testing.

"Now the computer will show one of these letters at a time in the center of the screen and if it is the letter 'X' (point) I want you to press the green or go button all the way down and as fast as you can. If it is any other letter just keep your finger on the red or stop area and don't press the green button. Remember only press the green button when you see the letter 'X' and as fast as you can. Then rest your finger in the red area and wait for the next letter. O.K. let's try some practice" (Hit return to present practice letters).

(During practice immediately point out any incorrect responses and missed targets. Also remind the subject to stay in the red area as needed)

After practice read aloud the feedback screen output. (If the subject responded to all the 'X's and responded no more than 1 time to a non-'X' begin task; otherwise repeat practice. If after 3 practice sessions the subject continues to fail, but appears to understand the test, (e.g. can state the task requirements) continue testing; otherwise discontinue testing.

(After practice). "We are now ready to begin. Remember to press the green button all the way down and as fast as you can, but only if you see the letter 'X'. Also remember to try to keep your finger on the red area at all other times.

There will be lots of letters so try to keep your eyes on the screen and try not to talk until we are finished. I will answer any further questions then. Are you ready? Let's begin." (Press return to start the task).

During the task if the subject obviously is not looking at the screen or is not resting their finger on the red area remind them of this but only twice. If this continues frequently after the reminders note this. If the child talks during the task instruct him/her to continue playing the game and that you will answer their questions after it is over.

AX-task

Select AX-task (2) on the menu and input the subject information. While the computer is "thinking" gently cover the keyboard.

"Now you're going to do something that is a little different than before. (Display letters). The computer is still going to put one of these letters on the screen at a time, but this time only press the green button to the letter 'X' if the letter 'A' was right before it. So I want you to wait until you see the letters 'A' and then 'X' right after each other in that order, then press the green button all the way down and as fast as you can. Remember to keep your finger on the red area at all other times. Let's try some practice" (begin to present practice letters).

(Again during practice point out any incorrect responses and missed targets. Also remind the subject to stay in the red area as needed).

After practice read aloud the feedback screen output. (If the subject responded to all the 'A-X's and responded no more than 1 time to non-'A-X's begin the task; otherwise repeat the practice. If after 3 practice sessions the subject continues to fail, but appears to understand the test, (e.g., can state the task requirements) continue testing; otherwise discontinue testing.

(After practice). "We are now ready to begin. Remember to press the green button all the way down and as fast as you can, but only after you have seen the letters 'A' and then 'X' in that order. Also remember to try to keep your finger on the red area at all other times. Remember there will be lots of letters so try to keep your eyes on the screen and try not to talk until we are finished. I will answer any further questions then. Are you ready? Then let's begin." (press key to start task).

During the task if the subject obviously is not looking at the screen or is not resting their finger on the red area remind them of this, but only twice. If this continues frequently after the reminders note this. If the child talks during the task instruct him/her to continue playing the game and that you will answer their questions after it is over.

NOTE To interrupt task (EXCEPT WHEN DISK USE LIGHT IS ON) simply turn the computer off. To restart wait several seconds and turn the computer on (data will be lost).

APPENDIX D

CCPT PERFORMANCE FOR 10-YEAR-OLD NORMATIVE GROUP
Means (Standard Deviations)

<table>
<tr><th>Measure</th><th>Gender*</th><th>X-task</th><th>AX-task</th><th>Comb. task</th></tr>
<tr><td>Hits
(n=18)</td><td>Combined</td><td>89.78
(0.43)</td><td>86.72
(3.08)</td><td>176.50
(3.07)</td></tr>
<tr><td>False Alarms
(n=18)</td><td>Combined</td><td>1.44
(2.18)</td><td>1.44
(1.79)</td><td>2.89
(3.36)</td></tr>
<tr><td rowspan="2">Response Time
(n=9,9)</td><td>males</td><td>608.42
(52.85)</td><td>533.79
(104.84)</td><td>571.10
(72.47)</td></tr>
<tr><td>females</td><td>679.04
(84.49)</td><td>584.68
(94.36)</td><td>631.86
(86.69)</td></tr>
<tr><td>Variability
(n=18)</td><td>Combined</td><td>97.14
(28.82)</td><td>127.43
(36.26)</td><td>112.29
(27.50)</td></tr>
<tr><td>Sensitivity
(n=18)</td><td>Combined</td><td>.9970
(.0010)</td><td>.9897
(.0086)</td><td>.9943
(.0045)</td></tr>
<tr><td rowspan="2">Response Bias
(n=9,9)</td><td>males</td><td rowspan="2">.4837
(.3509)</td><td>.7209
(.2236)</td><td>.6280
(.2940)</td></tr>
<tr><td>females</td><td>.7994
(.1231)</td><td>.7267
(.1981)</td></tr>
</table>

*male & female scores are presented separately when significantly different

APPENDIX E

OUTLYING SCORES

Subject#	Age (yrs.)	Gender	Measure	Score
131	7.3	male	AX-False Alarms	70
188	8.9	male	AX-False Alarms	46
189	10.8	male	X-Hits	77

APPENDIX F

INTERCORRELATIONS OF WISC-R SUBTESTS

	Info.	Sim.	Arith.	Digits
Information	1.000	.452*	.402*	.260*
Similarities		1.000	.271*	.170
Arithmetic			1.000	.240*
Digit Span				1.000

*p<.01 on 2-tailed test of significance

APPENDIX G

NORMATIVE DATA ON CCPT X-TASK
Means (Standard Deviations) <medians>

	Age Group				
Measure	6 years (n=24)	7 years (n=27)	8 years (n=19)	9 years (n=31)	10/11 yrs. (n=23)
Hits	84.79	83.44	86.95	88.61	89.56
	(2.92)	(6.10)	(4.30)	(1.82)	(0.90)
	<85.00>	<86.00>	<89.00>	<89.00>	<90.00>
False Alarms	2.42	3.33	2.21	1.81	1.26
	(2.16)	(3.65)	(1.93)	(2.47)	(2.03)
	<2.00>	<2.00>	<2.00>	<1.00>	<0.00>
Response Time (males)	800.17	753.81	700.86	679.08	618.16
	(117.98)	(79.50)	(64.25)	(82.14)	(59.54)
	<782.25>	<771.58>	<690.33>	<665.00>	<597.15>
(females)	852.38	830.90	744.79	662.48	683.13
	(64.72)	(64.12)	(68.16)	(61.76)	(76.82)
	<831.77>	<824.81>	<750.18>	<649.02>	<680.83>
Variability	151.85	152.44	128.23	117.82	100.54
	(24.18)	(29.30)	(25.41)	(27.21)	(27.75)
	<154.36>	<144.67>	<126.96>	<113.03>	<93.52>
Sensitivity	.9841	.9797	.9898	.9944	.9966
	(.0082)	(.0169)	(.0121)	(.0051)	(.0022)
	<.9842>	<.9856>	<.9952>	<.9967>	<.9970>
Response Bias	.7970	.7153	.6108	.6054	.5400
	(.1412)	(.2506)	(.2604)	(.2412)	(.3277)
	<.8023>	<.7758>	<.6972>	<.6975>	<.6975>

NORMATIVE DATA ON CCPT AX-TASK
Means (Standard Deviations) <medians>

	Age Group				
Measure	6 years (n=24)	7 years (n=25)	8 years (n=19)	9 years (n=32)	10/11 yrs. (n=23)
Hits	75.29 (9.46) <78.00>	78.80 (10.57) <83.00>	82.05 (8.19) <84.00>	84.50 (5.63) <86.50>	87.17 (2.90) <88.00>
False Alarms	3.88 (2.86) <5.00>	4.16 (5.45) <3.00>	3.32 (4.19) <1.00>	2.81 (3.66) <1.00>	1.13 (1.69) <1.00>
Response Time (males)	636.02 (88.81) <633.92>	633.17 (126.94) <633.92>	618.60 (92.06) <628.80>	574.84 (92.67) <574.98>	543.89 (99.19) <525.88>
(females)	730.87 (80.94) <730.28>	695.92 (83.86) <674.52>	690.21 (81.16) <691.10>	578.84 (105.18) <525.00>	596.02 (88.43) <570.56>
Variability	185.70 (41.30) <182.06>	177.86 (33.34) <172.40>	170.20 (34.73) <161.51>	154.34 (41.61) <145.59>	124.01 (33.00) <121.11>
Sensitivity	.9562 (.0276) <.9661>	.9661 (.0306) <.9772>	.9756 (.0251) <.9832>	.9827 (.0169) <.9870>	.9910 (.0080) <.9918>
Response Bias (males)	.7395 (.3262) <.8632>	.7311 (.2665) <.8364>	.8083 (.1742) <.8380>	.6844 (.3141) <.8171>	.7167 (.2002) <.6973>
(females)	.9069 (.0543) <.8932>	.8444 (.1270) <.8881>	.8290 (.1438) <.8810>	.7812 (.2070) <.8825>	.8147 (.1128) <.8523>

NORMATIVE DATA ON CCPT COMBINED TASK
Means (Standard Deviations) <medians>

	Age Group				
Measure	6 years (n=24)	7 years (n=25)	8 years (n=19)	9 years (n=31)	10/11 yrs. (n=23)
Hits	160.08	162.16	169.00	173.42	176.74
	(10.74)	(15.14)	(11.86)	(6.66)	(2.85)
	<160.00>	<167.00>	<173.00>	<176.00>	<177.00>
False Alarms	6.29	7.08	5.53	4.36	2.39
	(4.25)	(7.54)	(5.25)	(5.22)	(3.16)
	<7.00>	<5.00>	<4.00>	<2.00>	<1.00>
Response Time (males)	718.10	690.78	659.73	627.37	581.03
	(96.80)	(100.60)	(64.00)	(77.66)	(73.29)
	<703.02>	<711.14>	<669.62>	<629.59>	<567.26>
(females)	791.63	763.41	717.50	620.66	639.58
	(60.81)	(63.90)	(71.55)	(72.03)	(80.21)
	<781.02>	<757.68>	<718.42>	<602.08>	<621.38>
Variability	168.78	164.86	149.21	134.98	112.28
	(24.33)	(26.66)	(24.60)	(29.32)	(24.80)
	<168.12>	<161.67>	<142.44>	<126.62>	<105.98>
Sensitivity	.9704	.9731	.9831	.9896	.9947
	(.0154)	(.0216)	(.0177)	(.0099)	(.0041)
	<.9716>	<.9800>	<.9900>	<.9936>	<.9956>
Response Bias (males)	.7808	.7342	.7592	.6400	.6466
	(.1856)	(.2439)	(.1768)	(.3385)	(.2666)
	<.8501>	<.8130>	<.7869>	<.8250>	<.6993>
(females)	.9111	.8276	.8154	.7846	.7651
	(.0618)	(.1485)	(.1598)	(.2238)	(.1866)
	<.9142>	<.8950>	<.8754>	<.8708>	<.7811>

APPENDIX H

SIGNIFICANT VARIABLES FOR TEACHER RATED GROUPS
Means (Standard Deviations)

	Group			
Variable	Below (n=10)	Average (n=55)	Above (n=50)	Well Above (n=10)
Teacher Conduct z*	.987 (1.808)	-.026 (1.012)	-.194 (.825)	-.388 (.311)
Teacher Hyperactive z*	1.422 (1.399)	.008 (1.306)	.001 (1.140)	-.579 (.275)
Teacher Impulsive z*	1.198 (.839)	-.224 (.658)	-.606 (.439)	-.758 (.359)
Teacher H. Index z*	1.837 (.908)	-.019 (.944)	-.227 (.795)	-.674 (.306)
Parent Learning z*	.590 (.991)	-.068 (1.089	-.661 (.703)	-.510 (.361)
Parent H. Index z*	.039 (.837)	-.317 (1.138)	-.819 (.750)	-.862 (.426)
WISC-R Information	9.80 (3.36)	11.09 (2.21)	12.66 (2.01)	14.10 (2.13)
WISC-R Similarities	11.50 (2.72)	11.89 (3.05)	13.56 (2.64)	14.70 (2.45)
WISC-R Arithmetic	8.80 (2.39)	11.14 (1.93)	11.34 (2.46)	13.30 (2.06)
WISC-R Digits	8.50 (2.84)	10.14 (2.16)	10.48 (2.48)	11.90 (2.88)

*z scores are relative to norms (Goyette et al., 1978)

APPENDIX I

ESTIMATED TEST-RETEST RELIABILITY FOR CLINICAL GROUP

CCPT Measure	X-task	AX-task	Combined
Hits	.980	.972	.988
False Alarms	.998	.997	.998
Response Time	.888	.938	.942
Variability	.881	.861	.841
Sensitivity	.998	.996	.998
Response Bias	.694	.789	.838

APPENDIX J

SELECTED EXAMPLES FROM THE BLISHEN SCALES (males)

Occupation	SES Index	SES Class
Physicians	74.22	6
Lawyers	72.73	6
Biologists	65.78	5
Psychologists	62.26	5
Insurance Salesmen	57.72	4
Foremen: Metal Machining	52.17	4
Mail & Postal Clerks	48.08	3
Receptionists	40.69	3
Plumbers	37.62	2
Bus Drivers	32.23	2
Farmers	23.02	1
Shoe Makers	19.92	1

(from Blishen & McRoberts, 1976)

PUBLICATIONS/PRESENTATIONS:

Blouin, A., Blouin, J., Perez, E., Barlow, J., & Seidel, W.T. (1986). Validity of DSM-III criteria for bulimia. paper presented at the Second International Conference on Eating Disorders, New York, NY.

Blouin, J., Blouin, A., Perez, E., Seidel, W.T., & Bushnik, T. (1986). Family history factors in bulimia. paper presented at the Second International Conference on Eating Disorders, New York, NY.

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Coleman, D., Epstein, L.H., & Seidel, W.T. (1979, October). EMG discrimination using a magnitude production procedure. paper presented at the meeting of the Society for Psychophysiological Research, Cincinnati, OH.

Conners, C.K., Blouin, A.G., & Seidel, W.T. (1982, October). The effect of breakfast on the cardiac response and behavior of children. paper presented at the meeting of the Society for Psychophysiological Research, Minneapolis, MI.

Seidel, W.T., & Corcoran, M.E. (1986). Relations between amygdaloid and anterior neocortical kindling. Brain Research, 385, 375-378.

VITA

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Summa cum laude, 1980

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Sara Spencer Foundation Research Award, 1988