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SUSTAINED ATTENTION IN HYPERACTIVE CHILDREN

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ABSTRACT

The ability of the hyperactive child to maintain attention on three tasks was examined. One of the tasks, a Choice Reaction Time Task, measured attention for brief periods, while the other two measured sustained attention. Of the latter two, one was an experimenter-paced task(the Continuous Performance Test) and the other a self-paced task(the Serial Reaction Task).

It was found that the hyperactive children were no different from the normal controls in their ability to direct their attention for brief periods. They were however, significantly inferior to the controls in their ability to sustain attention, particularly on the experimenter-paced task. The effect of the stimulant drug methylphenidate was evaluated and found to be effective in improving performance on all three tests. Implications of these findings for the education of hyperactive children were discussed.

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by

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PREFACE

It has often been observed in the clinical literature that a major characteristic of children labeled "hyperactive" is their short attention span. However, to date no attempt has been made to examine in detail the nature of the attentional deficit in these children. Clinical observation suggests that the ability of hyperac-tive children to attend for brief periods is not impaired. However, the maintenance of attention to tasks over longer periods of time appears to be one of their major problems.

The present dissertation therefore compared the performance of hyperactive children with that of normal children on three tests of attention. One of the tests required that the children attend for brief periods. The other two tests required the children to attend for longer periods. Of these latter two tests, one was self-paced, that is the child could respond when he wanted,and the other was experimenter-paced or controlled. The latter type of task has been found with normal adults to be more sensitive to impairments in attention than are self-paced tasks. It was predicted that the performance of hyperactive children would be inferior to that of control children on the self-paced, and especially on the experimenter-paced task.

The present study also examined the effects of the stimulant drug, methylphenidate on the performance of hyperactive children on these three attention tasks.

CHAPTER 1

INTRODUCTION

There is comparatively little objective information available concerning either the functioning of hyperactive children or the effects of the various pharmacological agents commonly used in the treatment of these children. The available literature is mainly restricted to uncontrolled clinical evaluations. Several years ago a research project was started at the Montreal Children's Hospital which involved gathering empirical data related to both the functioning of hyperactive children and the effects of the various medications commonly used in their treatment. The present thesis was but one part of this larger study. Its purpose was to examine an area of behaviour which has repeatedly been reported in the clinical literature to be deficient in hyperactive children, namely attention. A secondary purpose was to examine the effect of the stimulant drug methylphenidate (Ritalin) on this behaviour.

Hyperactivity in Children

The definition and measurement of general activity level is complex, particularly so in humans. There does not appear to be one uniform level of activity which could be used to characterize an individual. Rather many levels have been isolated which correspond to the different behaviours measured (Cromwell, Baumeister and Hawkins, 1963). Furthermore, there is little agreement on whether activity level, defined as the amount and vigour of body movement, is a constant or a fluctuating personality characteristic. Some investigators have suggested that it is a stable characteristic of the individual from infancy through at least early adulthood (Fries and Woolf, 1953; Fries, 1954). Others have found no evidence for such constancy (Escalona and

Heider,1959; Thomas,Birch,Chess,Hertzig and Korn, 1963). In spite of all the problems with activity level as a psychological construct, it is generally agreed that activity level may significantly affect the course of behavioural development in children(Escalona,1968).

Children are often described as overactive, particularly by parents and teachers. Lapouse and Monk(1958) estimated that some fifty percent of all children between the ages of six and twelve are described by their mother as overactive. Stewart,Pitts,Craig and Dieruf(1966) estimated that four percent of all school age children show an excessive level of activity sufficiently sustained such that it is a serious source of complaint. These children have been labeled "hyperactive" by clinicians. Hyperactivity was found to be the most common referral problem in four child guidance clinics (Patterson, Jones,Whittier and Wright,1965) and it has been estimated that forty percent of all children referred to mental health clinics show what is called the "hyperactive syndrome" (Rogers,Lilienfeld and Pasamanick,1955).

Given the problems surrounding the definition of activity level, it is by no means surprising to find that there is little agreement on the definition of hyperactivity. For some investigators it implies a greater quantity of movement(Schulman,Kaspar and Throne,1965), but this has been questioned by others (Werry and Sprague,1969).
It has been suggested that the "overactivity" of the "hyperactive child" may be a reflection of the short attention span and rapidly changing goal direction of such children(Cromwell,Baumeister and Hawkins, 1963). Thus these investigators argue that the hyperactive child may be thought of as a child whose behaviour is "fragmented" or disorganized and continually changing in direction, such that an impression of a high level of activity is created. Whether

hyperactive children differ from normal children in the quantity or in the quality of their activity is a question which must await further advances in our understanding and measurement of activity.

Hyperactivity has often been observed in children with psychoses (Freedman, Effron and Bender, 1955; Fish, 1960), mental retardation (Levy and Perry, 1949; Bair and Herold, 1955; Carter and Maley, 1957; Tischler, Gibson, McGeer and Nuttall, 1961) and epilepsy (Bradley,1950; Ounsted, 1955). However, it is with the group of hyperactive children of normal intelligence who have none of these pathologies that the present thesis is concerned. There is some evidence that these children differ from normal children on several characteristics. Such children are said to be continually in motion, unable to concentrate, clumsy and impulsive.

Statements concerning the quantity of motion usually come from parents and teachers who complain that the child cannot sit still and is always on the move. Hyperactive children have been found to be reliably differentiated from control children with respect to such classroom behaviours as " purposive behaviour that is not classroom activity" and " disorderly behaviour toward the teacher" (Douglas, Weiss and Minde, 1969). Using as a measure of restlessness a stabilimetric cushion similar to that used by Sprague and Toppe (1966), Sykes, Douglas, Weiss and Minde(unpublished study) found hyperactive children to be significantly more restless than control children during testing on an attention task. Moreover, while both groups of children showed a significant increase in restlessness with time on the task, the increase was greater in the case of the hyperactive children.

Evidence for a short attention span and poor concentration in these children was found by Sykes, Douglas, Weiss and Minde (unpublished study). These investigators found that on a test requiring sustained attention, namely the Continuous Performance Test (Rosvold, Mirsky, Sarason, Bransome and Beck, 1956), hyperactive children detected significantly fewer signals than the control children.

On tests of motor development involving both gross and fine motor coordination, hyperactive children were found to be significantly retarded compared to their normal age mates (Douglas, Weiss and Minde, 1969). It is possible however, that part of their poor motor performance may be due to their impulsivity. Conners and Greenfeld (1966) found them to have less inhibitory control over a voluntary startle response than did a group of neurotic children. Campbell, Douglas and Morgenstern (1969) also found that hyperactive children were more likely to respond impulsively than normal children on a task which required the abstraction of a simple figure from a complex one.

Thus, there is now some objective evidence for earlier clinical statements which described hyperactive children as restless, inattentive, clumsy and impulsive. Certain other clinical statements made about these children, however, have less clear-cut and objective evidence to support them. These latter statements are concerned with the intellectual status of such children and the "organic" aetiology of hyperactivity.

That hyperactive children may have certain intellectual deficits is suggested by several studies which found that these children often do poorly academically. For example, in a follow-up study of 64 hyperactive children first seen five years earlier, Weiss, Minde, Douglas, Werry and Nemeth (1969) found that 70 percent of the hyperactive children as compared with only 15 percent of the control children had failed at least one grade. Thirty five percent of them had failed two or more grades. Burks (1960) also found hyperactive children to be an average of one grade level behind their age mates.

It is tempting to attribute the poor academic performance of hyperactive children to an intellectual deficit. Yet to date there is little evidence to support such an hypothesis. There can be no doubt that certain hyperactive children have specific cognitive and learning deficits. Any large sample of children selected randomly from the school population will contain a number of such children. The question is whether a sample of hyperactive children have a higher incidence of such deficits than a randomly selected sample of normal children. Douglas, Weiss and Minde (1969) did find some evidence for cognitive impairment when they gave hyperactive and normal children a battery of tests commonly used in the assessment of learning disabilities. Out of a total of 48 comparisons on the various tests and subtests, the hyperactive children were significantly inferior to the normal control children on seven of them. These seven tests were: the Lincoln-Oseretsky Motor Development Scale, the Goodenough Draw-a-Man Test, the Bender-Gestalt Visual Motor Test, the Eye-Motor Coordination subtest and the Total Score of the Frostig Developmental Test of Visual Perception, and the Auditory Decoding and Auditory-Vocal Automatic subtests of the Illinois Test of Psycholinguistic Abilities. These findings suggest that hyperactive children have problems in the areas of visual-motor performance and motor coordination. However, it is notable that the hyperactive children showed no impairment on the remaining 41 comparisons. Freibergs and Douglas (1969) have also found no difference between the performance of hyperactive and normal children on a concept attainment task under continuous reinforcement. The hyperactive children were, however, significantly inferior to the control children on the same task under partial reinforcement. In view of the findings of Freibergs and Douglas (1969) and Douglas, Weiss and Minde (1969), it seems more plausible that motivational or attentional difficulties, rather than cognitive difficulties alone, may be responsible for the poor academic performance of hyperactive children. Furthermore, as Levy(1959) and Freibergs(1965) have suggested, the poor academic performance of these children may also be due to their restlessness as well as their inattentiveness during formal teaching. It was the purpose of the present thesis to examine systematically one of these hypotheses, namely that hyperactive children differ from normal children in ability to keep their attention on a task over a long period.

Just as there is little evidence for an intellectual deficit in these children, there is also little support for the hypothesis of organic impairment. Although the majority of psychiatric reports on hyperactive children have offered an organic explanation of hyperactivity (Knobel,Wolman and Mason, 1959; Clements and Peters,1962; Clements,1966), evidence for gross brain damage in these children has not yet been found. Consequently the term "minimal cerebral dysfunction" (MacKeith and Pax, 1963) has been advanced to describe them. This term is meant to imply that the biological dysfunction or "damage", if any, is of a minimal or obscure nature; for example, some sort of biochemical irregularity or pre- or para-natal brain insult.

In an attempt to investigate the hypothesis of organic impairment, hyperactive and normal children have been compared with respect to their neurological and electroencephalographic status and the incidence in their life histories of pre- and para-natal factors thought to be associated with damage. The evidence for neurological impairment is sparse. No differences in neurological status were found between a control group and a mixed group of children with behaviour disorders, hyperactivity and learning problems (Stevens, Sachdev and Milstein, 1968). Out of a total of 140 neurological signs, hyperactive children were found to be inferior to control children on only seven items (Werry, Weiss, Dogan, Minde and Douglas, 1969). All seven signs were minor or "soft" signs and six of them were related to motor coordination.

Various investigators have found an incidence of abnormal EEGs ranging from 35 to 50 percent in hyperactive children and in mixed groups of hyperactive and behaviour problem children (Werry, Weiss and Douglas, 1964; Werry, Weiss, Dogan, Minde and Douglas, 1969; Stevens, Sachdev and Milstein, 1968). These studies have, however, differed with respect to the incidence of abnormal EEGs found in their normal control groups such that it is difficult to draw conclusions concerning the EEG status of hyperactive children relative to normal children. For example, the Stevens et al. study and the studies referred to in their article found an incidence of EEG abnormalities ranging from 7 to 19 percent in their control samples. The Werry et al. studies, on the other hand, found the incidence of EEG abnormality in control children to be similar to that of the hyperactive children, namely between 35 and 50 percent. It is possible that the different procedures used by these investigators in selecting their control subjects may account for their different results. In the studies by Werry et al. the EEG records of normal children who had received an EEG examination on admission to hospital for medical reasons were used. In contrast, the Stevens et al. control group was selected directly from the normal school population.

There is also no strong evidence for a higher incidence, in hyperactive than in normal children, of pre- and para-natal factors thought to be associated with damage. No differences were found between hyperactive and control children when mothers were questioned about complications of pregnancy, delivery and post-natal development (Werry, Weiss and Douglas, 1964; Stevens, Sachdev and Milstein, 1968). Using hospital records rather than mothers' reports, Minde, Webb and Sykes (1968) also concluded that there was little evidence for the hypothesis that chronic hyperactivity was the result of complications of pregnancy and delivery.

Thus, the evidence for central nervous system damage or dysfunction derived from neurological, EEG and birth data is insufficient to warrant any firm conclusions concerning the organic aetiology of hyperactivity. The studies which support this view generally depend for their evidence on minor or "soft" signs, the significance of which is unclear and contentious at the present time. The only reasonably direct evidence for central nervous system dysfunction in hyperactive children was provided by Laufer, Denhoff and Solomons (1957). These investigators found that the photo-metrazol threshold of these children was significantly lower than that of non-hyperactive children. On the basis of Gastaut's (1950) suggestion that an abnormally low photo-metrazol threshold is indicative of diencephalic dysfunction, Laufer et al. hypothesized that the dysfunction of hyperactive children may lie in the diencephalon. However, the study of Laufer et al. has never been replicated. Consequently further data must be collected before any definite statements can be made concerning either the existence or the nature of the dysfunction in hyperactive children.

Effects of Drugs on Hyperactive Children.

In the treatment of hyperactivity in children, pharmacology has assumed the major role, although behaviour modification techniques have been used with some success (Patterson, 1964; Patterson, Jones, Whittier and Wright, 1965; Doubros and Daniels, 1966). A number of authors have suggested that the stimulant drugs, particularly the amphetamines and methylphenidate, are the most useful in the treatment of hyperactivity (Laufer and Denhoff, 1957; Weiss, Werry, Minde, Douglas and Sykes, 1969; Weiss, Minde, Douglas, Werry and Sykes, 1969; Millichap and Fowler, 1967).

The amphetamines have produced several kinds of changes in hyperactive children. Laufer, Denhoff and Solomons (1957) found that the abnormally low photo-metrazol threshold of their group of hyperactive children was returned to a normal level by the drug amphetamine. Other studies have demonstrated a beneficial effect at the behavioural level from the amphetamines, particularly with dextro-amphetamine sulphate. Dextro-amphetamine has been found to reduce motor restlessness in hyperactive children as measured by a stabilimetric cushion (Sprague, Werry and Scott, 1967) or by behavioural ratings (Zrull, Westman, Arthur and Rice, 1964; Weiss, Werry, Minde, Douglas and Sykes,1969; Conners and Rothschild, 1968). Hyperactive children have also been found to make fewer impulsive errors (Eisenberg, Conners and Lawrence, 1965; Epstein, Lasagna, Conners and Rodriguez, 1968; Connors and Rothschild,1968), to be less distractible (Weiss, Werry, Minde, Douglas and Sykes, 1969), and to make fewer errors on a discrimination task (Eisenberg, Conners and Lawrence, 1965; Conners, 1966) when treated with dextro-amphetamine.

The effect of dextro-amphetamine on more complex functions which involve higher processes such as learning and intellectual performance is unclear. In a review of the amphetamines, Freeman (1966) came to the conclusion that it is not yet possible to state with any certainty what effect these drugs have on learning in children. Dextro-amphetamine was found to have no effect on the memory and complex task performance of a group of children with learning disabilities and school behaviour problems (Conners, Eisenberg and Barcai, 1967). Nor have reliable changes been produced with this drug on a battery of cognitive tests given to hyperactive children (Weiss,Werry, Minde, Douglas and Sykes, 1969; Millichap and Fowler, 1967).

Related to the amphetamines is the stimulant drug methylphenidate (Ritalin). It is the effect of this drug on the sustained attention of hyperactive children that is examined in this thesis.

Methylphenidate.

Methylphenidate is chemically related to the amphetamines (Jacobson, 1960). Both the amphetamines and methylphenidate are classed as central nervous system stimulants (A.M.A., 1958). Methylphenidate, however, is regarded as a mild cortical stimulant somewhere between caffeine and the amphetamines with respect to action (Drill, 1958). It is said to have few peripheral vascular or sympathetic effects (Lytton and Knobel, 1959; Jacobson, 1960) and no pulse and heart rate effects (Carter and Maley, 1957). This latter statement is questionable since Knights and Hinton (1969) and Cohen, Douglas and Morgenstern (1969) found significant increases in the heart rate of hyperactive children who were given methylphenidate. Little is known as yet about the specific mode of action of methylphenidate for it was synthesized as recently as 1954 (Meier, Gross and Tripod, 1954). However, insofar as it is chemically related to the amphetamines it is possible that its mode of action is similar to theirs.

While the precise mode of action of the amphetamines is also largely unknown, there is some suggestive evidence. A recent study by Carr and Moore (1969) found that dextro-amphetamine released norepinephrine in the brain of cats in vivo. How the norepinephrine was released is uncertain. The drug may either release the chemical from the nerve terminal or it may act by blocking the reuptake of the chemical. Furthermore, the authors point out that the released norepinephrine may not arise solely from neurons containing the catecholamines, for norepinephrine is probably taken up by other structures as well. Stein and Wise (1969) also found amphetamine released norepinephrine in the brain. Their findings suggest that amphetamine may have a regional specificity. They found that while amphetamine increased the concentration of norepinephrine in the amygdala it did not do so in the hypothalamus. Both Carr and Moore (1969) and Stein and Wise (1969) believe that the release of norepinephrine by the amphetamines was a true physiological effect and not merely an artifact of the methods used.

A further question arises as to whether norepinephrine acts as a transmitter substance in the brain. Stein and Wise (1969) and Wise and Stein (1969) suggest that norepinephrine is a central transmitter despite the lack of conclusive evidence. They found that self-stimulation in the medial forebrain bundle released norepinephrine. Also the systemic administration of norepinephrine facilitated self-stimulation when there was reason to believe that the functional reservoir of norepinephrine was depleted. It is concluded, with due caution, that the stimulating effects of the amphetamines may be mediated by increasing the concentration of norepinephrine available for transmission.

To return to methylphenidate, the most obvious behavioural effect of this drug on animals is to increase general activity level. This finding has been replicated with a variety of measures including direct observation of the animal's activity (Bindra and Baron, 1959; Mendelson and Bindra, 1962; Bindra and Auchel, 1963), the tilt cage (Fregly and Black, 1964), the spring cage (Kabara and Riegel, 1965), photoelectric cells (Millichap and Boldrey, 1967) and the locomotor wheel and Y maze (Marriott, 1968). Methylphenidate has been found to increase operant responding with schedules of reinforcement that produce low levels of response and to decrease response rate under schedules that lead to high rates of response (Stretch and Dalrymple, 1968).

The effect of methylphenidate on the avoidance responses of rats depends upon the nature of the avoidance response specified by the investigator (Thompson and Shuster, 1968). When the required avoidance response was immobility, methylphenidate reduced avoidance behaviour by increasing activity (Bindra and Auchel, 1963). When the avoidance behaviour was an active response then avoidance was facilitated by methylphenidate (Stretch, Blackman and Alexander, 1966; Stretch and Skinner, 1967).

It might be speculated that the drug-induced changes mentioned above were the result of an increased sensitivity to environmental stimuli. Mendelson and Bindra (1962) noted that the increase in general activity with methylphenidate was reflected mainly in the repeated sniffing of the apparatus by the animals. This interpretation has also been offered by Plotnikoff and Fitzloff (1963).

Whereas methylphenidate has been reported to increase activity level in rats, it apparently has the opposite effect in hyperactive children. Activity as measured by a parental rating scale was reduced in hyperactive children (Weiss, Minde, Douglas, Werry and Sykes, 1969; Knights and Hinton, 1969). The drug also reduced motor restlessness while the child was seated (Sprague,Barnes and Werry, 1968). Methylphenidate is also reported to have produced a non-significant reduction in activity as measured by an actometer strapped to the wrist, in children with hyperactivity and learning problems (Millichap, Aymat, Sturgis, Larsen and Egan, 1968). The authors suggested that if the recording time had been longer, the reduction in activity might have reached significance.

Methylphenidate has also reduced troublesome social behaviours (Conners and Eisenberg, 1963; Sprague, Barnes and Werry, 1968), improved attention to class work and teacher-pupil contacts (Sprague, Barnes and Werry, 1968) and increased verbal productivity (Creager and Van Riper, 1967). Also,impulsivity has been reduced (Conners, Eisenberg and Sharpe, 1964; Eisenberg, Conners and Lawrence, 1965; Campbell, Douglas and Morgenstern, 1969; Sykes, Douglas, Weiss and Minde, unpublished study) and attention to tasks increased (Knights and Hinton, 1969; Sykes, Douglas, Weiss and Minde, unpublished study).

The effect of methylphenidate on more complex behaviours is not so clear. No effect was found on the performance of emotionally disturbed children on a paired-associate learning task (Conners, Eisenberg and Sharpe,1964). However, on a one-trial learning task with hyperactive, emotionally disturbed boys, there was a significant reduction in both errors and response latencies with the drug (Sprague, Barnes and Werry, 1968). On the Wechsler Intelligence Scale for Children, Douglas, Weiss and Minde (1969) found that the Full Scale, Verbal Scale and the Similarities subtest were improved in hyperactive children with the drug. In contrast, Knights and Hinton (1969) found a drug effect on the Performance Scale and the Coding, Picture Completion and Block Design subtests in a similar group of children.

To summarize, it is thought that methylphenidate may act by enhancing inhibitory controlling mechanisms or by exerting a general alerting effect (laufer, Denhoff and Solomons, 1957; Conners, Eisenberg and Sharpe, 1964). Behaviourally, methylphenidate has been found to reduce motor restlessness, impulsivity and troublesome social behaviours in hyperactive children. No conclusions can be drawn at the present time with respect to its action on higher processes such as learning and intellectual abilities.

Given the many different aspects of behaviour affected by the drug, it is possible that the effect of methylphenidate may be to improve the general ability of hyperactive children to maintain attention to task-relevant material rather than to improve their performance in specific cognitive areas. For this reason, one of the interests of the present thesis was to examine the effect of methylphenidate on a variety of tests of attention.

Attention

The majority of behaviours investigated by psychologists involve attention to some degree. Certainly attention has been a topic of perennial interest in psychology. However, as Treisman (1964) points out, the earlier investigations of attention which used the introspective or subjective method were largely unsuccessful. It was not until recent years, with the emphasis on man as an information-handling system, that substantial progress in the understanding of attentive phenomena was made. This increasing interest in the study of attention has led to investigations not only of its neural substrates but also of its behavioral aspects. Investigators are now placing increasing emphasis on the role of attention in the development of infants and young children (Flavell and Hill, 1969), in the pathogenesis of mental retardation (Zeaman and House,1963) and in cognitive development (Jeffrey, 1968; Fellows, 1968). The field of attention is rapidly expanding and the amount of literature is already considerable. The present author is therefore highly selective in the material presented in this brief review, the main focus of which concerns the factors involved in sustained attention.

The model of attention used in the present study is the one proposed by Broadbent (1958). Basically Broadbent's main point is that since an individual has a limited capacity to process information, there must be some selection from among competing stimuli. Broadbent conceptualizes this selection process in terms of the screening of incoming material by a filter. Certain material is passed by the filter into a limited-capacity channel and up to higher centres , while other material is either excluded by the filter, or re-routed to a short-term memory store where it can be held for a brief period of time. Thus selection in Broadbent's model is on the input or sensory side. Other investigators have questioned whether material is indeed excluded or blocked by such a filter. Treisman (1960) suggests that rather than blocking material, the filter may attenuate or lessen the influence of the meaning of competing messages. In other words, the informational content of competing messages may not be immediately excluded but may rather be subjected to a hierarchy of tests. For example, importance to the individual might be one of the factors determining whether the informational content of the competing message is perceived.

Other modifications of Broadbent's model of attention have been proposed by Neisser (1967) and Norman (1969). Such modifications tend to be concerned with whether the unattended stimulus is blocked by the filter (Broadbent), not analysed or synthesized (Neisser), or attenuated at some higher level (Norman). Nevertheless, despite their differences all of these investigators agree that when attention is paid to one stimulus source, the individual is not usually aware of the nature or the content of the stimulus from an unattended source. All agree that the ability to divide attention, that is the ability to attend to two or more things at the same time is quite limited. Only when the informational content of the two messages is quite low can individuals attend to them both at the same time.

Usually however, rather than attending to one source alone and ignoring the other(s), people tend to switch from one source to another very rapidly. Such switching may occur not only "voluntarily" but also "involuntarily". It is a common experience for people to be "distracted" by passing sights, sounds and irrelevant thoughts. To quote Neisser (1967):

> "In waking life also, a hundred or a thousand "thoughts" appear briefly and are gone again even when we are primarily engaged in purposeful activity. The extent to which these fleeting thoughts are developed, and are permitted to interrupt the main direction of mental activity, varies from person to person and from time to time. For the most part, they are immediately forgotten, like the

> dreams they so strongly resemble. Occasionally they interrupt ongoing activity, and we recognize a "mental block", a "lapse of attention", or a "Freudian slip". (p.298).

Both characteristics of the individual and of the task itself have been found to be related to the frequency of such lapses and to the length of time attention can be maintained on a task. Neisser (1967) notes that there are individual differences in the degree to which fleeting thoughts interrupt a subject's ongoing mental activity or sustained attention. Lewis, Bartels, Campbell and Goldberg (1967) present evidence which suggests that such individual differences in ability to sustain attention may be present in the first year of life and may be related to the neurological condition of infants at birth. More specifically, these investigators found that infants with scores of seven, eight or nine on the Apgar scale, which rates an infant's neurological condition at birth, had significantly shorter fixation times to various task stimuli during the first year of life than did infants with high scores of 10 (perfect condition). The stimuli used were a matrix of moving lights and a film-strip of face-like figures. Ability to maintain attention and to exclude task-irrelevant stimuli has also been found to improve with age, at least from infancy to early adulthood (Grim, 1967; Elliot, 1964,1966; Maccoby and Konrad, 1967; Hagen and Sabo, 1967).

As for task variables, efficiency of attention has been found to be related to both the length and the pace of the task. Broadbent explains lapses in attention, or mental blocks which occur with time on the task, in terms of novelty. By novelty he means not merely the unusual event, the loud noise, the sudden movement, etc., but also material which has not recently been passed through the filter as compared to material that has just been processed. In Broadbent's terms, mental blocks or lapses in attention occur as a result of the filter switching momentarily from one class of events to another containing more novel information. Such momentary lapses in attention have been found to increase with time on the task (Broadbent, 1958).

The importance of novelty in determining both the focus and duration of children's attention and their reaction times to stimuli has been demonstrated by Endsley (1967), Lewis, Goldberg and Rausch (1967) and Witte and Cantor (1967). Briefly, Endsley (1967) found that the more exposure pre-school children had to familiar toys the more likely they were to select new or novel ones, while Lewis et al. (1967) found that familiar toys regained their interest for the children after they had repeatedly been exposed to the new ones. Witte and Cantor (1967), furthermore, found that children's lever pulling responses were faster to novel than to familiar stimuli. That novelty is an important factor in determining both the direction and duration of attention is well documented (Berlyne, 1958; Fantz, 1964).

The pace, as well as the duration of the task, has been found to influence the efficiency of sustained attention. Many tasks do not require that an individual maintain his attention to them continually until they are completed, but rather permit the individual to take "time-out" for short periods and then return and take it up again where he left off. For example, an individual when reading can stop for a moment and go for a drink or talk to somebody and then return to his reading. Activities such as these do not necessarily show any decline in efficiency even though the individual may continue them for many hours. In contrast, certain other simple tasks may show an impairment in efficiency with time spent on the task. An example of such a task is one which requires the individual to monitor a screen and report the occurrence of events or signals that appear at uncertain intervals. In this type of vigilance task, the detection of signals invariably declines over time. Broadbent (1958) has labeled the former type of task "self-paced" and the latter "experimenter-paced". The main difference between these two types of task is that on the experimenter-paced task the individual cannot regulate the appearance of the signals and thus control for his fluctuating attention as he can in the self-paced task. If the signal is of short duration and if it is coincident with a brief lapse in the attention of the observer, then the signal will not be reported. If however, the observer is allowed a brief rest from the task, or if the monotony of the task is reduced by a telephone call from the experimenter, then the decline in the detection of signals can either be stopped or reduced (Mackworth, 1968).

Several factors have been found to influence the efficiency of attention on experimenter-paced or vigilance tasks. In the usual vigilance task, signals have to be detected against a background of non-signal events. Detection rate has been found to depend both on the background event rate (Mackworth, 1968) and the expectancy of the observer concerning the probability of signals (Colquhoun and Baddeley, 1967). Furthermore, the length of time on the task is also related to efficiency of detection and number of false alarms (when a non-signal event is reported as a signal). Jerison (1967) has suggested that both the detection and false alarm rate might be explained in terms of changes in both the type and frequency of observing responses.

According to Jerison, Pickett and Stenson (1965), observing responses may be divided into three types, alert, blurred and distracted. In the blurred condition there will be a decrease in sensitivity, that is a change in the ability to distinguish between signal and non-signal events. In the distracted condition the observer will not actually observe the signal or, as several investigators have found, the signal may be fixated without being seen by the observer (Baker, 1960;

Mackworth, Kaplan and Metlay, 1964; Schroeder and Holland, 1968). Schroeder and Holland (1968) report that the slower the signal rate and the longer the time on the task, the greater the incidence of these "blind spots".

Mackworth (1968) has speculated about the physiological mechanisms underlying the decline in performance on vigilance tasks. Briefly, she suggests that there are two neural mechanisms involved. One is the arousal response or alpha block and the other the evoked potentials produced by the background or non-signal events. She suggest that habituation of the arousal response will decrease sensitivity or the ability to distinguish between signal and non-signal events, whereas habituation of the evoked potentials will result in a decrease in the number of detections and false alarms.

In the present investigation, the model of attention adopted was that of Broadbent. To summarize, Broadbent suggests that because man has a limited capacity to process information there must be selection. The ability to pay attention to a certain class of stimuli for any length of time is limited, since attention fluctuates. There are individual differences with respect to this ability which may be related to both birth conditions and genetic factors. Age is another factor which influences the ability to maintain attention. Momentary lapses of attention to the task at hand are thought to be the result of a switch of attention from task-relevant to task-irrelevant stimuli. As time on the task increases, the frequency of such switches increases. Certain types of task are more sensitive than others to such fluctuations in attention. More specifically, a self-paced task, that is one where the individual can regulate the flow of information to correspond with his fluctuating attention, does not necessarily show any impairment with time. On the other hand, an experimenter-paced task, or one in which important information arrives at unpredictable times, is more susceptible to fluctuations in attention.

In the light of the above, the present author selected certain tests which would measure different aspects of attention in hyperactive children. It was predicted that hyperactive children would have no problem in directing their attention for brief periods of time but that they would have difficulty in maintaining attention for longer periods. It was also expected that they would have less difficulty with a self-paced than with an experimenter-paced task. Consequently three tasks were selected to measure different aspects of attention, namely the Choice Reaction Time Task, the Serial Reaction Task and the Continuous Performance Test.

Choice Reaction Time Task.

The Choice Reaction Time Task was chosen to measure the ability of hyperactive children to attend for brief periods. Basically, reaction time tasks measure the length of time required for a subject to respond to a stimulus after he has been warned in some way that it will appear. Thus the period of attention required is very brief, namely from the time the subject is told to pay attention until the stimulus appears. Tasks involving a number of such trials are usually referred to as "simple" reaction time tasks.

The task can be made more complex by increasing the number of stimuli to which the subject has to react. In this type of task, usually referred to as "choice" reaction time, the subject is required to make a particular response to each of the several stimuli as they appear. This situation makes it possible to examine the effect on reaction time of increasing the number of relevant stimuli and their appropriate responses, as well as the effect of introducing additional "irrelevant" or distracting dimensions into the stimuli.

Reaction time has been found to vary with the age of the child (Luria, 1932; Hohle, 1967; Elliot, 1964,1966; Grim, 1967), the number of responses or "choices" available (Hohle, 1967; Smith, 1968) and the length and regularity of the interval between the warning and the onset of the stimulus (i.e., preparatory interval) (Hohle, 1967).

Several investigators have conducted studies designed to show that the improvement found on these tasks with increasing age is the result of improved attention and not of other factors such as improved motor coordination or motivation (Slater-Hammel, 1953; Henry, 1952, as cited by Hohle, 1967; Elliot, 1964).

It seemed reasonable to hypothesize in the present study that hyperactive children would be no different from normal children in their ability to pay attention for brief periods of time on a choice reaction time task when they were continually oriented to the task by the experimenter. This hypothesis was based on clinical observation of the behaviour of hyperactive children while they were performing on cognitive tests (Douglas, Weiss and Minde, 1969). In this one-to-one situation, where they were continually oriented to the test items and allowed frequent breaks by the examiner, hyperactive children could do as well as normal children on most of these tests. In other words, their attention for short periods did not appear to be impaired. Consequently, their reaction times to stimuli which appeared after brief intervals were not expected to differ from those of normal children.

The task used also made it possible to break down the reaction times into two components and compare them in hyperactive and normal children. The first component labeled "simple" reaction time was the length of time the subjects took to note the onset of the stimulus and to lift their finger off the button. The second component or "choice" reaction time involved the length of time from the appearance of the stimulus and the recognition of its identity to the selection and implementation of the correct response. Division of reaction time into these two components made it possible to determine whether hyperactive and normal children differed with respect to (a) stimulus onset reaction time and (b) choice reaction time.

The reaction times of hyperactive and normal children were compared in the present study under three conditions, namely when (a) two stimuli, (b) four stimuli and (c) four stimuli with an irrelevant dimension were presented. These conditions were chosen in order to determine whether an increase in the amount of relevant or irrelevant information to be processed would have differential effects on the reaction times of hyperactive and normal children.

Serial Reaction Task.

The Serial Reaction Task (S.R.T.) was chosen to measure the ability of hyperactive children to sustain attention over a prolonged period of time on a task which was essentially self-paced. The S.R.T. consists of a series of lights which are arranged in a horizontal row with a response button directly underneath each. The subject is required to extinguish the lights as they appear by pressing the button corresponding to the light. As one light is turned off, another immediately comes on. Thus the task requires continuous work but the subject is able to work at his own pace, although he is usually instructed to work as quickly as he can.

It is generally found that when the task lasts for ten minutes or more, there is a decline during the first five minutes in the number of correct responses made, and an increase in the incidence of incorrect responses. An incorrect response is one where the subject presses a button corresponding to a light that is not on. After the initial decline there is usually a stable rate of responding for the remaining five minutes (Herrington, 1967). Furthermore, the rate of responding is not regular but is punctuated by discrete gaps otherwise known as "blocks" (Bills, 1931,1964) or "involuntary rest pauses" (Herrington, 1967). Bills (1931) was one of the first to investigate such "blocks" in continuous work. The tasks he used were alternate addition and subtraction, reversible perspective, colour naming, opposites and substitutions. His description of blocks is worth quoting.

> "(1) In mental work involving considerable homogeneity and continuity there occur, with almost rhythmic regularity, blocks or pauses during which no response occurs. These blocks occupy the time of from 2-6 responses. They have an average frequency of about three per minute, although individuals differ in this respect. (2) Practice tends to reduce the frequency and size of the blocks. (3) Fatigue tends to increase the frequency and size of the blocks, producing a greater irregularity in the flow of responses without reducing the actual number of responses per minute to any extent, over periods up to one hour. (4) The responses between the blocks tend to bunch toward the center, so that a regular wave-like effect of rarefaction and condensation, alternating, is produced.....Fatigue tends exaggerate the bunching. (5) Individuals who respond rapidly tend to have less and shorter blocks than slow individuals. (6) There is a consistent tendency for errors to occur in conjunction with blocks, suggesting that the cause of errors lies in the recurrent low condition of neural functioning which the blocks reveal". (Bills,1931, pp. 243-244).

A number of authors (e.g., Herrington, 1967; Claridge, 1967) have interpreted performance on the S.R.T. in terms of Eysenck's theory (Eysenck, 1962). Briefly, the theory states that the initial level of performance on the task, or more specifically the rate of correct responding during the first minute or two, indicates the level of positive drive. The decline seen in the rate of correct responding is said to be a measure of the accumulation of reactive inhibition which causes both the involuntary rest pauses and the errors. The brief pause dissipates the reactive inhibition so that responding can continue until the accumulation of reactive inhibition again produces a pause. Reduction of reactive inhibition during the pauses is said to reinforce the occurrence of the rest pauses such that a conditioned association is formed. Thus, the incidence of rest pauses and errors is thought to be a function of both reactive and conditioned inhibition (Herrington, 1967).

Broadbent (1958) has discussed the S.R.T. in terms of his filter model and has criticized the "reactive inhibition" explanation. If reactive inhibition is understood to mean inhibition of motor responding with repetition of the same response, then such an explanation could not account for many of the findings obtained when subjects are given continuous work. For example, Broadbent noted that it was difficult to produce a decrement in performance on a task which required merely muscular effort unless that muscular effort was very great, for example, lifting heavy objects as against a simple finger movement. Furthermore, Broadbent pointed out that an error on the S.R.T. is not the result of motor inhibition since an error is a perfectly well-coordinated response but one which does not correspond to the stimulus presented. According to Broadbent this failure in information processing occurs not because of "perceptual inhibition", but rather because task-irrelevant or novel stimuli are occupying the perceptual mechanism and preventing the task-relevant information from getting through.

The period when task-irrelevant rather than task relevant information is passed through the system is usually referred to as a block. That a block has occurred is evident from S's response record since either no response occurs for a short period or else one or more errors are made. In fact the evidence suggests that the incidence of errors rather than the rate of correct responding is a more sensitive measure of the occurrence of blocks. Both Bills (1931) and Broadbent (1953) have found that error rate, but not rate of correct responding, is affected by conditions thought to be conducive to the occurrence of blocks (e.g., noise or fatigue). According to Broadbent, the reason that rate of correct responding on the S.R.T. is not highly correlated with the occurrence of blocks is that the S.R.T. is a self-paced task. Consequently the subject can make up for any momentary reduction in efficiency by responding quickly and accurately in between blocks. However, if the S.R.T. is made into an experimenter-paced task by presenting the stimuli at a rate independent of the subjects' responses, the rate of correct responding is found to decline with time on the task and to reflect the occurrence of blocks (Broadbent, 1953).

In view of the clinical literature which describes hyperactive children as "distractible" that is, more likely to pay attention to task-irrelevant information, it was hypothesized that the S.R.T. performance of hyperactive children would be significantly worse than that of normal children. More specifically it was hypothesized that hyperactive children would make a greater overall number of errors on the S.R.T. than would normal children and that although errors would increase with time on the task for both groups, the rate of increace would be greater for hyperactive than for normal children. Because number of correct responses has been found not to be a good measure of the occurrence of blocks,it was not expected that the two groups of children would differ on this measure.

Continuous Performance Test.

The Continuous Performance Test (C.P.T.) is an experimenter-paced vigilance task which can be presented in either visual or auditory form. The studies to be described below have used the visual form. In this task a series of letters are presented one at a time on a screen and the subject is required to monitor the screen continuously and to make a response whenever a certain specified stimulus appears. Usually the significant stimulus is the letter X or the letter X when preceded by the letter A. The occurrence of the significant stimulus is unpredictable and all of the stimuli appear quite rapidly and for a very short time. Usually the stimuli appear at intervals of 1.0 second and are of 0.2 second duration. Such a task requires sustained attention, usually for ten minutes or more. Because this is an experimenter-paced rather than a self-paced task, lapses in attention coincident with the appearance of the significant stimuli are readily reflected in rate of correct responding as errors of omission.

The majority of the investigations with this test have been done by Mirsky and his colleagues, who have been concerned with the specification of the neural correlates of impaired performance. Their essential hypothesis is that accurate performance on the C.P.T. is dependent mainly on the integrity of certain sub-cortical areas, particularly the midbrain and reticular formation. Support for such an hypothesis comes from three sources, namely from experiments with sleep- deprived subjects, from those using brain-damaged and epileptic patients and from studies of the effects of various drugs on this task.

Because sleep and wakefulness or alertness are known to be regulated in part at least, by subcortical mechanisms (Mirsky and Rosvold, 1960; Mirsky and Cardon, 1962), Mirsky concluded that the poorer C.P.T. performance of sleep-deprived subjects indicated that correct responding on the task was related to the state of subcortical mechanisms. More specifically, the performance of normal individuals deprived of sleep for up to 72 hours was impaired on the C.P.T. but was much less impaired on a self-paced task (Kornetsky, Mirsky, Kessler and Dorff, 1959; Mirsky and Cardon, 1962). Moreover, the degree of impairment was directly related to the amount of sleep deprivation. It appears that the effect of sleep deprivation is to increase the frequency of "blocks" or "lapses" in attention (Williams, Lubin and Goodnow, 1959) which, as has previously been discussed, reflect themselves in rate of correct responding in experimenter-paced more than in self-paced tasks.

Having observed that hypersynchronous (high amplitude) activity similar to that seen in the EEG records of sleeping subjects also characterized the EEG records of brain-damaged individuals, Rosvold, Mirsky, Sarason, Bransome and Beck (1956) reasoned that the C.P.T. performance of brain-damaged individuals should be impaired. They did in fact find significant differences between the C.P.T. performance of a brain-damaged and a matched control group, although these two groups did not differ significantly on other more conventional self-paced tests of attention (e.g., Digit Span and Digit Symbol Substitution Test of the Wechsler-Bellevue). Also, patients with centrencephalic epilepsy performed more poorly on the C.P.T. than did patients with focal epilepsy (both temporal and frontal lobe foci) (Mirsky, Primac, Marsan, Rosvold and Stevens, 1960; Lansdell and Mirsky, 1964). Furthermore, unilateral temporal lobe ablation, that is the removal of mainly cortical tissue, produced no impairment on the C.P.T. (Lansdell and Mirsky, 1964). In view of the fact that Penfield and Jasper (1954) have suggested that centrencephalic epilepsy is subcortical and focal epilepsy cortical in origin, these findings suggest that subcortical dysfunction is related to poor performance on the C.P.T.

The final line of evidence relating C.P.T. performance to the integrity of subcortical mechanisms comes from drug studies carried out by Mirsky and his colleagues. Several studies have found that the C.P.T. performance of normal subjects was impaired to a greater extent than their Digit Symbol Substitution Test performance when they were given chlorpromazine. This drug is a central nervous system depressant believed to act on subcortical structures especially the reticular formation (Mirsky and Kornetsky, 1964; Kornetsky, Humphries and Evarts, 1957; Mirsky, Primac and Bates, 1959). In contrast, performance of subjects on the Digit Symbol Substitution Test was impaired to a greater extent than performance on the C.P.T. when they were given lysergic acid, secobarbital, meprobamate and phenobarbital (Mirsky and Rosvold, 1960; Townsend and Mirsky, 1960). These latter drugs are thought to have their major effect on cortical structures (Mirsky and Rosvold, 1960; Mirsky and Kornetsky, 1964).

The exact reason for failure to detect significant stimuli on the C.P.T. is not yet known although the question is currently being investigated (cf. Mirsky and Rosvold, 1963; Mirsky and Tecce, 1968). It has been observed that errors of omission by centrencephalic patients on the C.P.T. frequently coincide with the paroxysmal burst of three-per-second spike and wave activity said to be characteristic of this disorder. However, errors of omission may also occur when there is no observable discharge or even when there appears to be EEG "alerting" (Mirsky and Rosvold, 1960). In view of these findings, Mirsky and Van Buren (1965) suggest that the attentional deficit and the spike and wave activity noted in the EEG are possibly separate symptoms of centrencephalic epilepsy each regulated by independent neural mechanisms.

In summary, it appears that there is some evidence to suggest that accurate performance on the C.P.T. is at least partly dependent upon the integrity of sub-cortical structures. However, at present there is little definite knowledge about either the exact role that sub-cortical structures play in the maintenance of alertness or the exact sites and modes of action of many of the drugs used in the above studies.

Because distractibility, or a high frequency of momentary lapses in attention to a task, is considered, clinically, to be a core symptom of hyperactivity, it was expected that hyperactive children would be poorer on the C.P.T. than normal children. The current suspicion that these children suffer from an impairment in sub-cortical rather than cortical structures (e.g., the diencephalon, Laufer,Denhoff and Solomons, 1957) would also predict that their performance on the C.P.T. would be impaired (cf., Mirsky above). Because the C.P.T. is an experimenter-paced rather than a self-paced task, it was expected that the greater incidence of lapses in attention in hyperactive children would be reflected in the fact that, compared with normal children. they would make both fewer correct responses and more errors, especially as time on the task increased. These findings were predicted for both the visual and auditory forms of the C.P.T.

To summarize, the following hypotheses were advanced.

(a) On the Choice Reaction Time Task there would be no differences between the mean reaction times of hyperactive and normal children.

(b) On the Serial Reaction Task it was predicted that hyperactive children would make a similar number of correct responses but significantly more errors than the control children, and that the incidence of these errors would increase more rapidly with time on the task for the hyperactive children.

(c) On the Continuous Performance Test it was predicted that hyperactive children would make fewer correct responses and more errors than the control children. Furthermore, it was predicted that the decline in correct responses and the increase in errors with time on the task would be significantly greater for the hyperactive children.

(d) Because the action of methylphenidate is largely a stimulating one and in view of the many positive findings in the literature, it was predicted that the drug would significantly improve the performance of hyperactive children on the tests where they showed an impairment.

CHAPTER II

GENERAL PROCEDURE AND EXPERIMENTAL DESIGN

Subjects.

A sample of 24 children diagnosed as "hyperactive" and 20 normal children, all English speaking and from the Montreal area, participated in this study.

(a) Clinical sample. The clinical sample was selected from children referred either to the Departments of Psychiatry or Psychology at the Montreal Children's Hospital, or directly to the Hyperactive Research Project. In order for a child to be accepted into the study, the parents (usually the mother) and the child's teacher had to specify as the major complaint an excessive level of activity. Furthermore, the child's hyperactivity had to have been present since early childhood and had to be sustained throughout most of the day.

In order to ensure as homogeneous a sample as possible, children whose Wechsler Intelligence Scale for Children(W.I.S.C.) Full Scale Intelligent Quotient (I.Q.) was less than 80 were excluded. Children diagnosed as psychotic, or whose major presenting symptoms were of an emotional or neurotic nature were also excluded, as were children with evidence of gross brain damage, cerebral palsy and epilepsy. Only one child had been treated for hyperactivity prior to the initial assessment and he had not been on medication for several years. All of the children except three were boys. All were attending regular school classes and were living at home with at least one parent with the exception of one boy who was living with his grandmother. The ages of the 24 hyperactive children ranged from 5 years 10 months to 13 years 4 months, with a mean age of 8 years 5 months and a standard deviation of 2 years 2 months. Their mean I.Q. was 99 with a standard deviation of 13.34.

(b) Control sample. A sample of 20 normal children was selected from the normal school population of the City of Montreal. According to the teacher's report all of the children were free from any emotional disturbance, were of average or better ability, and were showing normal progress in school. The 20 control children were matched individually with 20 of the 24 hyperactive children on the basis of age, sex and I.Q. (W.I.S.C. Full Scale). The mean age of the control group was 8 years 3 months with a standard deviation of 1 year 8 months. The respective figures for the 20 matched hyperactive children were 8 years 2 months and 1 year 2 months. The mean I.Q. of the Control Group was 103 with a standard deviation of 12, while for the matched Hyperactive Group it was 102 (s.d. = 13). The Hyperactive and Control groups did not differ on mean age ($t = 1.86$, $df = 19$, NS) or I.Q. ($t = 1.17$, $df = 19$, NS).

Apparatus.

The apparatus was assembled by technicians in the Biophysics Department of the Montreal Children's Hospital.

A 15 x 15 x 21.5 inch grey metal cabinet (Figure 1) housed the stimulus presentation equipment and response manipulanda. The front panel of the cabinet was inclined at an angle of 55° from the base of the cabinet. In the centre of the cabinet a multiple stimulus projector (Grason-Stadler, E4580) was mounted at the back of the panel, such that the viewing surface (1 inch in diameter) was clearly visible to S. One and one-half inches below the stimulus projector a push-button manipulandum (Grason-Stadler, E8670A) was mounted, the surface disk being 1½ inches in diameter. Arranged in a semi-circle in the upper part of the panel were five clear plastic push-buttons, each 3¼ inches apart and at a distance of 8 inches from the centre of the

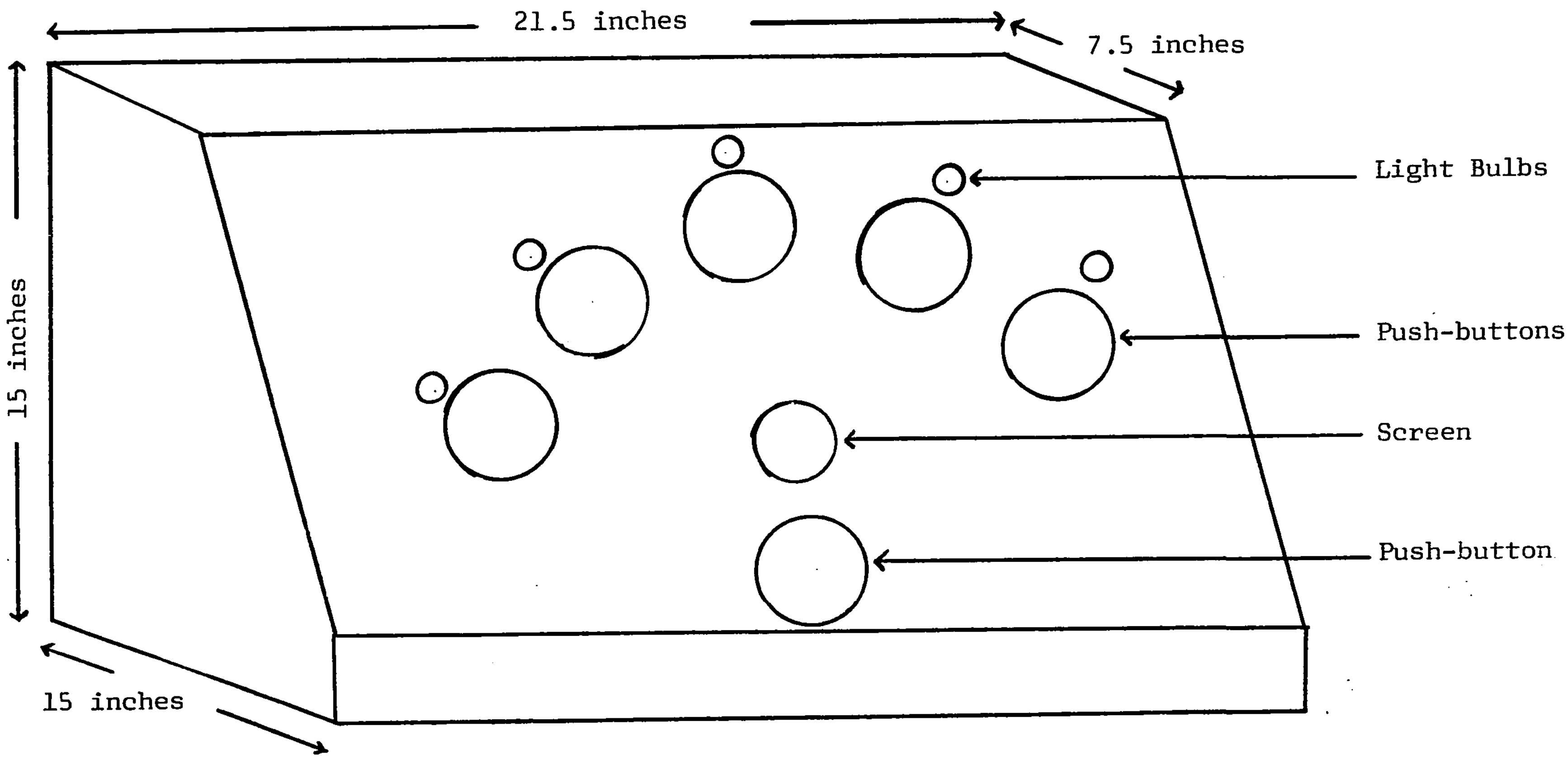

FIGURE 1

STIMULUS AND RESPONSE CABINET

lower push-button. The surfaces of these push-buttons were also 1¼ inches in diameter, and they were attached to micro-switches (Grayhill snap action switches, 7-26 SPDT) mounted in the rear of the panel. Immediately above each of the five push-buttons was a small light bulb covered with a red dome (Dialco Pilot Light Assembly).

The presentation and programming of the stimuli was done automatically by Grason-Stadler programming and timing equipment. In the case of the auditory stimuli, these were presented through a Roberts Model 770 four track stereophonic tape recorder, with the stimuli recorded on 1½ mil acetate tape (Audiotape, type 1257). Responses were recorded automatically on a miniature Four Channel Event Recorder (Rustrak, Model 92), and reaction times were measured with two precision timers (Standard Electric Time Company, Model S-1) graduated to .01 second.

Stimuli.

(a) Choice Reaction Time. The Choice Reaction Time tasks required the S to press one of two, or four push-buttons, each of which displayed a stimulus which corresponded to one of the stimuli presented on the screen. There were three sets of stimuli, one set for each of the three conditions. All the stimuli were drawn on small cards which were inserted into the slots of the upper push-buttons. In Condition A there were two stimuli, a triangle and a circle (Figure 2a). In Condition B there were four stimuli, a triangle, a circle, three small circles drawn in a horizontal line, and three horizontal lines (Figure 2b). In Condition C there were the same four stimuli as used in Condition B, but instead of white shapes on a black background each of the shapes had a different coloured background. The triangle had a red background, the circle a blue background, the three circles a green background and the three lines a yellow background (Figure 2c). In Conditions A and B the stimuli on the cards were identical to the stimuli that appeared on the

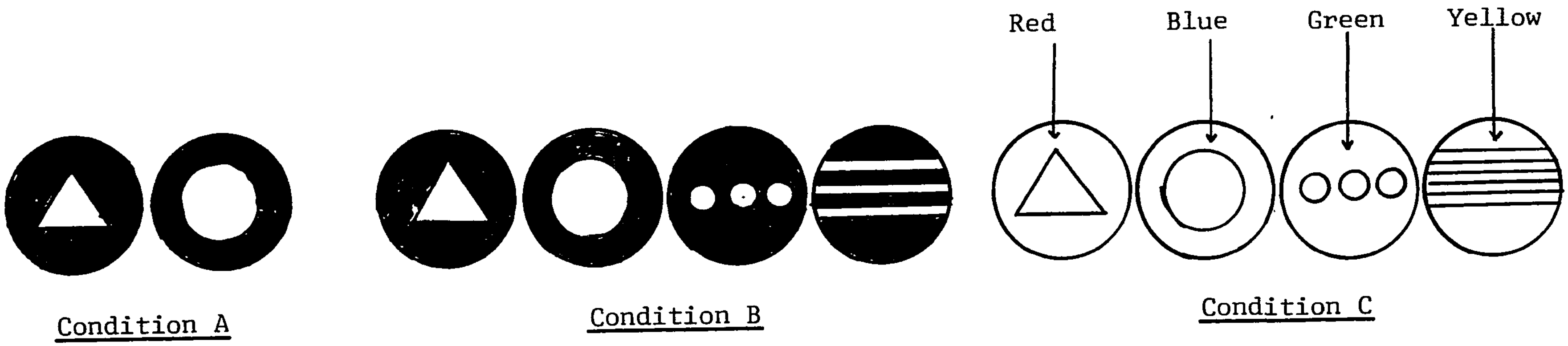

FIGURE 2

CHOICE REACTION TIME TASK STIMULI

screen, namely white shapes on black backgrounds. In Condition C , however, the coloured background which appeared with a particular shape on the screen was always discrepant with the coloured background associated with that shape on the card. For example, on the screen the triangle might appear with the colours green, yellow or blue, but never with the colour red.

In each condition there were four practice trials followed by 12 actual trials. The appearance of the stimuli on the screen was randomized within each condition, with the restriction that each shape occurred with equal frequency.

(b) Serial Reaction Task. The stimuli to which the S was required to respond were lights. There were five lights, each associated with an individual push-button. At the start of the task one light would be turned on and the S would be instructed to tap the button corresponding to the light. The response would extinguish the light, which would be immediately replaced by another light requiring a response, and so on. The order of appearance of the five lights was randomized over a series of 100 stimuli and this series was repeated for a total period of nine minutes.

(c) Continuous Performance Test (Visual Mode). The stimuli for this test were the twelve letters A, C, E, H, K, L, N, P, S, U, X, Z. One letter at a time appeared on the screen, with a stimulus duration of 0.2 of a second and an interstimulus interval of 1.5 seconds. The significant stimulus, to which S was instructed to respond, was the letter X when it was immediately preceded by the letter A. The 12 letters were randomized over a series of 100 stimuli, with the restriction that there were 15 significant stimuli (i.e., A followed by X) within the total run of 100 stimuli. With an interstimulus interval of 1.5 seconds, the total run of 100 stimuli took 2½ minutes to complete.

As the task itself lasted for 15 minutes this meant that within one testing session the run of 100 randomized stimuli was repeated six times. There was also a set of 25 similar practice stimuli.

(d) Continuous Performance Test (Auditory Mode). The stimuli for the auditory form of the C.P.T. were the same 12 letters as used in the visual form. The letters were recorded on one channel of a tape by a female voice at an interstimulus interval of 1.5 seconds. On the second channel of the tape, a pure tone of brief duration was recorded coincident with each individual letter. By means of a switching amplifier, the tone which was not audible to S paced the Grason-Stadler recording equipment and the Four Channel Event Recorder so that an accurate record of the S's responses to each auditory stimulus was obtained. Again, the significant stimulus was the letter X when preceded by the letter A, and the order of appearance of individual letters during a run of 100 stimuli was identical to that in the visual form of the C.P.T. The run of 100 stimuli was repeated six times (as for the visual form) so that a single session on the task lasted 15 minutes. There was also a practice set of 25 stimuli.

Procedure.

The experiments were carried out at the Montreal Children's Hospital. Each child was usually brought to the Hospital by his(her) mother and left in E's charge. With one exception all the hyperactive children were seen for the initial tests and the retests on weekday mornings. In the case of the one exception, the child was seen during the afternoons of weekdays. The normal control children were all seen on Saturdays, the majority in the morning. Each S was tested individually.

Each S took the tests (with the exception of the W.I.S.C.) in a small room (4 x 6 x 8 feet) adjacent to E's room and connected to it by a one-way screen. The S's room was bare of all objects with the exception of the display cabinet and a chair. S was seated on a padded wooden cushion on the chair which had sidearms. The chair was directly in front of the display cabinet. Each S was told by E:

> " We are going to do some tests which I think you will enjoy doing. We will do a few tests first of all and then we will stop and go and get something to drink and eat. Okay? Now I will tell you what I want you to do, so listen to me very carefully".

E then gave specific instructions relevant to the task that S was then to do. The instructions for the four tasks are given below.

(a) Choice Reaction Time Task. There were three conditions in this task and prior to the administration of each condition there were four practice trials. E placed the stimulus cards (the triangle and the circle in the case of Condition A) in the slots of the appropriate push-buttons and said to S:

> " This is a triangle and this is a circle (pointing to them). Listen carefully and I will tell you what I want you to do. I want you to put your finger on this push-button and hold it down (E demonstrating by placing his finger on the lower push-button and holding it down). I want you to look at this screen (pointing). When I say, "Here we are", you will see one of these two shapes, either the triangle or the circle, appear on the screen. As soon as the screen lights up, before you have even recognized what shape it is, I want you to take your finger off the push-button as quickly as you can and then, as quickly as you can, press the correct button here (pointing to the appropriate buttons). Press this button if it is the triangle and this one if it is the circle. Remember, as soon as the screen lights up, and before you even recognize what shape it is, you take your finger off here as quickly as you can (pointing to the lower push-button), and then as quickly as you can you press the correct button here (pointing to the buttons). I want you to do both things, taking your finger off this push-button here and then pressing the correct one here, as fast as you can, because I am measuring how fast you can do it, and the faster you do it the higher your score. Alright?"

E then went to his room and presented the four practice stimuli consecutively to S. Prior to the presentation of each stimulus, E made sure, by observing S through the one-way screen, that S had his finger on the lower push-button and was looking at the screen. For each trial, E said "Are you ready? Here we are", and two seconds later presented the stimulus. Upon completion of the four practice trials, E spoke to S through the one-way screen, saying:

> "Good. Now we are going to do it for good. Remember, as soon as the screen lights up and before you recognize what the shape is, take your finger off the push-button as quickly as you can, and then as quickly as you can press the correct button".

The instructions for all three conditions were similar, except that in the case of Condition C, S was told that when the shape appeared on the screen it would come with a colour different from the one on the card. S was, however, to ignore the colour, as it was not important, and to press the button corresponding to the shape that appeared on the screen.

(b) Serial Reaction Task. Before joining S in his room, E activated the equipment so that the first light of the test was turned on. Upon joining S, E pointed to the light and said:

> "You see this light? If I tap this button (pointing to the correct button) it turns the light off and another one (pointing to it) goes on. If I tap the button under this light, it turns the light off and another one goes on (demonstrating). However, if I tap a button underneath a bulb that is not lighted (demonstrating) nothing happens, but it is counted as a mistake. Now what I want to do is to turn off as many lights as I can, but make as few mistakes as I can. Watch me".

E then demonstrated by quickly tapping the correct buttons to turn off the lights. E also tapped a few wrong buttons and explained to S that these were mistakes which he must try not to make. S then practiced for a few minutes while E encouraged, repeated the instructions, and emphasized to S the necessity for accurate responding. As soon as S's responses were reasonably well-coordinated, E turned off the lights and told S:

> " Now we are going to do it for good. I will go into the other room and turn on the first light. I will say, "Are you ready, get set, go", and as soon as I say "go" I want you to start turning off the lights as quickly as you can, but make sure at the same time that you make as few mistakes as you can. The test will last for ten minutes and I want you to keep going as fast as you can all the time. Do not stop. You must keep going. Alright?"

E then returned to his room and,when S was ready, started the test.

(c) Continuous Performance Test (Visual Mode).C.P.T.(V).

> " You see this screen (E points to the screen on the cabinet), on this screen you will see letters, one letter at a time. There are twelve different letters in all, the letters A, C, E, H, K, L, N, P, S, U, X and Z. Listen carefully and I will tell you what to do. Whenever you see the letter X coming immediately after the letter A, I want you to press this button here (E points to the lower push-button and presses it). So, if you see the letter A and then the letter X, you press this button (E presses push-button) as soon as you have seen the letter X, and before the next letter comes on. If there is no A before the X, for example you may see the letter C then X, or P then X, you do not press the button. You only press the button when the X follows after the A. And you only press to the letter X, not to any other letter for that would be counted as a mistake. When you press the button you only press once and then let go (E demonstrates), you do not press more than once and do not keep the button pressed down. Is that clear? Do you know what you are to do? (If S expressed any doubt the instructions were repeated). E then continued, First of all we will have a practice. I will go into the other room and turn the letters on. Then I will come back here and we will do a few together. Look at the screen."

E then left S's room and switched on the practice stimuli, returning immediately to S's room. If S made no mistakes during the run of 25 practice stimuli, E turned off the stimuli and prepared for the actual testing.

> "Good. Now we are going to do it for good. I'm going into the other room and I will start the letters. The test will last for fifteen minutes and every time you see the letter X following immediately after the letter A, you press, but you do not press at any other time. While you are doing the test you must always look at the screen (E points). If you turn away or look around (E demonstrates) then an AX may come on and you will not see it. So you must always look at the screen. And do not get off your seat. Alright?"

E then returned to his room, made sure that S was ready and then started the test. If S made any mistakes during the practice session, the instructions and the practice stimuli were repeated until S reached a criterion of no mistakes during the run of 25 stimuli.

During the actual testing E also observed S's behavior through the one-way mirror and recorded all gross movements of his head and eyes away from the screen on the Four Channel Event Recorder.

(d) Continuous Performance Test (Auditory Mode) C.P.T.(A). The procedure and instructions here were identical to those for the Visual Mode, except for small changes necessitated by the fact that Ss would be hearing rather than seeing the stimuli.

Design.

The order of administration of the four tests,C.R.T., S.R.T., C.P.T.(V) and C.P.T. (A), were counterbalanced over the 24 hyperactive Ss, each S receiving the tests in one of 24 possible orders. The 20 normal controls were also randomly assigned to one of the 24 orders. In the case of the C.R.T. there were three conditions and thus six possible orders, and Ss were again randomly assigned in equal numbers to one of these orders.

At the end of the initial testing, which lasted about two hours including a ten-minute break, each S was given either the Verbal or the Performance Scale of the W.I.S.C. Another graduate student gave the other half of the test a few days later.

Each child, as he was accepted into the study, was assigned a number taken from a list supplied by the Ciba Pharmaceutical Company of Dorval. Each number had two bottles of pills (labeled (1) and (2)). At the end of the first visit the psychiatrist gave the mother bottle number (1), together with instructions concerning the administration of the pills (see below). An appointment was then made with the mother for her to bring in the child two weeks later for the second session of testing. At the end of the second session the psychiatrist gave the mother bottle number (2) and a third and final appointment for two weeks later was made. Care was taken to ensure both that the child had received the pills throughout each two week period and that on the day of testing he had taken his pills in the morning.

The tests and test procedures during the second and third sessions were identical to the initial session, except that the W.I.S.C. was not readministered.

Each hyperactive child acted as his own control for the drug part of the study and received both methylphenidate and a placebo each for a two week period. The methylphenidate and placebo pills were identical in shape and colour. The order of administration of the medications (active/placebo; placebo/active) was randomized over each series of 10 cases according to a code provided by the Ciba Pharmaceutical Company. As a result the investigator did not know which compound a child was on at a particular time. There were 12 Ss on placebo during their second visit and the active compound during their third visit, and 11 Ss on the active compound during their second visit and the placebo during their third visit. This made a total of 23 Ss, since one of the 24 hyperactive children dropped out of the study after the initial testing and was not included in the drug analyses.

The parents of the hyperactive children were not informed that their child would receive an inactive compound during part of the study and were led to believe that both compounds would be helpful to the child.

The drugs were titrated for each child by the psychiatrist in the following manner. The psychiatrist instructed the mother to give the child one half of a 10 mg. pill the first morning at breakfast. On the second day the dose was raised to one pill in the morning. On the third day, one pill in the morning and one half pill at lunch were given. The fourth day the dose was one pill at breakfast and one at lunch. Drug dosage was increased gradually in this manner. Each evening the psychiatrist spoke to the mother over the telephone, to advise her with respect to any side-effects that may have appeared. The dose was increased until such time as the psychiatrist considered that an optimum clinical dose had been reached. He based this decision on the mother's reports on the child's behaviour and the appearance of side-effects.

At the time of testing the mean daily dosage of methylphenidate was 57.00 mgs. (range 10 - 100 mgs.), with a mean dosage of 31.50 mgs. in the morning and 25.50 mgs. in the afternoon. All retests commenced one hour after the ingestion of the morning dose.

Scoring and Analysis of the Data.

(a) Choice Reaction Time Task. For each of the three conditions, A, B, and C, there were two reaction times for each trial, referred to as "simple" and "choice" reaction time. Simple reaction time was a measure of the elapsed time from the appearance of the stimulus on the screen to the time that S lifted his finger off the lower push-button. Choice reaction time was a measure of the elapsed time from the moment that S lifted his finger off the lower push-button to the time that he pressed the upper push-button corresponding to the stimulus on the screen. Mean simple and mean choice reaction times based on the twelve trials in each condition were the dependent variables used in the analyses of this task.

(b) Serial Reaction Task. Records from the total nine minutes on the task were divided into three, three-minute periods in order to examine any changes in performance over time. There were two scores: number of correct responses and number of incorrect responses or errors. A correct response was one made to the button which corresponded to the light that was on at the time. An incorrect response was one made to a button whose corresponding light was not on. Total correct and incorrect responses per period were the dependent variables used in the analysis of the S.R.T.

(c) Continuous Performance Test. The two forms of the C.P.T., visual and auditory, were scored in the same manner. The total 15 minutes of the test records were divided into three, five-minute periods so that any changes over time could be examined. There were two scores: number of correct responses and number of incorrect responses. In each five minute period 30 significant stimuli(A then X) were presented. The correct score was the number of significant stimuli or signals detected. For a response to be counted as correct it had to be made between the appearance on the screen of the letter X(when the X had followed an A) and the appearance of the next letter in the sequence, an interval of 1.5 seconds. An incorrect response was defined as any response to a non-significant stimulus.

Because the two forms of the C.P.T., visual and auditory, were identical except for the fact that the stimuli were delivered in different modalities, these two tests were analysed together. Number of correct and also incorrect responses per five minute period on both the visual and auditory forms of the C.P.T. were the dependent variables in the analyses of the C.P.T.

The scores from all three attention tasks were analyzed by means of repeated mesures design analyses of variance (Winer,1962,pp.319 and

and 368). Prior to completion of the main analyses, F max tests (Winer, 1962) were applied to all data to test for homogeneity of variance. Where nonhomogeneous variances were found, transformed scores were used. If variances were still nonhomogeneous after transformation of the data, a conservative test was applied to the F ratios obtained (Winer, 1962, p.322). In the analyses of the drug data the conservative test was always used since in this type of design the assumption of symmetry of variance/covariance matrices is questionable (Winer, 1962, p.340).

The test-retest reliability of each of the three attention tasks was assessed by computing product-moment correlation coefficients (Ferguson, 1959) between the initial and retest performance of the 12 hyperactive _S_s whose first retest occurred when they were on placebo.

CHAPTER III

RESULTS

Reliabilities of the C.R.T., S.R.T. and C.P.T.

The reliabilities of the three tests of attention are shown in Table 1. For the C.R.T., only the reliability for Condition C(four stimuli + colour) was significant. For the S.R.T. and the two forms of the C.P.T. (visual and auditory), the reliabilities for correct responses were high, while those for the incorrect responses were lower but still statistically significant.

Correlations of Age and Intelligence with Attention Tasks.

The correlations of age and I.Q. with performance on the three attention tasks are shown in Table 2.

With but few exceptions, in both the Hyperactive and Control groups, age was significantly correlated with Total Reaction Time on the C.R.T. and with number of correct and incorrect responses on the S.R.T. and C.P.T. The significant correlations of age with these dependent measures ranged from +0.80 for correct S.R.T. responses in the Control Group to +0.38 for correct C.P.T.(V) responses in the Control Group. Four correlations with age were not significant; namely, (1) the correlation between age and the total reaction times of Ss in the Hyperactive Group for Condition C of the C.R.T., (2) the correlation of age with the number of incorrect responses made by the hyperactive Ss on the S.R.T., and the correlation of age with the number of incorrect responses made by the Control Group on both the (3) visual C.P.T. and (4) the auditory C.P.T. Three of these four correlations did however show a trend in the expected direction.

Intelligence Quotient (I.Q.) on the other hand, was only minimally related to performance on these three tasks since only two of the 18 correlations were statistically significant, namely I.Q. and the number

TABLE 1

RELIABILITIES OF THE THREE ATTENTION TASKS

	r	p
(a) Choice Reaction Time Task.		
Condition A	+0.24[1]	NS
Condition B	+0.40	NS
Condition C	+0.76	<.005
Correlations based on Total Reaction Time.		
(b) Serial Reaction Task.		
Correct responses	+0.85	<.005
Incorrect responses	+0.54	<.05
(c) Continuous Performance Test.		
Visual:		
Correct responses	+0.87	<.005
Incorrect responses	+0.50	<.025
Auditory:		
Correct responses	+0.87	<.005
Incorrect responses	+0.59	<.025

[1] df = 10 for all correlations.

TABLE 2

CORRELATIONS OF ATTENTION TESTS WITH AGE AND INTELLIGENCE

(a) Choice Reaction Time Task.

		Condition A	Condition B	Condition C
Hyperactive	Age	-0.42 * [1,2]	-0.50 **	-0.33
	I.Q.	-0.17	-0.01	-0.05
Control	Age	-0.68 ***	-0.70 ***	-0.62 **
	I.Q.	-0.14	-0.36	-0.32

(b) Serial Reaction Task.

		Correct responses	Incorrect responses
Hyperactive	Age	+0.73 ***	-0.11
	I.Q.	+0.37	-0.43 *
Control	Age	+0.80 ***	+0.56 **
	I.Q.	+0.21	-0.07

(c) Continuous Performance Test.

		Visual		Auditory	
		Correct	Incorrect	Correct	Incorrect
Hyperactive	Age	+0.50 **	-0.60 ***	+0.48 **	-0.66 ***
	I.Q.	+0.43 *	-0.03	+0.37	-0.004
Control	Age	+0.38 *	-0.19	+0.60 ***	+0.15
	I.Q.	-0.06	-0.12	+0.23	+0.17

---

[1] Correlations reported for the C.R.T. are those between Total Reaction Time and age or I.Q.

[2] df = 18 for all correlations.

* $p < .05$ ** $p < .025$ *** $p < .005$

of incorrect responses made by hyperactive Ss on the S.R.T. ($r = -0.43$, $p < .05$) and I.Q. and the number of correct responses they made on the visual C.P.T. ($r = +0.43$, $p < .05$).

Choice Reaction Time Task.

(a) Hyperactive-Control Comparisons. The means and standard deviations for the two groups (Hyperactive and Control) over the three conditions (A,B, and C) are presented in Table 3. The dependent measures in this table are mean Simple and mean Choice reaction times. The results of a three-way, repeated measures design analysis of variance are presented in Table 4.

The main effect for Groups was not significant indicating that the reaction times of the hyperactive and control Ss were similar on this task. There was a trend however, for the Simple and Choice reaction times of hyperactive and control Ss to be different under the three conditions (Groups x Reaction Time x Conditions interaction, $F = 2.46$, $< p .10$). This trend is illustrated in Figure 3 and indicates that the addition of distracting colours in Condition C affected the Simple and Choice reaction times of hyperactive and control Ss differentially. The addition of colours increased the Choice Reaction Time of hyperactive Ss and the Simple Reaction Time of control Ss.

The main effects for Condition and Reaction Time were also significant (see Table 4). The significant Conditions factor indicated that the reaction times of both hyperactive and control Ss were longer in Condition C (mean = 2.58) than in Condition B (mean = 2.27) or Condition A (mean = 1.94; $p < .005$ for all comparisons between means by Duncan's test). The significant Reaction Time factor indicated that the Simple Reaction Times of both groups was significantly longer than their Choice Reaction Time over the three conditions (mean Simple Reaction Time = 4.04, mean Choice Reaction Time = 2.75, $p < .005$). No other

TABLE 3

MEANS AND STANDARD DEVIATIONS OF HYPERACTIVE AND CONTROL SUBJECTS ON THE CHOICE REACTION TIME TASK OVER THE THREE CONDITIONS.

Condition		A	B	C
Hyperactive (N = 20)	Simple	0.61(0.17)[1]	0.69(0.21)	0.75(0.21)
	Choice	0.38(0.28)	0.45(0.19)	0.55(0.41)
			Overall mean = 3.43(0.64)	
Control (N = 20)	Simple	0.55(0.13)	0.66(0.17)	0.78(0.19)
	Choice	0.40(0.13)	0.47(0.15)	0.50(0.22)
			Overall mean = 3.36(0.66)	
Both groups (N = 40)	Condition A	1.94(0.21)		
	Condition B	2.27(0.29)		
	Condition C	2.58(0.25)		
Mean Simple Reaction Time = 4.04(0.48)				
Mean Choice Reaction Time = 2.75(0.45)				

[1] Standard deviations in brackets.

TABLE 4

THREE-WAY ANALYSIS OF VARIANCE OF HYPERACTIVE AND CONTROL SUBJECTS ON THE CHOICE REACTION TIME TASK OVER THE THREE CONDITIONS AND TWO REACTION TIMES.

Source	SS	df	MS	F	P
Between Ss					
Groups	0.0020	1	0.0020	0.046	
Subj.w.groups	1.6384	38	0.0431		
Within Ss					
Condition	0.5218	2	0.2609	62.119	<.005
Groups x Condition	0.0080	2	0.0040	0.952	
Condition S(groups)	0.3193	76	0.0042		
Reaction Time	1.8995	1	1.8995	39.491	<.005
Groups x RT	0.0009	1	0.0009	0.019	
RT S(groups)	1.8289	38	0.0481		
Condition x RT	0.0006	2	0.0003	0.037	
Groups x Condition x RT	0.0403	2	0.0202	2.46	<.10
Condition x RT S(groups)	0.6250	76	0.0082		
Total	6.8847	239			

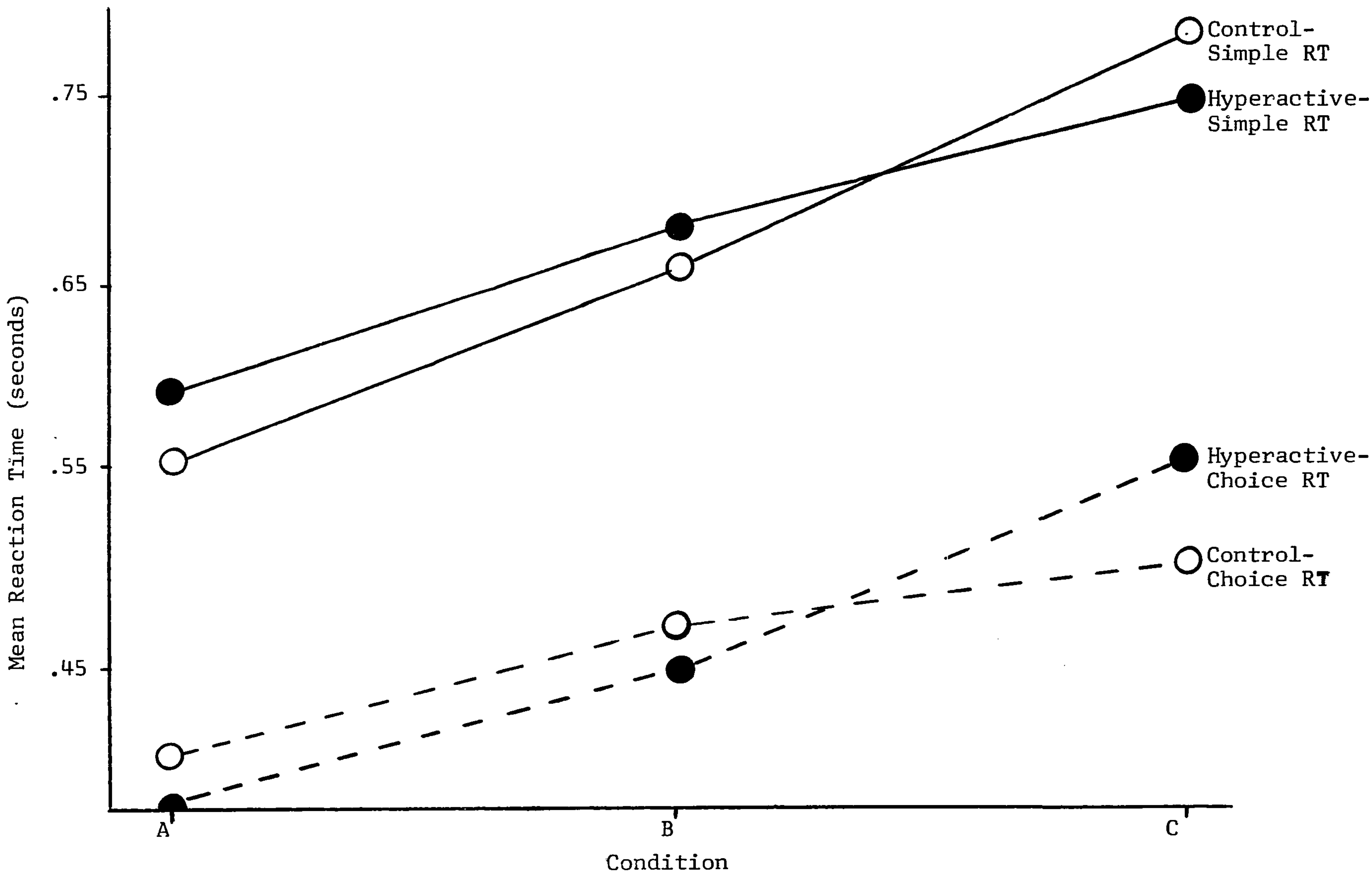

FIGURE 3

COMPARISON OF THE SIMPLE AND CHOICE REACTION TIMES OF THE HYPERACTIVE AND CONTROL GROUPS ON THE CHOICE REACTION TIME TASK (N = 20 PER GROUP) interactions approached significance.

(b) Drug Analyses. The mean reaction times and standard deviations of the Pre, Placebo and Active Drug groups for the three conditions of the C.R.T. are presented in Table 5. The results of a three-way analysis of variance completed on the drug data are presented in Table 6.

The main effects for Drug, Condition and Reaction Time were significant ($p < .005$), as was the interaction of Drug x Condition ($p < .05$). The significant drug effect indicated that the overall mean reaction times of Ss when they were on active drug (mean = 2.98) were significantly faster than when they were on Placebo (mean = 3.26) or on no drug (mean = 3.48, $p < .005$ for all comparisons between means by Duncan's test). The significant Drug x Condition interaction suggested that the Drug factor had a differential effect on the three conditions of the C.R.T. However, examination of a graph of this interaction (Figure 4) revealed that the active drug decreased reaction time a consistent amount over the three conditions compared to the reaction time of Ss when on placebo. Thus the significant Drug x Condition interaction mainly reflects the fact that the addition of a colour during pre testing increased Ss' reaction times to a greater extent(perhaps because of its novelty) than it did on second or third testing when Ss were on either active drug or placebo.

The significant main effects of Condition and Reaction Time again reflected the fact that Ss in all drug groups had longer reaction times in Condition C than B or A and that Simple Reaction Time was significantly slower than Choice Reaction Time.

No other interactions reached significance. From this it may be concluded that the effect of the active drug was independent of both Condition(A, B and C) and type of reaction time(simple and choice) measured.

TABLE 5

MEANS AND STANDARD DEVIATIONS OF THE THREE DRUG GROUPS FOR THE THREE CONDITIONS OF THE CHOICE REACTION TIME TASK

Condition		A	B	C
Pre-Drug (N=22)	Simple	0.60(0.20)[1]	0.67(0.20)	0.74(0.23)
	Choice	0.42(0.16)	0.46(0.21)	0.59(0.28)
		Overall mean = 3.48(0.63)		
Placebo (N=22)	Simple	0.53(0.17)	0.67(0.19)	0.72(0.22)
	Choice	0.42(0.13)	0.45(0.12)	0.47(0.15)
		Overall mean = 3.26(0.62)		
Active (N=22)	Simple	0.51(0.15)	0.61(0.12)	0.65(0.14)
	Choice	0.37(0.10)	0.40(0.18)	0.44(0.21)
		Overall mean = 2.97(0.58)		

[1] Standard deviations in brackets.

TABLE 6

THREE-WAY ANALYSIS OF VARIANCE COMPARING THE SIMPLE AND CHOICE REACTION TIMES OF THE THREE DRUG GROUPS OVER THE THREE CONDITIONS OF THE CHOICE REACTION TIME TASK.

Source	SS	df	MS	F	P
Between Ss	2.76	21			
Within Ss					
Drug	0.27	2	0.135	10.39	<.005
Drug x Ss	0.55	42	0.013		
Condition	0.54	2	0.270	54.00	<.005
Condition x Ss	0.20	42	0.005		
Reaction Time	2.69	1	2.690	25.14	<.005
RT x Ss	2.25	21	0.107		
Drug x Condition	0.04	4	0.010	3.33	<.05
Drug x Condition x Ss	0.25	84	0.003		
Drug x RT	0.02	2	0.010	0.67	
Drug x RT x Ss	0.64	42	0.015		
Condition x RT	0.03	2	0.015	1.67	
Condition x RT x Ss	0.36	42	0.009		
Drug x Condition x RT	0.04	4	0.010	1.67	
Drug x Condition x RT x Ss	0.53	84	0.006		
Total	11.17	395			

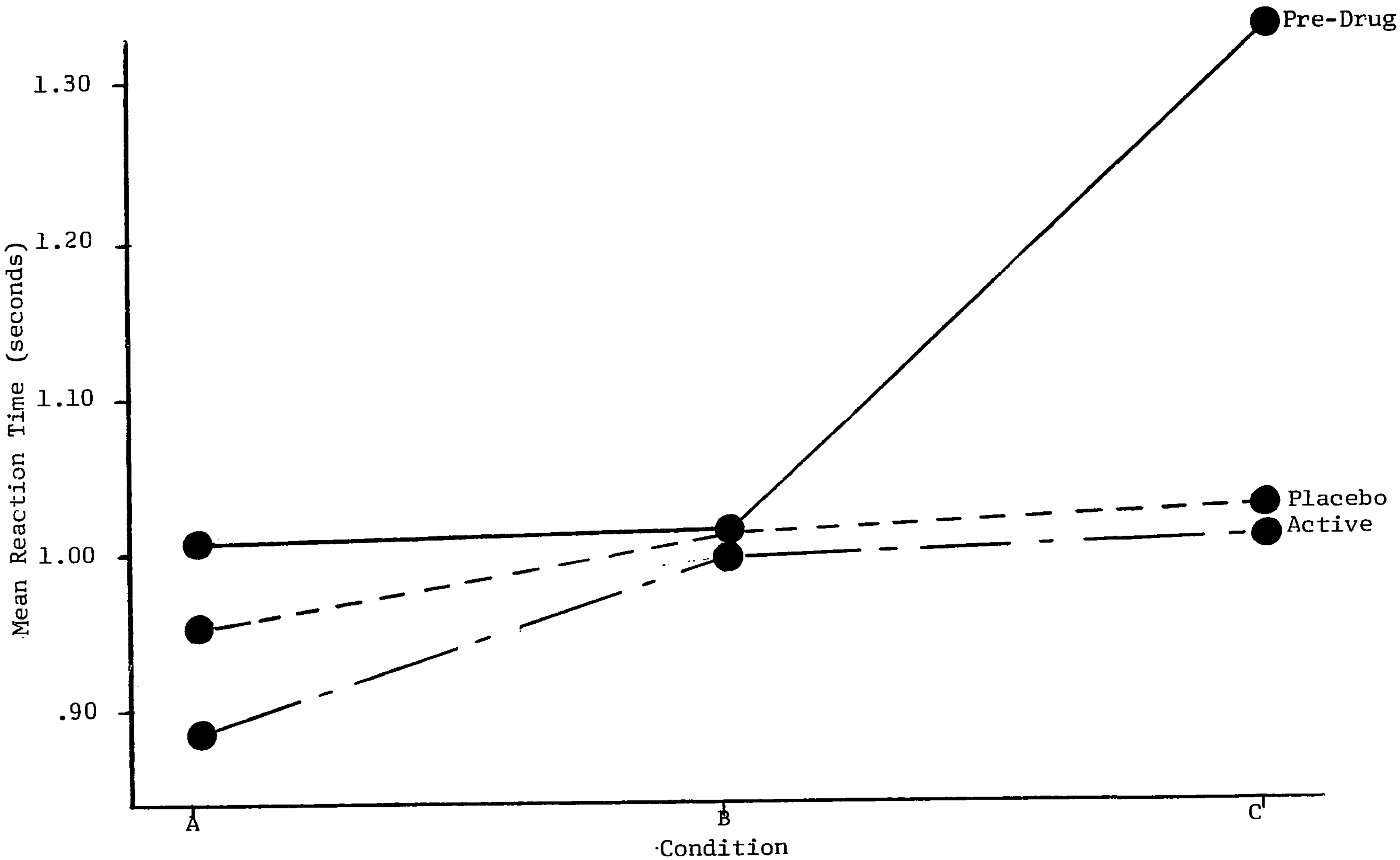

FIGURE 4

COMPARISON OF TOTAL REACTION TIMES OF THE THREE DRUG GROUPS ON THE CHOICE REACTION TASK OVER CONDITIONS, (N = 22 PER GROUP)

Serial Reaction Task.

(a) Hyperactive-Control Comparisons. The means and standard deviations of the number of correct and incorrect responses made by the Hyperactive and Control groups over the three periods on the S.R.T. are shown in Table 7. The analyses of variance completed on the number of correct and incorrect responses made by the two groups on the S.R.T. are presented in Tables 8a and 8b respectively.

Hyperactive Ss did not differ from normal Ss with respect to mean correct responses on the S.R.T. ($F = 1.59$, NS, Table 8a). However, the hyperactive Ss made significantly more incorrect responses than did normal Ss (mean errors for Hyperactive Group = 29.15; mean errors for Control Group = 18.85, $p < .05$).

In the analyses of both correct and incorrect responses there was a significant main effect for Period which indicated that the performance of both groups of Ss deteriorated at a similar rate with time on the task.

(b) Drug Analyses. Table 9 presents the means and standard deviations of the number of correct and incorrect responses for the three drug groups over the three periods on the S.R.T. Tables 10a and 10b summarize the findings of two analyses of variance completed on these data.

The main effect for Drug was significant in the analyses both of correct and incorrect responses ($p < .005$) indicating that Ss made more correct and fewer incorrect responses when they were on drug (mean correct = 634.43; mean incorrect = 10.17) than when they were on placebo (mean correct = 586.12; mean incorrect = 19.87) or no drug at initial testing (mean correct = 462.61; mean incorrect = 30.74; $p < .005$ for all comparisons).

The interaction of Drug x Period was also significant in the

TABLE 7

MEANS AND STANDARD DEVIATIONS OF CORRECT AND INCORRECT RESPONSES OF HYPERACTIVE AND CONTROL SUBJECTS ON THE SERIAL REACTION TASK OVER THREE TIME PERIODS.

Period		1st	2nd	3rd	Total
Hyperactive (N = 20)	Correct	160.05(30.14)	148.15(32.40)	148.20(31.02)	456.40(91.72)
	Incorrect	8.20(6.16)	9.85(6.76)	11.10(7.02)	29.15(18.11)
Control (N = 20)	Correct	173.75(30.13)	160.65(30.55)	158.20(30.15)	492.60(89.96)
	Incorrect	5.60(4.28)	6.00(4.01)	7.25(4.90)	18.85(11.47)
Both Groups (N = 40)	Correct	166.90(31.13)	154.40(32.45)	153.20(31.10)	
	Incorrect	6.90(5.40)	7.93(5.82)	9.18(6.28)	

TABLE 8

TWO-WAY ANALYSES OF VARIANCE OF THE CORRECT AND INCORRECT RESPONSES MADE BY THE HYPERACTIVE AND CONTROL SUBJECTS OVER THE THREE PERIODS OF THE SERIAL REACTION TASK (N = 20 PER GROUP)

(8a) Correct Responses. (8b) Incorrect Responses.

Source	(8a) df	(8a) MS	(8a) F	(8a) P	(8b) df	(8b) MS	(8b) F	(8b) P
Between Ss								
Groups	1	4368.14	1.59		1	353.63	4.63	$<.05$
Subj.w.gps	38	2750.75			38	76.55		
Within Ss								
Period	2	2302.54	54.42	$<.005$	2	51.93	5.43	$<.01$
Groups x Period	2	35.63	0.84		2	5.21	0.54	
Period(S.w.gps)	76	42.23			76	9.57		

TABLE 9

MEANS AND STANDARD DEVIATIONS OF CORRECT AND INCORRECT RESPONSES OF THE THREE DRUG GROUPS ON THE SERIAL REACTION TASK OVER THREE PERIODS.

Period		1st	2nd	3rd	Total
Pre-Drug (N=23)	Correct	161.96(36.23)[1]	149.87(38.85)	150.78(39.41)	462.61(113.12)
	Incorrect	8.79(6.10)	10.30(6.59)	11.65(8.28)	30.74(19.41)
Placebo (N=23)	Correct	209.17)46.12)	191.30(48.53)	185.65(49.81)	586.12(142.38)
	Incorrect	4.91(4.43)	7.83(5.28)	7.13(6.40)	19.87(14.31)
Active (N=23)	Correct	219.26(39.36)	210.17(40.45)	205.00(38.89)	634.43(117.67)
	Incorrect	2.39(2.29)	3.38(2.78)	4.30(4.14)	10.17(8.04)

[1] Standard deviations in brackets.

TABLE 10

TWO TWO-WAY ANALYSES OF VARIANCE OF THE CORRECT AND INCORRECT RESPONSES MADE BY THE THREE DRUG GROUPS ON THE SERIAL REACTION TASK OVER THE THREE PERIODS.

(10a) Correct Responses.

Source	df	MS	F	P[1]
Within Ss				
Drug	2	60202.67	71.14	$<.005$
Drug x Ss	44	846.24		
Period	2	5135.90	62.05	$<.005$
Period x Ss	44	82.77		
Drug x Period	4	286.04	4.96	$<.025$
Drug x Period x Ss	88	57.71		

(10b) Incorrect Responses.

Source	df	MS	F	P[1]
Within Ss				
Drug	2	811.49	22.52	$<.005$
Drug x Ss	44	36.04		
Period	2	104.37	8.65	$<.005$
Period x Ss	44	12.06		
Drug x Period	4	8.72	1.24	
Drug x Period x Ss	88	7.05		

[1] Conservative test.

analysis of correct, but not incorrect responses. This interaction, shown in Figure 5, seems to have occurred mainly because the correct responding of the Active and Placebo groups declined from Periods 1 to 2 to 3 while that of the Pre-Drug Group declined from Periods 1 to 2 but not from Periods 2 to 3. However, it is the comparison of Placebo and Active Drug groups that is the important one here and Figure 5 indicates that the effect of the active drug compared to the placebo was not dependent upon Period.

The main effect for Period was again significant in the analyses of both correct and incorrect responses indicating that the performance of Ss in all three drug conditions (Pre,Placebo and Active) declined with time on the task.

Continuous Performance Test.

(a) Hyperactive- Control Comparisons. The means and standard deviations for the number of correct and incorrect responses made by the Hyperactive and Control groups over the three periods of the C.P.T. (V) and C.P.T.(A) are presented in Table 11. The results of two three-way analyses of variance completed on the C.P.T. data for correct and incorrect responses may be found in Tables 12a and 12b.

The significant Groups factor obtained in both analyses indicated that hyperactive Ss made significantly fewer correct responses and significantly more incorrect responses on both forms of the C.P.T. (visual and auditory) than did the control Ss. In actual fact hyperactive Ss made an overall average of 121.05 correct and 37.55 incorrect responses while control Ss made an average of 153.00 correct and 11.60 incorrect responses on both forms of the C.P.T. combined ($p < .005$ for all comparisons). The fact that there was no significant interaction of Groups by Task suggests that it was appropriate to combine Ss' scores on the two forms of the C.P.T., since the performances of the two

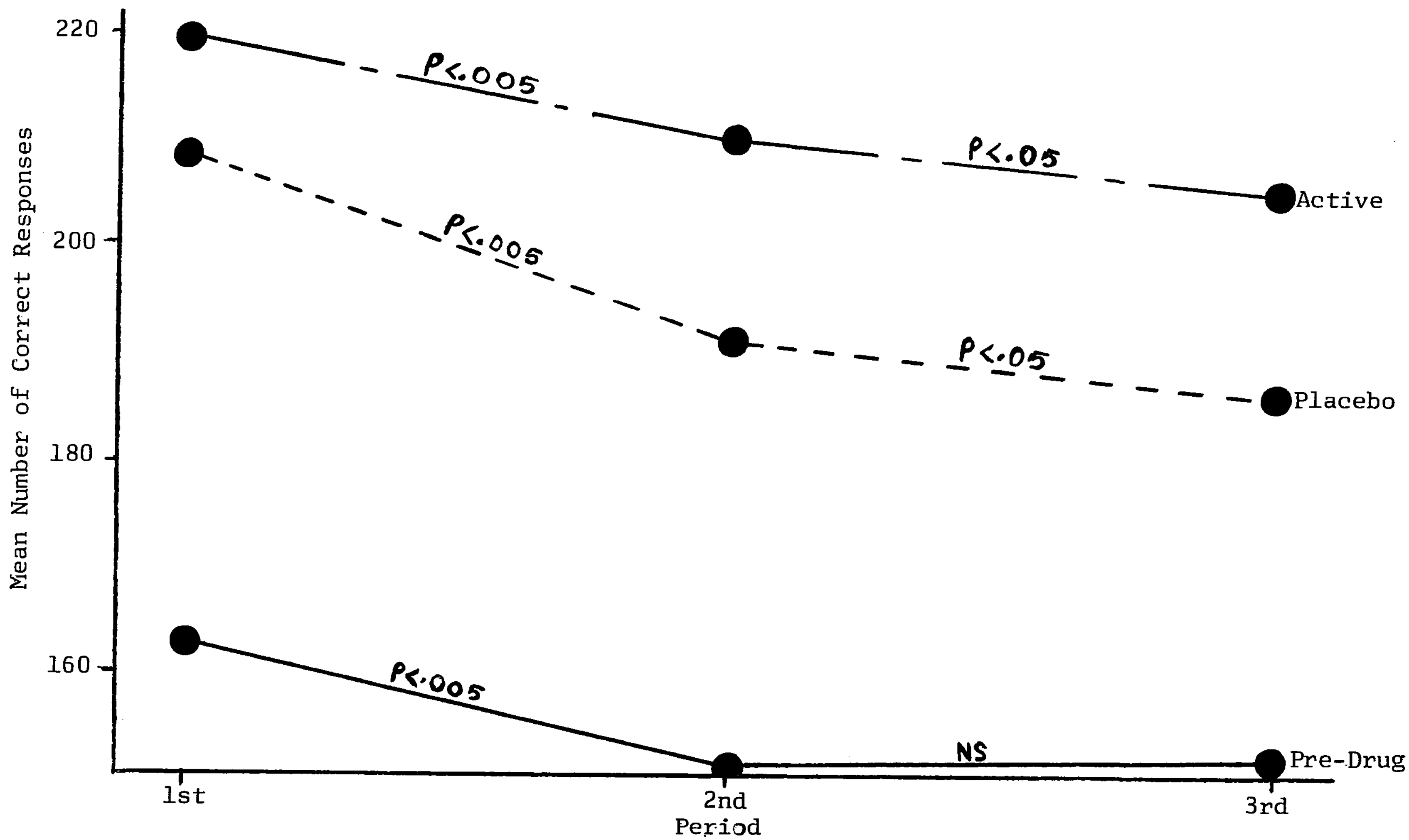

FIGURE 5

COMPARISON OF CORRECT RESPONSES MADE BY THE THREE DRUG GROUPS ON THE SERIAL REACTION TASK OVER PERIODS, (N = 23 PER GROUP)

TABLE 11

MEANS AND STANDARD DEVIATIONS OF CORRECT AND INCORRECT RESPONSES OF HYPERACTIVE AND CONTROL SUBJECTS ON THE CONTINUOUS PERFORMANCE TEST OVER TASKS AND PERIODS.

		Visual			Auditory			Total
Period		1st	2nd	3rd	1st	2nd	3rd	
Hyperactive (N = 20)	Correct	26.00(3.95)	22.65(6.29)	22.45(6.50)	17.95(6.00)	16.25(6.54)	15.75(7.89)	121.05 (33.00)
	Incorrect	5.55(5.18)	6.90(7.89)	6.05(5.18)	5.35(5.67)	6.65(6.91)	7.05(6.18)	37.55 (28.55)
Control (N = 20)	Correct	28.70(1.22)	28.20(3.00)	27.85(2.76)	22.85(4.33)	22.45(5.95)	22.95(4.90)	153.00 (18.26)
	Incorrect	1.90(2.15)	2.00(2.25)	1.30(1.17)	2.80(2.42)	2.05(1.85)	1.55(1.50)	11.60 (7.60)

Visual and auditory forms combined.

	Correct Responses			Incorrect responses		
Hyperactive:	43.95(8.94)	38.90(11.90)	38.20(13.21)	10.90(8.76)	13.55(12.63)	13.10(9.99)
Control:	51.55(4.74)	50.65(7.88)	50.80(6.98)	4.70(3.81)	4.05(3.17)	2.85(1.87)

Tasks and groups combined.

Periods	1st	2nd	3rd
Correct	47.75(8.04)	44.73(11.63)	44.50(12.23)

Groups and periods combined.

	Visual	Auditory
Correct	77.88(13.28)	59.10(19.08)
Incorrect	11.85(13.39)	12.73(13.61)

TABLE 12

TWO THREE-WAY ANALYSES OF VARIANCE OF THE CORRECT AND INCORRECT RESPONSES MADE BY HYPERACTIVE AND CONTROL SUBJECTS OVER THE TWO TASKS AND THREE PERIODS OF THE CONTINUOUS PERFORMANCE TEST

(12a) Correct Responses — (12b) Incorrect Responses

Source	df	(12a) MS	(12a) F	(12a) p[1]	(12b) MS	(12b) F	(12b) p[1]
Between Ss							
Groups	1	1712.01	14.45	<.005	6.2575	15.22	<.005
Subj.w.gps	38	118.50			0.4112		
Within Ss							
Task	1	2350.01	115.20	<.001	0.0833	0.60	
Group x task	1	34.50	1.69		0.0345	0.25	
Task S(gps)	38	20.40			0.1384		
Period	2	65.88	9.52	<.01	0.0091	0.18	
Gps.x Period	2	36.36	5.25	<.05	0.1961	3.94	<.06>.05
Period S(gp)	76	6.92			0.0498		
Task x Period	2	7.43	1.02		0.0026	0.05	
Gps. x Task x Period	2	3.70	0.51		0.0412	0.79	
Task x Per. x S(gps)	76	7.29			0.0519		

[1] Conservative test applied.

groups were not differentially affected by the nature of the task.

The number of correct and incorrect responses made by the Hyperactive Group did however depend on the Period (Group x Period interaction, $p < .05$ for correct and $p < .06 > .05$ for incorrect responses). These two interactions are illustrated in Figures 6a and 6b. Observation of these figures indicates that whereas the number of correct responses made by the Hyperactive Group declined significantly from Periods 1 to 2, there was no decline in the Control Group. Similarly, hyperactive Ss made significantly more errors[1] with time on the task, while control Ss actually made fewer incorrect responses from Periods 1 to 3.

Two other main effects were significant in the analysis of variance completed on the number of correct responses made by the two groups on the C.P.T. These were the main effects for Task and for Period. The significant Task factor indicated that Ss in both groups made significantly more correct responses on the visual (mean 77.88) than on the auditory form of the C.P.T. (mean = 59.10, $p < .005$). The significant Period factor indicated that there was a decline in the number of correct responses from Periods 1 to 2 ($p < .005$) but not from Periods 2 to 3. This significant factor was a function of a decline in the Hyperactive Group, not in the Control Group (cf., significant interaction of Groups x Period mentioned above).

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[1] There were three broad categories of errors, namely impulsive responses (e.g., a response to the letter A before the next letter had arrived), slow responses (a response to a significant stimulus but too slow to be counted as a correct response) and random responses (to non-significant stimuli other than A or X). The hyperactive Ss made significantly more ($p < .05$) impulsive errors and random responses on both forms of the task than the control Ss. However, the two groups did not differ with respect to number of slow responses on the auditory form of the C.P.T., although they did differ on the visual form ($p < .05$).

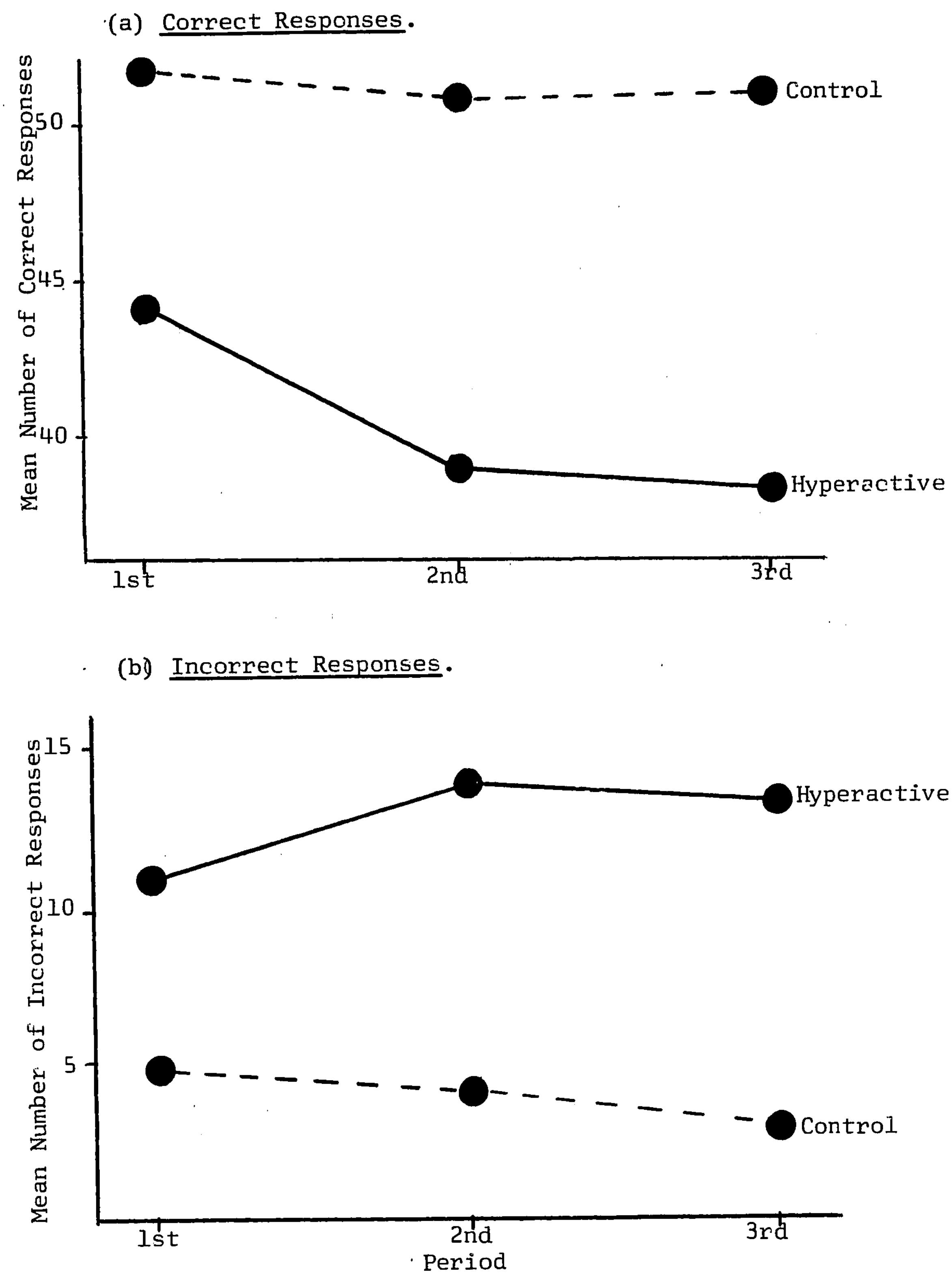

FIGURE 6

COMPARISON OF THE HYPERACTIVE AND CONTROL GROUPS ON THE CONTINUOUS PERFORMANCE TEST OVER PERIODS.
(N = 23 PER GROUP)

The Hyperactive and Control groups were also compared with respect to "multiple responses" and "non-observing behaviours". A multiple response is one where two or more responses are made in rapid succession. The hyperactive Ss (mean = 3.00) made significantly more such responses than the control Ss (mean = 0.80, $p < .01$). Non-observing behaviours on the visual C.P.T. were also more frequent in the Hyperactive Group (mean = 6.70) than in the Control Group (mean = 0.30, $p < .01$).

(b) Drug Analyses. The means and standard deviations of the number of correct and incorrect responses made by the three drug groups on the two forms of the C.P.T. are presented in Table 13. The analyses of variance completed on these data are presented in Table 14(a and b).

The main effect for Drug was significant in the analyses of both correct and incorrect responses. This finding indicates that the hyperative children made significantly more correct and fewer incorrect responses when they were on active drug (mean correct = 154.49, mean incorrect = 10.73) than when they were on placebo (mean correct = 123.62, mean incorrect = 24.62) or on no drug (mean correct = 123.53, mean incorrect = 35.70; $p < .005$ for all comparisons except for the difference between the pre-drug and placebo mean correct responses which was non-significant).

In the analysis of correct responses there were also significant Drug x Task and Drug x Period interactions. The Drug x Task interation suggested that performance on the auditory form of the C.P.T. as compared to the visual form was relatively more impaired at the time of initial testing than either when the children were receiving the active drug or the placebo (Figure 7). The significant Drug x Period interaction reflected the fact that the children while on placebo showed a significant decline in rate of correct responding not only from Periods 1 to 2, but also from Periods 2 to 3. While the rate of

TABLE 13

MEANS AND STANDARD DEVIATIONS OF CORRECT AND INCORRECT RESPONSES OF THE THREE DRUG GROUPS ON THE CONTINUOUS PERFORMANCE TEST OVER TASKS AND PERIODS.

Period		Visual 1st	Visual 2nd	Visual 3rd	Auditory 1st	Auditory 2nd	Auditory 3rd	Total
Pre-Drug (N=23)	Correct	25.96(3.05)	22.52(6.69)	22.43(6.73)	18.52(6.29)	17.30(6.78)	16.80(7.99)	123.53 (41.83)
	Incorrect	5.35(4.85)	6.22(7.54)	5.74(4.97)	5.65(5.74)	6.26(6.71)	6.48(6.30)	35.70 (27.75)
Placebo (N=23)	Correct	25.30(4.75)	22.04(7.88)	20.52(8.28)	21.09(7.24)	18.17(8.93)	16.50(9.76)	123.62 (41.83)
	Incorrect	5.61(4.27)	3.22(2.88)	4.04(4.50)	4.26(6.35)	4.91(6.61)	4.78(7.04)	24.62 (29.03)
Active (N=23)	Correct	28.61(2.39)	27.35(3.80)	26.87(4.39)	24.83(5.19)	23.35(6.83)	23.48(6.28)	154.49 (24.27)
	Incorrect	1.65(2.23)	1.39(1.88)	1.48(1.65)	1.91(2.33)	2.30(2.46)	2.00(2.75)	10.73 (10.32)

Visual and auditory forms combined.

	Correct			Incorrect		
Pre-Drug	44.48(9.05)	39.82(12.04)	39.23(13.27)	11.00(8.26)	12.48(12.17)	12.22(10.03)
Placebo	46.39(10.70)	40.21(15.32)	37.02(16.49)	7.87(10.12)	8.13(8.68)	8.82(11.10)
Active	53.44(6.69)	50.70(8.75)	50.35(9.78)	3.56(3.89)	3.69(3.75)	3.48(3.44)

Periods combined.

	Correct Visual	Correct Auditory	Incorrect Visual	Incorrect Auditory
Pre-Drug	70.91(16.00)	52.61(20.08)	17.30(15.17)	18.39(16.73)
Placebo	67.87(20.12)	55.74(25.38)	10.87(10.78)	13.96(19.43)
Active	82.83(10.28)	71.65(17.17)	4.52(4.64)	6.22(6.88)

TABLE 14

TWO THREE-WAY ANALYSES OF VARIANCE OF CORRECT AND INCORRECT RESPONSES BY THE THREE DRUG GROUPS ON THE CONTINUOUS PERFORMANCE TEST BY TWO TASKS OVER THREE PERIODS

		(14a) Correct Responses			(14b) Incorrect Responses		
Source	df	MS	F	p[1]	MS	F	p[1]
Within Ss							
Drug	2	1221.07	27.20	<.005	600.19	11.83	<.005
Drug x Ss	44				50.74		
Task	1	2212.19	21.97	<.005	44.02	1.24	
Task x Ss	22	100.67			35.48		
Period	2	329.74	27.14	<.005	5.05	0.71	
Period x Ss	44	12.15			7.13		
Drug x Task	2	57.43	4.32	<.05	4.03	0.23	
Drug x Task x Ss	44	13.30			17.77		
Drug x Period	4	30.16	5.81	<.01	2.53	0.35	
Drug x Period x Ss	88	5.19			7.16		
Task x Period	2	7.05	0.70		1.98	0.47	
Task x Period x Ss	44	10.03			4.20		
Drug x Task x Period	4	5.13	0.94		2.27	0.37	
Drug x Task x Period x Ss	88	5.45			6.16		

[1] Conservative test applied.

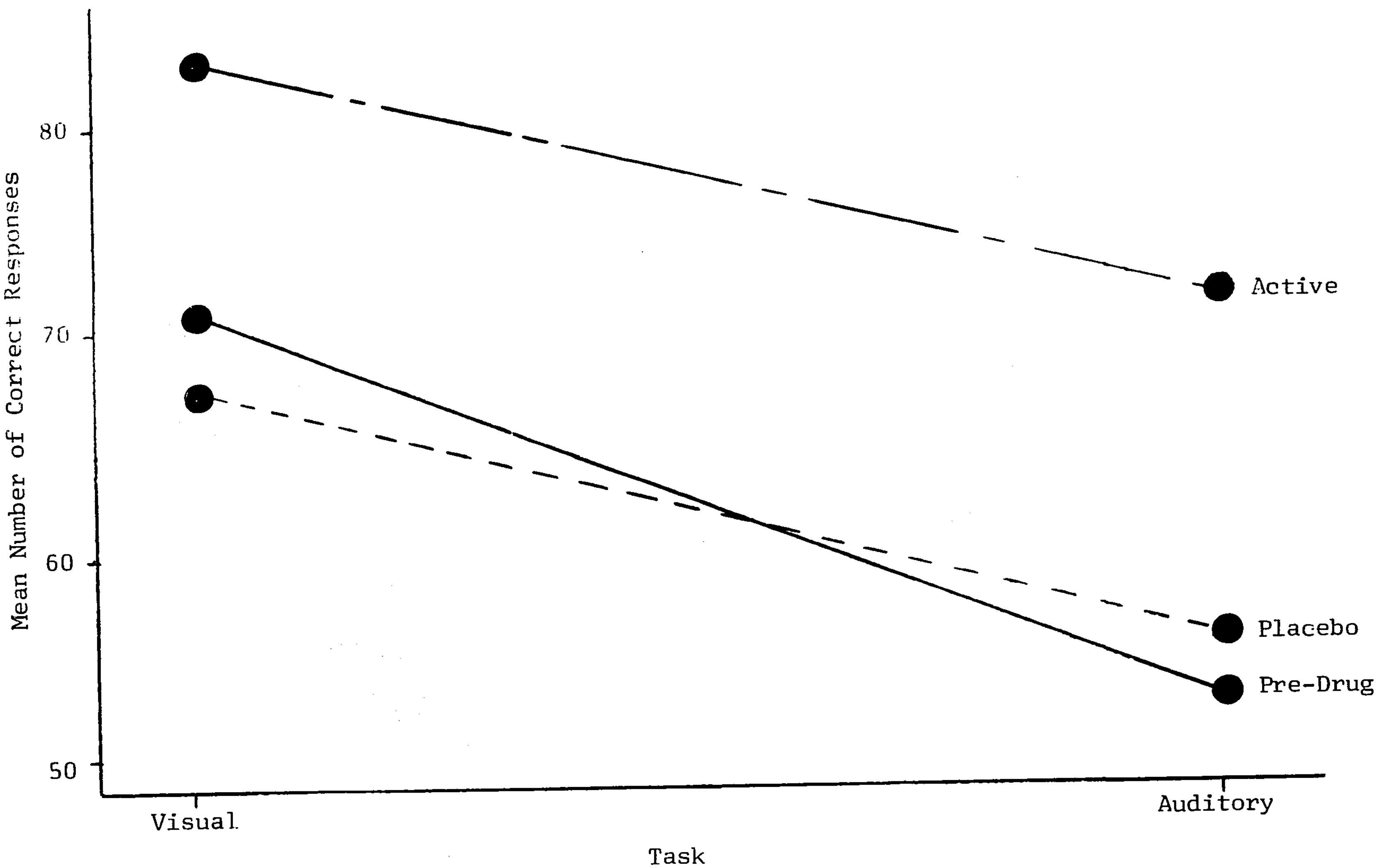

FIGURE 7

COMPARISON OF CORRECT RESPONSES MADE BY THE THREE DRUG GROUPS ON THE CONTINUOUS PERFORMANCE TEST OVER TASKS.
(N = 23 PER GROUP)

correct responding at initial testing and during active drug administration showed a decline only from Period 1 to 2 (Figure 8).

The significant main effects for Task and Period in the analysis of correct responses indicated that performance of all three groups was less accurate on the auditory C.P.T. than the visual C.P.T. and that the number of correct responses declined from Period 1 to 2.

There was a significant reduction in multiple presses with the active drug (mean = 0.35) compared to both pre-drug (mean = 2.70) and placebo (mean = 2.48, $p < .001$). Non-observing behaviours were also significantly reduced in the Active Drug Group (mean = 0.26) in comparison to the Pre-Drug Group (mean = 6.30) and the Placebo Group (mean = 6.22, $p < .05$).

Summary of the Main Findings of the Present Study.

Hyperactive-Control Comparisons.

(1) The mean reaction times (Total, Simple and Choice) of hyperactive Ss were no different from those of normal Ss for all three conditions of the C.R.T. (Conditions A,B,C).

(2) On the S.R.T., hyperactive Ss made more incorrect responses than control Ss but a similar number of correct responses. The performance of both groups deteriorated at a similar rate with time on the task.

(3) Hyperactive Ss made significantly fewer correct and more incorrect responses on the C.P.T. than did normal Ss. Furthermore, hyperactive Ss made fewer correct responses and more incorrect responses with time on the task. In contrast , for normal Ss the number of correct responses showed no decline with time and the number of incorrect responses they made decreased with time on the task. The decline in the performance of hyperactive Ss occurred between Periods 1 and 2 but not between Periods 2 and 3.

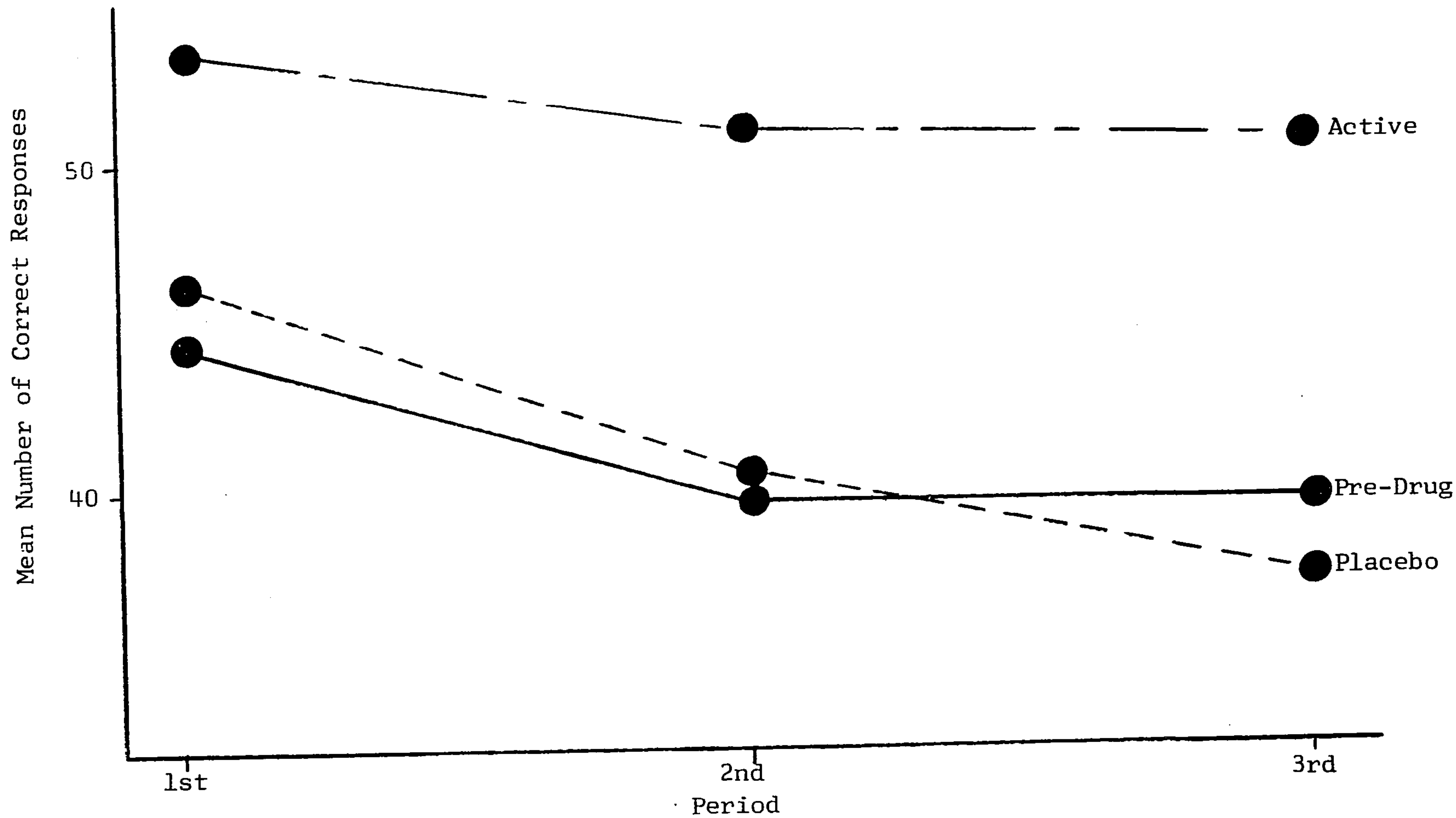

FIGURE 8

COMPARISON OF CORRECT RESPONSES MADE BY THE THREE DRUG GROUPS ON THE CONTINUOUS PERFORMANCE TEST OVER PERIODS, (N = 23 PER GROUP)

<u>Drug Results</u>.

(1) On the C.R.T. task, <u>S</u>s on active drug had significantly faster reaction times than when they were on placebo or no drug (i.e., initial testing). Compared to placebo, active drug improved performance consistently over all three conditions(A,B,C) of the C.R.T.

(2) On the S.R.T., <u>S</u>s on active drug made significantly more correct and fewer incorrect responses than when they were on placebo or on no drug (initial testing) and this finding held over all three periods on the S.R.T.

(3) On the C.P.T., <u>S</u>s on active drug made significantly more correct and fewer incorrect responses than when they were on placebo or no drug. They also observed the screen more efficiently and made fewer impulsive responses (multiple presses).

CHAPTER IV

DISCUSSION

Reliability of the Three Attention Tasks and Their Relation to Age and I.Q.

In view of the fact that the majority of the reliability coefficients on all three attention tasks reached statistical significance, it may be concluded that the responses of hyperactive subjects were reasonably consistent from initial testing to retesting two weeks later. It should be noted however that the reliabilities of some of the tests and some types of scores were higher than that of others. For example, test-retest reliabilities were high for number of correct responses on both the Serial Reaction Task and the Continuous Performance Test (visual and auditory), all correlations being above 0.80. Although statistically significant, the correlations were somewhat lower for incorrect responses on these same tests (all at or above 0.50). The reliability of correct responses on the visual Continuous Performance Test is similar to that found by Rosvold, Mirsky, Sarason, Bransome and Beck (1956), namely 0.74.

The reliability coefficients for the Choice Reaction Time Task were much lower, especially in Conditions A and B where they failed to reach significance. These low values may be due to the narrow range of reaction times within this relatively homogeneous group of children on these simple tasks. Such an explanation is supported by the fact that when the test became more difficult, as in Condition C, the reliability value was higher (0.76) and statistically significant.

The scores of both the hyperactive and the normal children on all three attention tasks were generally found to be significantly related to the age of the child. On the other hand, intelligence was rarely found to be related to performance, at least within the I.Q. range (above 80) used in the present study.

The Nature of the Attention Problem in Hyperactive Children.

The prediction that hyperactive children would have no problem in directing their attention to a task for brief periods of time was supported. On the Choice Reaction Time Task, which was chosen to assess ability to attend for brief periods, the total,"simple" and "choice" reaction times of the hyperactive subjects were no different from those of the normal controls. Furthermore, the reaction times of the hyperactive children did not differ significantly from those of the control children when the number of stimuli and responses, and thereby the amount of information to be processed, was increased. The addition of a colour distractor also produced a similar increase in the total reaction times of both groups of children. However, there was a trend, significant only at the ten percent level, for the "choice" reaction times of hyperactive subjects to increase when a colour distractor was added(Condition C). In order to discuss this finding, the meaning of "simple and "choice" reaction times must first be considered.

It will be recalled that the term "simple" was used to denote the time taken by the child to recognize the onset of the stimulus, while the term "choice" denoted time from the recognition of stimulus onset to response choice. It was expected that "simple" reaction times would be shorter than "choice" reaction times. In actual fact "simple" reaction times were longer than "choice" reaction times. It would appear that although the instructions repeatedly asked the subjects to remove their finger from the lower push-button as soon as a stimulus appeared, the children were unable to do this and waited until they recognized the stimulus. In other words, they were more concerned with identifying the stimulus than with responding quickly, or in the terms used by Titchener (1910, as cited by Hohle, 1967) they adopted "sensory" rather than "motor" sets. In fact, the reaction time labeled "simple" in the present study would be more accurately labeled "choice" and the reaction time labeled "choice" should be labeled "motor response" reaction time). Woodworth and Schlosberg (1954) have suggested that the set adopted by subjects depends upon the nature of the task, "motor" sets being adopted when the stimuli are few in number, simple and distinct, and "sensory" sets being adopted when there are many stimuli and when they are complex. The children in both groups of the present study apparently tended to adpot a sensory set in all three conditions. However, it was when irrelevant information was introduced (i.e., a colour distractor) that certain differences between the reaction times of the two groups appeared. More specifically, the "simple" reaction times of the control subjects increased when a colour distractor was added(Figure 3), that is the normal children spent longer recognizing the stimulus before responding. In contrast, there was a trend for the hyperactive children in Condition C _not_ to spend additional time recognizing the stimulus but to release the lower push-button quickly and then to spend additional time making their response choice. This finding, although only a trend, suggests that when hyperactive children are presented with stimuli containing distracting or irrelevant dimensions, they tend to begin responding faster than normal children. It might be worthwhile in future studies to investigate the effect on the reaction times of hyperactive children of systematically increasing the number of irrelevant dimensions. Because this was the only difference found between hyperactive and normal children on the Choice Reaction Time Task and because it was only a trend, any interpretation of the finding must wait upon further studies.

Although the attention of hyperactive children was not impaired on tasks requiring brief periods of concentration, the findings of this study suggest that they are impaired in their ability to maintain attention over longer periods of time. On the Serial Reaction Task the hyperactive children made significantly more errors than the normal controls, although there was no difference between the two groups with respect to number of correct responses. It was mentioned previously that the incidence of errors on the Serial Reaction Task is considered to be a more accurate indicator of momentary lapses of attention than the rate of correct responses. This was based on the finding of Bills (1931) that the rate of correct responses was little affected by an increase in blocking on the task, and the finding of Broadbent(1953) that noise produced an increase in errors but did not affect correct responses. Broadbent (1958) suggested that a high incidence of momentary lapses in attention would not necessarily be reflected in a lower incidence of correct responses if the subject compensated for the lapse by responding more rapidly between blocks. Thus, it is probably reasonable on the basis of the error data, to argue that hyperactive children are more subject than normal children to brief lapses in attention on the Serial Reaction Task, in spite of the fact that there was no difference between the groups in number of correct responses. Presumably, the hyperactive children were responding more rapidly than the control children in between their more frequent lapses in attention. This hypothesis could be tested by measuring directly the rate of correct responding in between blocks in the two groups of children.

The prediction that momentary lapses in attention would increase with time on the task in both groups of children but at a faster rate in the hyperactive subjects was only partially supported. The fact that both groups of subjects showed a significant increase in errors over time indicates that their attention to the task was increasingly subject to brief lapses. However, there was no evidence that such lapses increased at a faster rate in the hyperactive children than in the normal children. Thus, it might be concluded that although the sustained attention of the hyperactive children compared to the control children is subject to a higher overall frequency of momentary lapses in attention, the increase in the incidence of such lapses with time occurs at a similar rate in the two groups. There is of course, no direct evidence for this statement other than the fact that errors on the Serial Reaction Task increased at the same rate in the two groups. However, this statement could be tested by measuring directly the occurrence of blocks and their increased incidence with time in the two groups of children.

The most striking evidence for the hypothesis of an impairment in sustained attention in hyperactive children comes from the findings on the Continuous Performance Test. On this test the hyperactive children not only made more errors than the control children but also fewer correct responses. Furthermore, whereas the number of correct responses made by the normal children did not decline with time on the task, the number made by the hyperactive children did decline, at least from the 1st to the 2nd five minute period. Also, while the number of errors made by the control group declined with time on the task, errors made by the hyperactive group increased from the first to the second period.

There is reason to believe that the failure to detect and respond to the appearance of a significant stimulus on the Continuous Performance Test reflects a momentary lapse in attention which is coincident with the appearance of the significant stimulus (Rosvold,Mirsky,Sarason, Bransome and Beck, 1956; Kornetsky, Mirsky, Kessler and Dorff, 1959; Mirsky and Cardon, 1962). Thus it can be stated that the hyperactive children are more subject to such lapses than the control children since they detected fewer significant stimuli than the controls. The finding that correct responses declined with time on the task in the hyperactive group but remained at a constant level in the control group suggests, at first sight, that the hyperactive children became increasingly more subject to lapses in attention whereas the control children did not. This suggestion conflicts with the finding on the Serial Reaction Task that both groups of children became increasingly more subject to lapses with time. It was in fact expected that both groups of subjects would show a significant decline in the detection of significant stimuli over time on the Continuous Performance Test. The failure of the control children to show any decline in their detection of significant stimuli with time on the task does not necessarily imply, in the present author's view, that they did not become increasingly more subject to brief lapses in attention with time. It is possible that the lack of decline in correct responding is related to the interstimulus interval of 1.5 seconds used in the present study. Broadbent (1958) has suggested that in adults the length of time it takes to switch attention twice is approximately 1.5 seconds. Thus, on the Continuous Performance Test an interstimulus interval of 1.5 seconds would allow a subject time to switch his attention away from the task and back to the task in between the appearance of two consecutive stimuli. There is evidence that the detection of significant stimuli is more accurate with a 1.5 second interstimulus interval than with a shorter interval. In an earlier study (Sykes, Douglas, Weiss and Minde (unpublished study), it was found that both normal and hyperactive children detected more significant stimuli on a visual Continuous Performance Test when the interstimulus interval was 1.5 seconds as compared to 1.0 second. However, it was not possible to state from this earlier study whether the control children showed a decline in correct responding over time at the 1.0 second interstimulus interval, as changes in detection over time were not examined. This explanation is of course tentative and must wait for its verification on future research. It would be quite possible to systematically vary the interstimulus interval on the Continuous Performance Test and examine the relative incidence of correct responding in the two groups of children. If the explanation were correct then one would expect to find a decline in the rate of correct responding in the normal children at the faster interstimulus interval. If the explanation is true, then the fact that the hyperactive children detected fewer significant stimuli than the control children suggests that their lapses in attention are of longer duration than those of the control children, and that they are unable therefore to switch their attention from task-relevant information and back again within the short period of time allowed on the task (1.5 seconds).

The incidence of errors on the Continuous Performance Test also differed significantly in the two groups of children. Not only did the hyperactive children make significantly more errors than the control children, but the incidence of errors increased with time on the task in the hyperactive group but declined in the control group. It was suggested on the basis of studies of performance on vigilance tasks (Broadbent, 1958;Mackworth, 1968) that errors on the Continuous Performance Test reflected a decreased sensitivity on the part of the observer which affects his ability to distinguish between significant and non-significant stimuli. Thus, not only the failure to detect a significant stimulus but also a response to a non-significant stimulus was believed to reflect impaired attentiveness. Jerison, Pickett and Stenson(1965) suggested that false-alarms, or the reporting of a non-signal event as a signal, was the result of blurred observing, which reflects a reduced state of attentiveness. It is important to note, however, that there is reason to believe that not all of the errors made on the Continuous Performance Test are due to impaired attentiveness.

Inspection of the records of the individual subjects reveals that a large proportion of errors fall into three broad categories, namely slow responses to significant stimuli, responses to part of the significant stimulus, and random responses to non-significant stimuli. The hyperactive children made significantly more errors of all types than the control children on both forms of the test (visual and auditory), with the exception that both groups made the same number of slow responses on the auditory form of the Continuous Performance Test.

A slow response is one made to a significant stimulus but which occurs too late to be included in the count of correct responses. There is reason to believe that slow responses reflect impaired attentiveness. Broadbent (1958) points out that in continuous work or on a vigilance task, the latency of detection of signals increases with time. In other words, the subject is slower to respond to the appearance of the signal. Broadbent suggests that this is due to the fact that the stimulus is not immediately processed, the subject's attention being elsewhere at the time the stimulus arrives. Thus, when it is processed, the result is a delayed or slow response. If it is accepted that a slow response reflects impaired attention, then one would expect a higher incidence of such responses on a task which is more susceptible to brief lapses in attention. Therefore, there should be more slow responses on the auditory than on the visual Continuous Performance Test, since both groups of children in the present study made significantly fewer <u>correct</u> responses on the auditory Continuous Performance Test . This in fact was the case. Both groups of children made significantly more errors that could be categorized as slow responses on the auditory than on the visual Continuous Performance Test.

Whereas slow responses suggest impaired attention, incorrect responses to parts of the significant stimulus (X preceded by A), for example, to the letter A alone, suggest to the present author an inability on the part of the subject to inhibit an incorrect response, rather than any confusion as to the identity of the stimulus due to lowered attentiveness. There is some evidence for this interpretation. The incidence of this type of error declined in the control group with time on the task. This suggests that normal children learn to inhibit these errors. Also, the hyperactive children when they returned two or four weeks later for retesting on placebo also made significantly fewer such errors than they had originally, although the number of correct responses was no different from initial testing. Furthermore, after making errors of this type the control children particularly would often make a facial grimace which implies that they were aware that they had made a mistake.

An alternative explanation, derived from vigilance studies, is that the decline in errors with time on the task reflects a reduced level of arousal (Mackworth, 1968). However, this explanation is not exceptable since a reduced level of arousal should also produce a decline in the rate of correct responses and this was not found in the control group.

While it is reasonable to believe that slow responses reflect impaired attentiveness and incorrect responses to part of a significant stimulus a lack of inhibitory control, it is by no means certain what the random responses to non-significant stimuli reflect. They may be the result of impaired attentiveness or of impulsivity.

In addition to the three types of errors just mentioned, the hyperactive children also made significantly more multiple responses than the control children. A multiple response is one where the child presses more than once in rapid succession. It is reasonable to believe that such a response reflects a lack of inhibitory control.

Finally, it was found on the Continuous Performance Test that the hyperactive children compared to the control children made many more non-observing responses, that is periods when they were not looking at the screen. It should be pointed out however, that the incidence of such non-observing behaviours while significantly greater in the hyperactive group than in the control group was still relatively low, and could not account for the significant differences between the two groups in their ability to detect significant stimuli.

In conclusion it may be stated that the sustained attention of hyperactive children in comparison to normal children is more susceptible to frequent brief lapses during which time the subject is largely insensitive to task-relevant material. These lapses were reflected in errors on the Serial Reaction Task, failure to detect significant stimuli and slow or delayed responses to significant stimuli on the Continuous Performance Test. Also there is evidence that hyperactive children are more impulsive than control children since they make significantly more multiple responses and impulsive errors on the Continuous Performance Test. These latter results support the findings of Conner and Greenfeld (1966) who found that hyperactive children lacked inhibitory control and Campbell, Douglas and Morgenstern (1969) who found that hyperactive children responded impulsively on a task requiring the abstraction of a simple figure from a complex one.

As to the nature of these brief lapses in attention, Broadbent (1958) suggested that they were due to the subject momentarily paying attention to task-irrelevant information at the expense of task-relevant information. This interpretation, in terms of distraction, is essentially the view of Cromwell, Baumeister and Hawkins (1963) who suggested that the overactivity of the hyperactive child might be a reflection of a short attention span and rapidly changing goal directions.

Whether the higher frequency of momentary lapses in attention in hyperactive children reflects central nervous system dysfunction or damage or a maturational delay in their development is uncertain. Mirsky and his colleagues (Mirsky,Primac, Marsan, Rosvold and Stevens, 1960; Lansdell and Mirsky, 1964) have implicated subcortical dysfunction, possibly biochemical in nature, as the reason for the impaired performance of centrencephalic epileptics and brain-damaged patients. However, it should be pointed out that the performance of the hyperactive children on the Continuous Performance Test is by no means as impaired as that of the brain-damaged children in the study by Rosvold, Mirsky, Sarason, Bransome and Beck (1956). In the Rosvold et al. study a group of brain-damaged children detected 46.26% of the significant stimuli. In contrast, the detection rate of a group of hyperactive children of similar age and intelligence as the children in the Rosvold et al. study, on a visual Continuous Performance Test with the same interstimulus interval and approximately the same task duration, was found to be 70.03% (Sykes, Douglas, Weiss and Minde, unpublished study). It is not possible to compare the scores of the hyperactive children with those of centrencephalic epileptics in Mirsky's studies, as all the epileptic patients tested were adults. It cannot be concluded, therefore, that the finding of impaired performance on both the Serial Reaction Task and the Continuous Performance Test in the hyperactive children necessarily implies subcortical dysfunction, although this remains a possibility, particularly in the light of the findings of Laufer, Denhoff and Solomons (1957) that hyperactive children had an abnormally low photo-Metrazol threshold.

An alternative view is that the impaired performance of the hyperactive children reflects a maturational lag. There are many studies which demonstrate that the ability to sustain attention and ignore irrelevant material is age dependent (Elliot, 1964,1966; Maccoby and Konrad, 1967; Hagen and Sabo, 1967; Grim, 1967). It is possible that the attentional deficit of hyperactive children represents simply a maturational lag rather than subcortical dysfunction. Further studies should therefore examine the sustained attention of older hyperactive children. If, as was suggested earlier (Cromwell, Baumeister and Hawkins, 1963), "hyperactivity" is taken to indicate rapid shifting of attention from one event to another, then studies already exist which suggest that hyperactivity (and by inference, short attention span) become less of a problem as hyperactive children grow older. For example, Lapouse and Monk (1958) found that younger children were more active than older children, while Weiss, Minde, Douglas, Werry and Nemeth (1969) found that in a five year follow-up of hyperactive children, the mean parental rating of hyperactivity was significantly reduced. Although these studies are suggestive, there is a need to study directly sustained attention in older hyperactive children before a "developmental lag" explanation of their impaired attention can be accepted.

In summary, hyperactive children were found on the Serial Reaction Task and the Continuous Performance Test to be inferior to normal children in their ability to sustain attention for long periods. It was suggested that they were more often subject to brief lapses in attention than normal children. In light of recent studies which have related impaired attention on vigilance tasks to changes in observing behaviour (Jerison, Pickett and Stenson, 1965) and in light of the suggestion that different aspects of impaired attention may be related to habituation of both the alpha block and the evoked potentials arising from the background stimulus events (Mackworth, 1968), it is suggested that future research should attempt to relate all these factors to the impaired performance of hyperactive children on both self- and experimenter-paced sustained attention tasks. Examination of observing behaviour, alpha block, evoked potentials, etc. would then enable more exact specification of both the nature and the factors involved in these lapses which are found more frequently in hyperactive children.

The Effect of Methylphenidate on Attention in Hyperactive Children.

Methylphenidate was found to have a number of beneficial effects on the performance of hyperactive children. The active drug significantly improved their performance on measures where they were found to do significantly more poorly than normal children, namely error responses on the Serial Reaction Task and correct and incorrect responses on the Continuous Performance Test. The drug also stopped the decline in correct responding from the seoond to the third period seen in the placebo group and significantly reduced impulsive responses (multiple presses) and non-observing behaviours. Furthermore, the drug improved performance of these subjects on measures where they showed no initial deficit relative to normal children, namely simple, choice and total reaction times on the Choice Reaction Time Task and correct responses on the Serial Reaction Task. Whether these latter effects are specific to hyperactive children or would also be true of normal subjects if they were given the drug is an important question for future research.

Thus methylphenidate improves the ability of the hyperactive child to maintain attention to a task over prolonged periods, presumably by reducing the frequency and duration of momentary lapses in attention. The drug also reduces impulsive responses on the Continuous

Performance Test and reduces the latency of responding on all three attention tasks. These findings are consistent with the results of other investigators. Campbell, Douglas and Morgenstern (1969) found that methylphenidate reduced impulsive responding in hyperactive children on a task which required the inhibition of an immediate response and Knights and Hinton (1969) found that the drug reduced the latency of responding in a similar group of children.

Various investigators have speculated as to the mode of action of methylphenidate. Conners, Eisenberg and Sharpe (1964) and Campbell, Douglas and Morgenstern (1969) suggest that it strengthens inhibitory controlling mechanisms. Werry, Sprague, Weiss and Minde(1969) suggest that it increases arousal such that the cortex can more effectively cope with incoming stimuli. The implication of this latter statement is that hyperactive children are at a relatively low level of general arousal prior to the administration of the drug. This is similar to the speculations of Laufer, Denhoff, and Solomons (1957) with respect to the action of amphetamine on hyperactive children. These authors suggested that the drug may act by raising the level of synaptic resistance in the area of the diencephalon. As a result the cortex would no longer be flooded by indiscriminate stimuli but would rather selectively reinforce and pattern incoming stimuli.

All of these authors realize the speculative nature of their suggestions. However, at the behavioural level it does seem clear that the drug improves the ability of hyperactive children to organize their behaviour more effectively. They appear to be less distracted by extraneous, task-irrelevant stimuli. This implies that incoming stimulation is more effectively filtered which suggests that inhibitory mechanisms are being selectively reinforced by the drug. It might however be the case that instead of merely strengthening the role of inhibitory mechanisms, the drug acts by selectively reinforcing the passage of task-relevant information through the cortex. It is now well established that there are reinforcement mechanisms in the brain (Olds and Milner, 1954; Olds,1962) and it is conceivable that they mediate between sensory events and behaviour. It is also conceivable that the drug acts selectively on these reinforcement mechanisms, for which there is some evidence in the case of amphetamine(to which methylphenidate is chemically related) (Stein, 1964; Stein and Wise, 1969).

It is frequently stated by the mothers of hyperactive children that their child can concentrate and be free from distraction if he is really interested. For example, hyperactive children may sit quietly and attentively for half an hour watching their favourite television programme. Thus, motivation or interest can selectively reinforce these children's attentive behaviours. Clinical observation suggests that something similar may be happening with the drug. A number of the mothers of hyperactive children commented that while on the drug their child, for the first time in his life, would spend long periods of time writing an essay, reading a book, making his bed etc. Thus it appears that not only is the ability to maintain attention increased with the drug, but it is possible that the drug acts selectively at the level of the reinforcement mechanisms mentioned above.

The above is of course, highly speculative, as little definite is known about the chemical action of the amphetamines let alone methylphenidate. However, the behavioural effects of the drug suggest that some selectively reinforcing mechanism may be affected by the drug.

Implications of the Study for Education

Although care must be taken when generalizing from the laboratory to the classroom, several suggestions concerning the education of hyperactive children may be made on the basis of the present findings. It should be noted however, that these suggestions are speculative and require careful experimentation prior to their implementation.

In view of the findings of the present study which indicate that hyperactive children can direct their attention for brief periods but have difficulty in maintaining attention on a task for long periods, it is suggested that they be given tasks broken up into short sections or steps. Upon completion of each section, there should be a short break from the task and then the child could be re-oriented to the next section by the teacher. The child,rather than the teacher, should determine the pace at which new material arrives. For it was shown in the present study that although the hyperactive children were impaired on a self-paced task (the Serial Reaction Task),they were far more impaired on an experimenter-paced task. In other words, a teaching machine which presents small bits of new information in systematic steps and which is regulated by the child himself would probably be better than the more conventional teaching methods used in most schools.

There is also evidence from the present study that both hyperactive and normal children attend more efficiently to visual than to auditory material. It is therefore suggested that in the case of hyperactive children particularly, attempts should be made when possible to present information through the visual modality.

The findings of the present study regarding the effects of methylphenidate on the performance of these children on attention tasks suggests that this drug might also help the child in a classroom setting. There is certainly a need to investigate the effect on academic performance of the long-term administration of methylphenidate. To the present author's knowledge, there are no studies available which examine the effect of methylphenidate for longer than two or three months. It cannot be assumed that the beneficial effects of the short-term administration of the drug will hold up over longer periods. There is also a paucity of good studies which examine the effectiveness of methylphenidate in conjunction with special educational techniques in reducing the school problems of hyperactive children. In view of the findings of Weiss, Minde, Douglas, Werry, and Nemeth (1969) that hyperactive children are seriously retarded academically, this is a particularly important area for future research.

SUMMARY

The performance of 20 hyperactive and 20 normal children was compared on three attention tasks, one requiring attention for brief periods on each trial (the Choice Reaction Time Task), and the other two requiring sustained attention for longer periods of from nine to fifteen minutes(the Serial Reaction Task and the Continuous Performance Test). The first of these latter two tests was self-paced, that is the subject could work at his own rate, while the second task was experimenter-paced or controlled.

Compared to normal children, hyperactive children were found to be impaired on both tests of sustained attention but not on the test requiring attention for brief periods of time. Moreover, hyperactive children appeared to do worse on the experimenter-paced than on the self-paced task.

The effect of the stimulant drug methylphenidate on the performance of hyperactive children on the three attention tasks was also examined . Compared to placebo, this drug was found to improve the scores of hyperactive children on all three tests, irrespective of whether they were inferior to normal subjects at initial testing on the tasks.

The differences found between the performance of hyperactive and normal children were explained in terms of a greater incidence of momentary lapses in attention in the former group and suggestions for the education of hyperactive children were advanced.

REFERENCES

American Medical Association, Council on Drugs. Journal of the American Medical Association, 1958, 166, 1040.

BAIR, H.V. & HEROLD, W. Efficacy of chlorpromazine in hyperactive mentally retarded children. A.M.A. Archives of Neurology and Psychiatry, 1955, 74, 363-364.

BAKER, C.H. Observing behavior in a vigilance task. Science, 1960, 132, 674-675.

BERLYNE, D.E. The influence of albedo and complexity of stimuli on visual fixation in the human infant. British Journal of Psychology, 1958, 49, 315-318.

BILLS, A.G. Blocking: a new principle of mental fatigue. American Journal of Psychology, 1931, 43, 230-245.

BILLS, A.G. A study of blocking and other response variables in psychotic, brain-damaged and personality-disturbed patients. Behavior Research and Therapy, 1964, 2, 99-106.

BINDRA, D. & AUCHEL, H. Immobility as an avoidance response and its disruption by drugs. Journal of the Experimental Analysis of Behavior, 1963, 6, 213-218.

BINDRA, D. & BARON, D. Effects of methylphenidylacetate and chlorpromazine on certain components of general activity. Journal of the Experimental Analysis of Behavior, 1959, 2, 343-350.

BRADLEY, C. Benzedrine and dexedrine in the treatment of children's behavior disorders. Pediatrics, 1950, 5, 24-37.

BROADBENT, D.E. Noise, paced performance and vigilance tasks. British Journal of Psychology, 1953, 44, 295-303.

BROADBENT, D.E. Perception and communication. New York: Pergamon Press, 1958.

BURKS, H.F. The hyperkinetic child. Exceptional Children, 1960, 27, 18.

CAMPBELL, Susan, DOUGLAS, Virginia & MORGENSTERN, G. Cognitive styles in hyperactive children and the effect of methylphenidate. Paper read at Canadian Psychological Association Annual Meeting, Toronto, June, 1969.

CARR, L.A. & MOORE, K.E. Norepinephrine release from brain by d-amphetamine in vivo. Science, 1969, 164, 322-323.

CARTER, C.H. & MALEY, M. Parenteral use of methylphenidate (Ritalin). Diseases of the Nervous System, 1957, 18, 146.

CLARIDGE, G.S. Personality and arousal. A psychophysiological study of psychiatric disorder. New York: Pergamon Press, 1967.

CLEMENTS, S.D. Minimal brain dysfunction in children. U.S. Department of Health, Education and Welfare, 1966.

CLEMENTS, S.D. & PETERS, J.E. Minimal brain dysfunction in the school-age child. Archives of General Psychiatry, 1962, 6, 185-197.

COHEN, Nancy, DOUGLAS, Virginia & MORGENSTERN, G. Psychophysiological concomitants of hyperactivity in children. Paper read at Canadian Psychological Association Annual Meeting. Toronto, June, 1969.

COLQUHOUN, W.P. & BADDELEY, A.D. Influence of signal probability during pretraining on vigilance decrement. Journal of Experimental Psychology, 1967, 73, 153-155.

CONNERS, C.K. The effect of dexedrine on rapid discrimination and motor control of hyperkinetic children under stress. Journal of Nervous and Mental Diseases, 1966, 142, 429-433.

CONNERS, C.K. & EISENBERG, L. The effects of methylphenidate on symptomatology and learning in disturbed children. American Journal of Psychiatry, 1963, 120, 458-464.

CONNERS, C.K., EISENBERG, L. & SHARPE, L. Effects of methylphenidate (Ritalin) on paired-associate learning and Porteus Maze performance in emotionally disturbed children. Journal of Consulting Psychology, 1964, 28, 14-22.

CONNERS, C.K., EISENBERG, L. & BARCAI, A. Effect of dextro-amphetamine on children: studies on children with learning disabilities and behavior problems. Archives of General Psychiatry, 1967, 17, 478-485.

CONNERS, C.K. & GREENFELD, D. Habituation of motor startle in anxious and restless children. Journal of Child Psychology and Psychiatry, 1966, 7, 125-132.

CONNERS, C.K. & ROTHSCHILD, G.H. Drugs and learning in children. In, Learning disorders, Volume 3. Seattle: Special Child Publications, 1968.

CREAGER, R.O. & VAN RIPER, Catherine. The effect of methylphenidate on the verbal productivity of children with cerebral dysfunction. Journal of Speech and Hearing Research, 1967, 10, 623-628.

CROMWELL, R.L., BAUMEISTER, A. & HAWKINS, W.F. Research in activity level. In Ellis, N.R. (Ed.), Handbook of mental deficiency. New York: McGraw-Hill, 1963.

DOUBROS, S.G. & DANIELS, G.J. An experimental approach to the reduction of overactive behavior. Behavior Research and Therapy, 1966, 4, 251-258.

DOUGLAS, Virginia, WEISS, Gabrielle & MINDE, K. Learning disabilities in hyperactive children and the effect of methylphenidate. Paper read at Canadian Psychological Association Annual Meeting. Toronto, June, 1969.

DRILL, V.E. Pharmacology in medicine. 2nd Edition. New York: McGraw-Hill, 1958.

EISENBERG, L., CONNERS, C.K. & LAWRENCE, S. A controlled study of the differential application of outpatient psychiatric treatment for children. Japanese Journal of Child Psychiatry, 1965, 6, 125-132.

ELLIOTT, R. Physiological activity and performance. A comparison of kindergarten children with young adults. Psychological Monographs, 1964, 78, No.10.

ELLIOTT, R. Physiological activity and performance in children and adults: a two year follow-up. Journal of Experimental Child Psychology, 1966, 4, 58-80.

ENDSLEY, R.C. Effects of differential prior exposure on preschool children's subsequent choice of novel stimuli. Psychonomic Science, 1967, 7, 411-412.

EPSTEIN, Lynn C., LASAGNA, L., CONNERS, C.K. & RODRIGUEZ, A. Correlation of dextro-amphetamine excretion and drug response in hyperkinetic children. Journal of Nervous and Mental Diseases, 1968, 146, 136-146.

ESCALONA, Sibylle K. The roots of individuality. Normal patterns of development in infancy. Chicago: Aldine, 1968.

ESCALONA, Sibylle K. & HEIDER, G. Prediction and outcome: a study of child development. New York: Basic Books, 1959.

EYSENCK, H.J. Reminiscence, drive and personality-revision and extension of a theory. British Journal of Social and Clinical Psychology, 1962, 1, 127-140.

FANTZ, R.L. Visual experience in infants: decreased attention to familiar patterns relative to novel ones. Science, 1964, 146, 668-670.

FELLOWS, B.J. The discrimination process and development. New York: Pergamon Press, 1968.

FERGUSON, G.A. Statistical analysis in psychology and education. New York: McGraw-Hill, 1959.

FISH, Barbara. Drug therapy in child psychiatry: psychological aspects. Comprehensive Psychiatry, 1960, 1, 55-61.

FLAVELL, J.H. & HILL, J.P. Developmental psychology. In Mussen, P.H. & Rosenzweig, M.R. (Eds.) Annual review of psychology. Palo Alto: 1969, 20, 1-56.

FREEDMAN, A.M., EFFRON, A.S. & BENDER, L. Pharmacotherapy in children with psychiatric illnesses. Journal of Nervous and Mental Diseases, 1955, 122, 479-486.

FREEMAN, R.D. Drug effects on learning in children - a selective review of the past thirty years. Journal of Special Education, 1966, 1, 17-37.

FREGLY, M.J. & BLACK, B.A. Effect of methylphenidate on spontaneous activity, food intake and cold tolerance of propylthiouracil-treated rats. Canadian Journal of Physiology and Pharmacology, 1964, 42, 415-429.

FREIBERGS, Vaira. Concept learning in hyperactive and normal children. Ph.D. thesis, McGill University, Montreal. August, 1965.

FREIBERGS, Vaira and DOUGLAS, Virginia. Concept learning in hyperactive and normal children. Journal of Abnormal Psychology, 1969. In press.

FRIES, M.E. Some hypotheses on the role of congenital activity type in personality development. International Journal of Psychoanalysis, 1954, 35, Part 6.

FRIES, M.E. & WOOLF, P.J. Some hypotheses on the role of congenital activity type in personality development. In The psychoanalytic study of the child Vol.VIII. New York: International Universities Press, 1953, 48-62.

GASTAUT, H. Combined photic-Metrazol activation of the brain. Electroencephalography and Clinical Neurophysiology, 1950, 2, 249.

GRIM, P.F. A sustained attention comparison of children and adults using reaction time set and the GSR. Journal of Experimental Child Psychology, 1967, 5, 26-38.

HAGAN, J. & SABO, R. A developmental study of selective attention. Merrill-Palmer Quarterly, 1967, 13, 159-171.

HENRY, F.M. Independence of reaction time and movement time and equivalence of sensory motivators of faster response. Research Quarterly of the American Association for Health, 1952, 23, 43-53.

HERRINGTON, R.N. The effect of amphetamine on a serial reaction task. Psychopharmacologia, 1967, 12, 50-57.

HOHLE, R.H. Component process latencies in reaction times of children and adults. In Lipsitt, L.P. & Spiker, C.C. (Eds.) Advances in child development and behavior, Vol. 3. New York: Academic Press, 1967.

JACOBSON, E. The comparative pharmacology of some psychotropic drugs. Bulletin of the World Health Organization, 1960, 21, 411-493.

JEFFREY, W.E. The orienting reflex and attention in cognitive development. Psychological Review, 1968, 75, 323-334.

JERISON, H.J. Signal detection theory in the analysis of human vigilance. Human Factors, 1967, 9, 285-288.

JERISON, H.J., PICKETT, R.M. & STENSON, H.H. The elicited observing rate and decision processes in vigilance. Human Factors, 1965, 7, 107-128.

KABARA, J.J. & RIEGEL, Carol A. Effect of methylphenidate on the incorporation of specifically labeled glucose. Biochemistry and Pharmacology, 1965, 14, 1928-1930.

KNIGHTS, R.M. & HINTON, G. The effects of methylphenidate (Ritalin) on the motor skills and behaviour of children with learning problems. Journal of Nervous and Mental Diseases, 1969. In press.

KNOBEL, M., WOLMAN, M.B. & MASON, E. Hyperkinesis and organicity in children. Archives of General Psychiatry, 1959, 1, 310

KORNETSKY, C., HUMPHRIES, O. & EVARTS, E.V. A comparison of the psychological effects of certain centrally acting drugs in man. Archives of Neurology and Psychiatry, 1957, 77, 318-324.

KORNETSKY, C., MIRSKY, A.F., KESSLER, Edith K. & DORFF, J.E. The effects of dextro-amphetamine on behavioral deficits produced by sleep loss in humans. Journal of Pharmacology and Experimental Therapeutics, 1959, 127, 46-50.

LANSDELL, H. & MIRSKY, A.F. Attention in focal and centrencephalic epilepsy. Experimental Neurology, 1964, 9, 463-469.

LAPOUSE, Rema & MONK, Mary A. An epidemiologic study of behavior characteristics in children. American Journal of Public Health, 1958, 48, 1134-1144.

LAUFER, M.W. & DENHOFF, E. Hyperkinetic behavior syndrome in children. Journal of Pediatrics, 1957, 50, 463-474.

LAUFER, M.W., DENHOFF, E. & SOLOMONS, G. Hyperkinetic impulse disorder in children's behavior problems. Psychosomatic Medicine, 1957, 19, 38-49.

LEWIS, M., BARTELS, Betty, CAMPBELL, Helen & GOLDBERG, Susan. Individual differences in attention. The relation between infants' condition at birth and attention distribution within the first year. American Journal of Diseases of Children, 1967, 113, 461-465.

LEWIS, M., GOLDBERG, Susan & RAUSCH, M. Attentional distribution as a function of novelty and familiarity. Psychonomic Science, 1967, 7, 227-228.

LEVY, S. Postencephalitic behavior disorder - a forgotten entity. A report of 100 cases. American Journal of Psychiatry, 1959, 115, 1062-1067.

LEVY, S. & PERRY, H.A. Phenylpyruvic acid factor in mental deficiency and mental illness. American Journal of Mental Deficiency, 1949, 54, 73-80.

LURIA, A.R. The nature of human conflicts. New York: Liveright, 1932.

LYTTON, G.J. & KNOBEL, M. Diagnosis and treatment of behavior disorders in children. Diseases of the Nervous System, 1958, 20, 334-344.

MACCOBY, Eleanor E. & KONRAD, K.W. The effect of preparatory set on selective listening: developmental trends. Monographs of the Society for Research in Child Development, 1967, 32, 1-29.

MacKEITH, R. & PAX, M. (Eds.) Minimal cerebral dysfunction. London: Heinemann Medical Books, 1963.

MACKWORTH, Jane F. Vigilance, arousal and habituation. Psychological Review, 1968, 75, 308-322.

MACKWORTH, N.H., KAPLAN, I.T. & METLAY, W. Eye movements during vigilance. Perceptual Motor Skills, 1964, 18, 397-402.

MARRIOTT, A.S. The effects of amphetamine, caffeine and methylphenidate on the locomotor activity of rats in an unfamiliar environment. International Journal of Neuropharmacology, 1968, 7, 487-491.

MEIER, J.G., GROSS, F. & TRIPOD, J. Ritalin: a new type of synthetic compound with specific central-stimulating active components. Klinische Wochenschrift, 1954, 32, 445-450.

MENDELSON, J. & BINDRA, D. Combination of drive and drug effect. Journal of Experimental Psychology, 1962, 63, 505-509.

MILLICHAP, J.G., AYMAT, F., STURGIS, Loretta H., LARSEN, Katherine W. & EGAN, Rosemary. Hyperkinetic behavior and learning disorders. American Journal of Diseases of Children, 1968, 116, 235-244.

MILLICHAP, J.G. & BOLDREY, E.E. Studies in hyperkinetic behavior. II. Laboratory and clinical evaluations of drug treatments. Neurology, 1967, 17, 467-472.

MILLICHAP, J.G. & FOWLER, G.W. Treatment of minimal brain dysfunction syndrome. Selection of drugs for children with hyperactivity and learning disabilities. Pediatric Clinics of North America, 1967, 14, 767-777.

MINDE, K., WEBB, G. & SYKES, D. Studies on the hyperactive child. VI. Prenatal and paranatal factors associated with hyperactivity. Developmental Medicine and Child Neurology, 1968, 10, 355-363.

MIRSKY, A.F. & CARDON, P.V. A comparison of the behavioral and physiological changes accompanying sleep deprivation and chlorpromazine administration in man. Electroencephalography and Clinical Neurophysiology, 1962, 14, 1-10.

MIRSKY, A.F. & KORNETSKY, C. On the dissimilar effects of drugs on the Digit Symbol Substitution and Continuous Performance Tests. Psychopharmacologia, 1964, 5, 161-177.

MIRSKY, A.F., PRIMAC, D.W. & BATES, R. The effects of chlorpromazine and secobarbital on the Continuous Performance Test. Journal of Nervous and Mental Diseases, 1959, 128, 12-17.

MIRSKY, A.F., PRIMAC, D.W., MARSAN, C.A., ROSVOLD, H.E. & STEVENS, Janice R. A comparison of the psychological test performance of patients with focal and non-focal epilepsy. Experimental Neurology, 1960, 2, 75-89.

MIRSKY; A.F. & ROSVOLD, H.E. The use of psychoactive drugs as a neuropsychological tool in studies of attention in man. In Uhr, L. & Miller, J.G. (Eds.) Drugs and behavior. New York: Wiley, 1960, 375-392.

MIRSKY, A.F. & ROSVOLD, H.E. Behavioral and physiological studies in impaired attention. In Votava, Z. et al. (Eds.) Psychopharmacological methods: proceedings of a symposium on the effects of psychotropic drugs on higher nervous activity. Oxford: Pergamon Press, 1963, 302-315.

MIRSKY, A.F. & TECCE, J.J. The analysis of visual evoked potentials during spike and wave activity. Epilepsia, 1968, 9, 211-220.

MIRSKY, A.F. & VAN BUREN, J.M. On the nature of the "absence" in centrencephalic epilepsy: a study of some behavioral, electroencephalographic and autonomic factors. Electroencephalography and Clinical Neurophsiology, 1965, 18, 348.

NEISSER, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

NORMAN, D.A. Memory and attention: an introduction to human information processing. New York: Wiley, 1969.

OLDS, J. Hypothalamic substrates of reward. Physiological Reviews, 1962, 42, 554-604.

OLDS, J. & MILNER, P. Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain. Journal of Comparative and Physiological Psychology, 1954, 47, 419-427.

OUNSTED, C. The hyperkinetic syndrome in epileptic children. Lancet, 1955, 2, 202-211.

PATTERSON, G.R. An application of conditioning techniques to the control of a hyperactive child. IN Ullman, L.P. & Krasner, L. (Eds.) *Case studies in behavior modification*. New York: Holt, Rinehart, Winston, 1964.

PATTERSON, G.R., JONES, R., WHITTIER, J. & WRIGHT, Mary A. A behavior modification technique for the hyperactive child. *Behavior Research and Therapy*, 1965, *2*, 217-226.

PENFIELD, W. & JASPER, H.H. *Epilepsy and the functional autonomy of the human brain*. Boston: Little Brown, 1954.

PLOTNIKOFF, N.P. & FITZLOFF, J. Effect of stimulants on isolated rats. *Archives of International Pharmacodynamics*, 1963, *145*, 421-429.

ROSVOLD, H.E., MIRSKY, A.F., SARASON, I., BRANSOME, E.D. & BECK, L.H. A continuous performance test of brain damage. *Journal of Consulting Psychology*, 1956, 20, 343-350.

ROGERS, M.E., LILIENFELD, A.M. & PASAMANICK, B. Prenatal and paranatal factors in the development of childhood behavior disorders. *Acta Psychiatrica Neurologica Scandinavia* (suppl. 102), 1955, 1-157.

SCHROEDER, S.R. & HOLLAND, J.G. Operant control of eye movements during human vigilance. *Science*, 1968, *161*, 292-293.

SCHULMAN, J.L., KASPAR, J.C. & THRONE, Frances M. *Brain damage and behavior. A clinical-experimental study*. Springfield, Illinois: Thomas, 1965.

SLATER-HAMMEL, A.T. Reaction time and speed of movement. *Perceptual Motor Skills Research Exchanges*, 1952, 4, 109-113.

SMITH, E.E. Choice Reaction Time: an analysis of the major theoretical positions. *Psychological Bulletin*, 1968, *69*, 77-110.

SPRAGUE, R.L., BARNES, K.R. & WERRY, J.G. Methylphenidate and thioridazine: learning, activity and behavior in emotionally disturbed boys. Unpublished study, Children's Research Center, University of Illinois, 1968.

SPRAGUE, R.L. & TOPPE, Lorraine K. Relationship between activity level and delay of reinforcement in the retarded. Journal of Experimental Child Psychology, 1966, 3, 390-397.

SPRAGUE, R.L., WERRY, J.S. & SCOTT, K.G. Effects of dextroamphetamine on activity level and learning in retarded children. Paper read at Midwestern Psychological Association Meeting, Chicago, May, 1967.

STEIN, L. Self-stimulation of the brain and the central stimulant action of amphetamine. Federal Proceedings, 1964, 23, 836-850.

STEIN, L. & WISE, C.D. Release of norepinephrine from hypothalamus and amygdala by rewarding medial forebrain bundle stimulation and amphetamine. Journal of Comparative and Physiological Psychology, 1969, 67, 189-198.

STEVENS, Janice R., SACHDEV, K. & MILSTEIN, V. Behavior disorders of childhood and the electroencephalogram. Archives of Neurology, 1968, 18, 160-177.

STEWART, M.A., PITTS, F.N., CRAIG, A.G. & DIERUF, W. The hyperactive child syndrome. American Journal of Orthopsychiatry, 1966, 36, 861-867.

STRETCH, R., BLACKMAN, D. & ALEXANDER, D. Some effects of methylphenidate on stimulus control of ratio avoidance behavior in the rat. Journal of the Experimental Analysis of Behavior, 1966, 9, 389-398.

STRETCH, R. & SKINNER, N. Methylphenidate and stimulus control of avoidance behavior. Journal of the Experimental Analysis of Behavior, 1967, 10, 485-493.

STRETCH, R. & DALRYMPLE, D. Effects of methyphenidate, pentobarbital and reserpine on behavior controlled by a schedule of inter-response time reinforcement. Psychopharmacologia, 1968, 13, 49-64.

SYKES, D.H., DOUGLAS, Virginia I., WEISS, Gabrielle & MINDE, K.K. Sustained attention in the hyperactive child and the effect of methylphenidate. Unpublished study, McGill University.

THOMAS, A., BIRCH, H.G., CHESS, Stella, HERTZIG, M.E. & KORN, S. Behavioral individuality in early childhood. New York: New York University Press, 1963.

THOMPSON, T. & SHUSTER, C.R. Behavioral pharmacology. New York: Prentice-Hall, 1968.

TISCHLER, B., GIBSON, W.C.., McGEER, E.G. & NUTTALL, J. Degrees of mental retardation in phenylketonurics. American Journal of Mental Deficiency, 1961, 65, 726-738.

TITCHENER, E.B. A text book of psychology. New York: MacMillan, 1910.

TOWNSEND, A.M. & MIRSKY, A.F. A comparison of the effects of meprobamate, phenobarbital and d-amphetamine on two psychological tests. Journal of Nervous and Mental Diseases, 1960, 130, 212-216.

TREISMAN, A.M. Contextual cues in selective listening. Quarterly Journal of Experimental Psychology, 1960, 12, 242-248.

TREISMAN, A. M. Selective attention in man. British Medical Bulletin, 1964, 20, 12-16.

WEISS, B. & LATIES, V.G. Enhancement of human performance by caffeine and the amphetamines. Pharmacological Reviews, 1962, 1, 1-36.

WEISS, Gabrielle, MINDE, K., DOUGLAS, Virginia, WERRY, J.S. & NEMETH, Elizabeth. Hyperactive children - five years later. Paper read at American Psychiatric Association Annual Meeting, Miami, May, 1969.

WEISS, Gabrielle, MINDE, K., DOUGLAS, Virginia, WERRY, J.S. & SYKES, D.H. A comparison of the effects of chlorpromazine, dextro-amphetamine and methylphenidate on the behaviour and intellectual functioning of the hyperactive child. Paper read at Canadian Psychiatric Association Annual Meeting, Toronto, June, 1969.

WEISS, Gabrielle, WERRY, J.S., MINDE, K., DOUGLAS, Virginia & SYKES, D.H. Studies on the hyperactive child V. Effect of chlorpromazine and dextroamphetamine on behaviour and intellectual functioning. Journal of Child Psychology and Psychiatry, 1969, 9, No.3-4.

WERRY, J.S. & SPRAGUE, R.L. Hyperactivity. In Costello, C.G. (edit.) Symptoms of psychopathology. New York: Wiley, In press.

WERRY, J.S., SPRAGUE, R.L., WEISS, Gabrielle & MINDE, K. Some clinical and laboratory studies of psychotropic drugs in children - an overview. In Smith, W.L. (Edit.) Symposium on higher cortical functions. Springfield, Illinois: Thomas, 1969 In press.

WERRY, J.S., WEISS, Gabrielle & DOUGLAS, Virginia. Studies on the hyperactive child I. Some preliminary findings. Canadian Psychiatric Association Journal, 1964, 9, 120-130.

WERRY, J.S., WEISS, Gabrielle, DOGAN, Kurtas, MINDE, K. & DOUGLAS, Virginia. Studies on the hyperactive child VII. Comparison of neurological findings between hyperactive, normal and neurotic children. Paper read at Canadian Psychiatric Association Annual Meeting, Toronto, June, 1969.

WILLIAMS, H.L., LUBIN, A. & GOODNOW, J.J. Impaired performance with acute sleep loss. Psychological Monographs, 1959, 73, 1-26.

WINER, B.J. Statistical principles in experimental design. New York: McGraw Hill, 1962.

WISE, C.D. & STEIN, L. Facilitation of brain self-stimulation by central administration of norepinephrine. Science, 1967, 163, 299-301.

WITTE, K.L. & CANTOR, G.N. Children's response speeds to the offset of novel and familar stimuli. Journal of Experimental Child Psychology, 1967, 5, 372-380.

WOODWORTH, R.S. & SCHLOSBERG, H. Experimental psychology. New York: Holt, 1954.

ZEAMAN, D. & HOUSE, Betty J. The role of attention in retardate discrimination learning. In Ellis, N.R. (Edit.) Handbook of Mental Deficiency. New York: McGraw Hill, 1963, 159-223.

ZRULL, J., WESTMAN, J., ARTHUR, B. & RICE, D. A comparison of diazepam, d-amphetamine and placebo in the treatment of the hyperkinetic syndrome in children. American Journal of Psychiatry, 1964, 121, 388-389.