CONCEPT LEARNING
IN HYPERACTIVE AND NORMAL CHILDREN

by

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INTRODUCTION

Hyperactivity is a common presenting symptom among children seen in psychiatric clinics, and refers to an excessive level of activity which is sufficiently sustained to become a serious source of complaint. Until recently interest in the hyperactive child was confined to the psychiatric literature. As a result, most of the information currently available deals with questions of diagnosis and treatment. The psychological functioning of the hyperactive child has received little attention, although some information on it has been presented in the form of incidental findings. In order to meet this need for objective, controlled data, a research project, in which the writer participated, was designed to study the behaviour of hyperactive children in a variety of test situations. The specific concern of the experiment reported in the present thesis was the behaviour of hyperactive children in a controlled learning situation, using a concept formation task.

Learning difficulties involving abstract or conceptual material have been mentioned in several descriptions of hyperactive children (Burks, 1957, 1960; Laufer, Denhof & Riverside, 1957; Laufer, Denhof & Solomons, 1957; Clements & Peters, 1962). The only objective evidence to support this contention, however, is the reasonably well established fact that hyperactive children tend to be retarded in academic achievement (Burks, 1960; Rosenfeld & Bradley, 1948). Since poor school performance can result from a number of different causes, the first aim of the present investigation was to determine whether or not hyperactive children have a true deficit of a conceptual nature. For this reason a concept learning task was chosen that would require

functioning at an abstract level for solution. In addition, variations were introduced in reinforcement schedule and intertrial interval, in an attempt to identify other variables that might produce learning decrements in hyperactive subjects.

A second aim of this study was to evaluate the effect of drug therapy on the learning efficiency of hyperactive children. Phenothiazine drugs (the so-called tranquilizers) have been reported as useful in the treatment of hyperactive patients and have become fairly widely used by therapists (Grant, 1962). A calming effect on behaviour and general clinical improvement have been reported in the clinical literature (Freed, 1957; Fish, 1960a, 1960b; Morris & Dozier, 1961). Little is known, however, of the effect of tranquilizers on other aspects of a child's functioning, particularly learning, and an urgent need for objective, controlled data is evident.

THE HYPERACTIVE SYNDROME

Hyperactivity can be found as one of the presenting symptoms in a number of different pathological conditions, including epilepsy (Bradley, 1950; Ounsted, 1955), mental deficiency (Bair & Herold, 1955; Carter & Maley, 1957), and childhood psychosis (Freedman, Effron & Bender, 1955; Fish, 1960). Apart from this, however, there is considerable agreement about the existence of a distinct and characteristic syndrome in which hyperactivity is the central and most important symptom (Kahn & Cohen, 1934; Bradley, 1955; Eisenberg, 1957; Laufer, Denhof & Riverside, 1957; Stevens & Birch, 1957; Levy, 1959; Burks, 1957, 1960; Kennard, 1960; Daryn, 1961; Clements & Peters, 1962). For reasons that are not known, the syndrome is most frequently found in school-age children and significantly more frequently in boys than in girls (Clements & Peters, 1962; Daryn, 1961; Burks, 1960). This syndrome has been variously referred to as the organic brain syndrome, post-encephalitic behaviour syndrome, hyperkinetic impulse disorder, Strauss syndrome, or hyperkinetic syndrome. As can be seen from the range in terminology, different workers tend to identify the syndrome with different specific aetiological factors, but the majority agree in stressing aetiology of an organic nature. Nevertheless, despite differences in opinion regarding the exact aetiology and differences in the nomenclature used, descriptions of the component symptoms are remarkably similar and include the following:

Hyperactivity - An excessive level of activity is undoubtedly the core symptom of the syndrome, to the extent that the whole syndrome is

often identified by its name. The patients are described as constantly in motion, running rather than walking, unable to sit still. Teachers complain that they cannot stay in their seat and constantly get up and disturb the classroom (Bradley, 1955; Eisenberg, 1957; Laufer, Denhof & Riverside, 1957; Sutherland, 1961; Clements & Peters, 1962). Much of this constant activity appears to be aimless, and the impression such a child leaves is one of "drivenness" (Kahn & Cohen, 1934).

Poor motor coordination - Hyperactive children are often described as awkward and clumsy. Either fine muscle performance (manual dexterity) or overall coordination (e.g. balance) may be involved, and in some cases both seem to be affected (Clements & Peters, 1962; Burks, 1960).

Distractibility - A short attention span and poor powers of concentration are considered typical of the hyperactive (Bradley, 1955; Eisenberg, 1957; Laufer, Denhof & Riverside, 1957; Clements & Peters, 1962). They are said to be "at the mercy of every sound and sight" (Eisenberg, 1957), presumably because of an inability to inhibit or exclude irrelevant sensory impressions.

Emotional instability - Descriptions of the hyperactive syndrome include a series of symptoms indicative of emotional instability, such as impulsiveness, low frustration tolerance and inability to delay gratification, hypersensitivity, irritability and frequent aggressivity (Bradley, 1955; Eisenberg, 1957; Laufer *et al.*, 1957 a; Levy, 1959; Sutherland, 1961; Clements & Peters, 1962). Rappaport (1964) has argued that such symptoms merely represent different aspects of the same underlying difficulty, i.e. inadequate impulse control and regulation.

Psychological Correlates of Hyperactivity

According to several sources, visual-motor difficulties are very frequent in hyperactive children. The evidence for this includes irregular, poorly formed handwriting, poor performance in copying geometric figures such as the Bender Gestalt Visual Motor Test, and on the Goodenough Draw-a-man or the House-tree-person tests (Clements & Peters, 1962; Burks, 1960; Levy, 1959; Laufer et al., 1957 a). Neither of these reports, however, included findings on any control subjects.

Little seems to be known of the intellectual functioning of hyperactives, apart from the frequent observation that their school performance is not satisfactory (Clements & Peters, 1962; Laufer et al., 1957 a; Rosenfeld & Bradley, 1948). These clinical observations are supported by the results of a more systematic study (Burks, 1960), in which hyperactive children were found to have marked reading difficulties and an average retardation of one year in academic achievement. IQ scores were also obtained in the same study, but no significant differences were found between the hyperactive and normal samples. According to Burks the only difference was that the hyperactive children showed more scatter in their subtest scores. Consistent patterns of deficiencies, however, could not be reliably determined.

Conceptual difficulties as characteristic of hyperactive children are reported by several authors (Clements & Peters, 1962; Burks, 1960; Rosenfeld & Bradley, 1948), without any supporting objective evidence. The main basis for these reports seems to be the children's poor academic performance, which is interpreted as resulting from specific learning defects in reading, spelling, or, in some cases, only arithmetic and number concepts. In discussing the nature of these

impairments, Clements & Peters (1962) refer to an impaired "capacity to receive, hold, scan, and selectively screen out stimuli in sequential order". Similarily, Burks (1960) suggests that the conceptual difficulties of the hyperactive reflect "inefficient patterning and processing (capabilities) of the brain". Other writers, however, have pointed out that the behavioural symptoms of the hyperactive child are such as to make adequate functioning in the classroom extremely difficult (Levy, 1959). Thus it is conceivable that school difficulties in the hyperactive do not stem from an impairment in intellectual capacity, but are by-products of the child's restlessness, inability to concentrate, etc.

The only objective evidence of relevance to this question comes from an experimental study by Switzer (1961), in which hyperactive boys were found to do more poorly than control groups of normal and hypoactive boys of the same age (8 and 12 years old). The task required reporting the sequence in which lights of different colours would go on in a horizontal array of identical boxes. It could be solved by memorizing either the list of colour names (verbal response), or the position of successively lit boxes (involving pointing, defined as a perceptuo-motor response). Hyperactive subjects, as compared to the other two groups, were found to give significantly more position than colour-naming responses. Within the framework of Werner's (1948) developmental theory, this funtioning at the perceptuo-motor, rather than the verbal-conceptual level, was interpreted as representing a maturational retardation in the hyperactive subjects. While these findings were not interpreted as representing a fundamental deficiency in the

hyperactive, they do support current clinical opinion in showing that hyperactive children do not function as readily at the "conceptual level".

There is a striking parallel between the cognitive deficits attributed to hyperactive children and the loss of conceptual ability or "abstract attitude" found in adult patients with frontal lobe damage (Goldstein & Gelb, 1918, 1924; Rylander, 1938; Nadel, 1938), or hemispheric lesions (Battersby, Krieger, Pollack & Bender, 1953). Similar deficits have also been reported for brain-injured children (Strauss & Lehtinen, 1947; Strauss, 1951). Considering the lack of direct evidence regarding cognitive functioning in hyperactives, the possibility arises that the descriptions discussed above may have been coloured by the widely held belief in an organic aetiology. Subjective bias in observation might easily arise, making the clinician hypersensitive to symptoms associated with brain damage and possibly neglectful of important evidence to the contrary. Because the aetiology of the syndrome is far from being conclusively established, the evidence will be discussed in the next section.

Aetiology of Hyperactivity

The first report of hyperactivity as the core of a distinct syndrome (Kahn & Cohen, 1934) was based on observations of patients with a history of encephalitis epidemica. These patients were described as having a surplus of drive, or inner impulsion, which was labelled "organic drivenness" and was attributed by the writers to damage at the brain-stem level. Since that time several lines of evidence linking the hyperactive syndrome to organic factors have been marshalled.

Results of conventional neurological examinations are usually negative in hyperactive children (Clements & Peters, 1962; Laufer et al., 1957 a; Burks, 1960). A high incidence of borderline or "soft" neurological signs, however, has been reported by a number of different investigators (Clements & Peters, 1962; Daryn, 1961; Burks, 1960; Sutherland, 1961). Unfortunately this finding is difficult to interpret because control subjects were not used for comparison. In a study where a control group was included, Kennard (1960) found equivocal neurological signs (such as dysfunctioning extraocular muscles, tremor of extended fingers, intention tremor and equivocal Babinski reflex) to be consistently more frequent among her mixed group of patients. The number of hyperactives in this group, however, was only 26% and separate data on them were not presented. Furthermore, the difference in incidence between the clinical and normal samples varied from symptom to symptom, but the magnitude of these differences was not submitted to statistical tests of significance.

Several authors have noted a greater incidence of abnormal electroencephalograms (EEG's) among children with disturbed behaviour than among control subjects (Jasper, Solomon & Bradley, 1938; Rabinovitch, 1956). Similar results for hyperactive subjects were reported by Burks (1960), who found that 57% of his sample of hyperactive children showed abnormal EEG tracings, as opposed to 9.6% of the normal control subjects. More than half of the abnormal tracings were of the paroxysmal, non-focal type. Other investigators, however, have failed to find a close correspondence between hyperactivity and any particular EEG pattern (Laufer et al., 1957 a; Knobel, Wolman & Mason, 1959; Daryn, 1961); many children with well-marked symptoms of the hyperactive

syndrome have normal EEG records, while a number of abnormal EEG's can be found in either disturbed children without the syndrome, or normal control subjects.

Some investigators have tried to establish a relationship between hyperactivity and a history of anoxia, febrile illness, and other potential sources of damage to the central nervous system. In a retrospective study of cases admitted to a children's psychiatric hospital (Rosenfeld & Bradley, 1948), a syndrome of six traits, including hypermotility and the related symptoms, was found to be eight times as frequent in children with a history of asphyxia neonatorum or pertussis than in a group of control patients. Similar results were obtained by Burks (1960) from a developmental questionnaire sent to parents of 4th grade children. In this case five times as many premature births were found among the hyperactive than among the control children. Burks also reported a higher incidence of births by Caesarean section, unusual presentation and anoxia among the hyperactives, as well as more records of meningitis, encephalitis, and blows on the head. The actual frequencies of occurrence of these incidents were not presented, however, and it is impossible to assess whether the differences between the hyperactive and control subjects were large enough to be meaningful. In general, these correlational studies must be interpreted with considerable caution, since they are based on retrospective data which may be distorted by selective bias in parents' recollections of traumatic incidents. Furthermore, many of the hyperactive children had no history of incidents that might have caused brain damage, while a number of the control subjects in Burks' (1960) study, who were normal in every way, had histories of asphyxia, pertussis, etc. Finally, in a longitudinal study of 50

babies with severe neonatal asphyxia (Fraser & Wilks, 1959), none were found to be hyperactive in the follow-up examination.

In summary, the evidence linking hyperactivity to various signs of brain damage is largely inconclusive. Signs indicative of brain damage, or at least suggestive of it, are present in some hyperactive patients and absent in others. Because of the number of patients in whom organic involvement cannot be demonstrated, a few writers have argued that hyperactivity in these cases is simply a manifestation of anxiety or a reaction to environmental stress (Blau, 1954; Pond, 1961). Others have gone to the opposite extreme and propose that a diagnosis of brain injury be made on the basis of the behavioural symptoms alone, even in the absence of any other evidence (Strauss & Lehtinen, 1947; Laufer et al., 1957 a; Levy, 1959; Clements & Peters, 1962).

What the majority of clinicians seem to agree upon, is that the hyperactive syndrome can be better understood from a physiological or organic point of view than within a conventional "psychodynamic" framework (Bradley, 1955; Burks, 1957, 1960; Clements & Peters, 1962; Comly, 1955; Eisenberg, 1957; Kennard, 1960; Knobel et al., 1959; Laufer et al., 1957 a, 1957 b; Levy, 1959; Morris & Dozier, 1961; Ounsted, 1955; Sutherland, 1961). Furthermore, in the more recent literature, there is agreement that brain damage in the sense of definite loss of tissue accounts for only a minority of cases with the hyperactive syndrome. Beyond that, three different types of formulations have been presented. The first hypothesis is that, at least in some cases of the hyperactive syndrome, there must be brain damage of either a minimal, borderline, or diffuse nature (Clements & Peters, 1962; Kennard, 1960; Bradley, 1955). These would be the patients with abnormal EEG's, "soft" neurological

signs, etc. The second, broader, formulation is that a functional disturbance of the central nervous system must be involved (Clements & Peters, 1962; Sutherland, 1961; Laufer, 1962). Such functional disturbance may have been triggered by specific traumata (e.g. anoxia) in some cases, but may be due to naturally occurring constitutional deviations in others. Chess (1960), for example, has proposed that hyperactivity be considered as representing one extreme end of a continuum of activity, the level of activity being a trait normally distributed in the population. An advantage of the notion of functional disturbance is that it avoids much of the confusion that has come to surround the use of the term "brain damage" (Sarason, 1949; Wortis, 1956; Eisenberg, 1957; Haynes & Sells, 1963). Finally, the third hypothesis conceives of the hyperactive syndrome as due to developmental retardation, or "maturational lag" (Knobel et al., 1959; Switzer, 1961). This hypothesis is supported by the clinical observations that hyperactive children tend to behave more like younger children than normal children of their own age, and by the finding that the hyperactivity tends to subside by the time a child reaches adolescence (Laufer, Denhof & Riverside, 1957; Levy, 1959).

With respect to a possible locus for either the dysfunction or the damage causing hyperactivity, the available evidence is limited and inconclusive. The argument has been advanced (Knobel, Wolman & Mason, 1959) that hyperactivity must involve a disturbance in the reciprocal innervations between the cerebral cortex and the diencephalon. This notion is consistent with available neurophysiological data (Stanley & Janes, 1949; Dusser de Barenne, Garol & McCulloch, 1942; Freeman &

Krasno, 1940; Mettler, 1935), which tend to indicate that the frontal cortex, acting through the caudate nucleus, normally exerts a suppressive influence on motor activity. Knobel et al. suggest that this inhibitory influence of the cortex is late in developing in hyperactive patients because of delayed maturation of the cortical neurons. This hypothesis finds some support in the paradoxical finding that hyperactivity is reduced by dextroamphetamine sulphate (Bradley, 1955; Levy, 1959), a stimulant presumed to act directly on the cortex. Laufer and his associates (1957b), on the other hand, have evidence suggesting the diencephalon as the locus for the difficulty. Hyperactive patients in this study were found to have significantly lower photo-Metrazol thresholds than a mixed diagnostic group who were not hyperactive. Low photo-Metrazol thresholds have been shown in other studies (Gastaut, 1950; Gastaut & Hunter, 1950), to indicate damage to, or dysfunction of the diencephalon. In view of the limited evidence supporting each hypothesis, it is difficult to arrive at definite conclusions, especially since the question of damage or dysfunction itself is far from being settled.

CHLORPROMAZINE

Experimental and Physiological Findings

The behavioural effect of chlorpromazine hydrochloride is "tranquilization" and includes reduced responsiveness to external stimuli, decreased motor activity, and depressed conditioned reflexes (Brodie, Sulser & Costa, 1961). Small doses of chlorpromazine are sufficient to reduce spontaneous locomotor activity in mice, rats, cats and monkeys (Dasgupta & Werner, 1955; Baruk, Launay & Berges, 1957; Bradley & Hance, 1957; Kaada & Bruland, 1960). Large doses have been found to depress both clinging and play responses in juvenile wild-born chimpanzees (Mason, Fitz-Gerald & Chang-Yit, 1963). Stereotyped behaviour in isolation-reared chimpanzees is also reduced by chlorpromazine (Fitz-Gerald, 1964). Conditioned avoidance responses are blocked under the influence of chlorpromazine in rats, even though the animals are still capable of responding to the unconditioned stimulus (Courvoisier, Ducrot & Julou, 1957; McMurray & Jacques, 1959; Weissman, 1959). In an experiment where discriminative stimuli were available to the animals (Ray & Marrazzi, 1961), chlorpromazine increased response latencies to the shock signal but had no effect on responses to the food signal.

The action of chlorpromazine on the electrical activity of the brain includes increased EEG synchronization and reduction of the activating responses produced by peripheral sensory stimulation (Unna & Martin, 1957; Kaada & Bruland, 1960) or by electrical stimulation of cortical, intralaminar thalamic and amygdaloid regions (Kaada & Bruland, 1960). EEG activation from direct reticular stimulation, on the other hand, is

not significantly affected by chlorpromazine (Bradley, 1957; 1959; Bradley & Elkes, 1957; Bradley & Hance, 1957; Killam, 1957; Killam & Killam, 1958). These findings tend to support Bradley's (1957) hypothesis that the specific action of chlorpromazine is to interfere with the sensory collateral input to the reticular formation, and not to the reticular neurons themselves. According to Kaada & Bruland (1960), however, the site of action of chlorpromazine in the central nervous system still remains a matter of conjecture. The neural substrate of the "attention reflex" (EEG activation) is not sufficiently known to allow definite statements as to where this reaction is blocked by chlorpromazine.

Performance decrements on simple sensori-motor tasks are typically found in studies using adult normal volunteers under acute doses of chlorpromazine (Delay, Pichot, Nicolas-Charles & Perse, 1959; Kornetsky, Humphries & Evarts, 1957; Kornetsky & Humphries, 1958; Primac, Mirsky & Rosvold, 1957; Mirsky, Primac & Bates, 1959; Schneider, 1960). Two tests on which decrements under chlorpromazine are quite consistent are the Digit Symbol Substitution Test (Kornetsky et al., 1957; Kornetsky & Humphries, 1958) and the Continuous Performance Test, a task requiring sustained and concentrated attention (Rosvold, Mirsky, Sarason, Bransome & Beck, 1956; Primac et al., 1957). The Digit Symbol Test is also considered to require concentrated attention, in addition to good visuo-motor coordination and an element of learning (Wechsler, 1944). Mirsky & Rosvold (1960) attribute these results to impaired attentiveness produced through the depressant action of chlorpromazine in the region of the mid-brain reticular formation. In support of this interpretation, Mirsky & Rosvold point out the similarity of chlorpromazine-produced decrements with those obtained

under sleep deprivation (Kornetsky, Mirsky, Kammen & Dorff, 1959). Furthermore, the EEG records of Ss under chlorpromazine were found to have common features with those of centrencephalic patients (Elkes, 1958).

Clinical Findings.

An enormous body of literature has accumulated since the first English-language report on the therapeutic benefits of chlorpromazine hydrochloride (Delay, Deniker & Harl, 1952). Thus in Bennet's 1957 review of studies published in the 1952-1956 4-year period, a total of 962 references were listed.

Numerous reports of the clinical effectiveness of chlorpromazine have been made on the basis of uncontrolled clinical trials, usually on series of patients belonging to widely different diagnostic categories. Most of these are not studies in the proper sense of the word, since they make no concession to the basic rules of experimental procedure. Even the most elementary precautions against subjective bias are frequently not taken. In an uncontrolled clinical trial with a mixed diagnostic group, Carter & Maley (1957) found chlorpromazine to be particularly effective in hyperactive, hyperirritable mental defectives. Overall clinical improvement under chlorpromazine, involving more subdued and cooperative behaviour has been further reported in emotionally disturbed or immature hyperactive patients (Freed, 1957; Fish, 1960a, 1960b; Morris & Dozier, 1961), in hospitalized acting-out patients (Flaherty, 1955), and in mixed groups of emotionally disturbed children (Gatski, 1955; Hunt, Frank & Krush, 1956). Reports based on uncontrolled trials, however, must be viewed with considerable caution, since they may well reflect the enthusiasm of the investigators or a "placeboid" response (Poser, 1964) on the part of the patients or their parents, rather than any genuine effects of the chemical agent.

Favourable changes under chlorpromazine have also been reported on the basis of more controlled studies. While the quality of the research methods used tends to be rather uneven, the following studies had at least minimal controls such as a placebo group or condition. A reduced level of activity was reported by Bair & Herold (1955) for 10 hyperactive institutionalized defectives receiving the drug, as compared to a group receiving a placebo. In a larger study comparing drug and placebo groups for different diagnostic categories (Freedman, Effron & Bender, 1955), a higher percentage of improved cases under chlorpromazine was found among the small samples of organic and hyperactive schizophrenic children. Improvement during chlorpromazine administration was also reported in an own-control study of 25 hyperactive emotionally disturbed children (Freed & Peifer, 1956). Finally, a striking improvement in muscle control and coordination was produced for several hours after injection in a group of severely spastic patients (Basmasian & Szatmari, 1955).

Two other investigations, however, have reported no clinical improvement. In a controlled study of hospitalized emotionally disturbed children, Lane, Huber & Smith (1958), found no significant differences in behaviour ratings after chlorpromazine treatment. More recently, Garfield et al. (Garfield, Helper, Wilcott & Muffly, 1962) also failed to demonstrate any superiority of chlorpromazine over placebo for the same type of subjects. It must be noted, however, that these negative results were obtained on mixed groups of emotionally disturbed children, only a few of whom were hyperactive.

In a general review covering the use of tranquilizers, Weatherall (1962) suggested that, in spite of the enthusiasm these drugs have generated, they might produce only limited therapeutic effects.

Grant (1962), on the other hand, in a review of the use of drugs in child psychiatry, concluded that there were strong indications for the effectiveness of chlorpromazine in reducing excessive levels of activity. Further systematic research is plainly necessary before more definite conclusions can be drawn.

Effects of Chlorpromazine on Learning and Intellectual functioning.

To the best of the writer's knowledge, only one controlled, double-blind study on the effects of chlorpromazine on learning in children has been published to date (Helper, Wilcott & Garfield, 1963). Two simple learning tasks were used in this study, an 8-item paired-associate task, and a 10-item serial learning task. Chlorpromazine was found to produce a significant decrement on paired-associate learning, especially on the later trials. Furthermore, the decrement was reversed following removal of the medication. No drug effects were found on the serial learning task or on the retention of either the serial or paired-associate material. Unfortunately a mixed diagnostic group was used in this study, and no attempt was made to correlate the observed drug reactivity with specific behavioural symptoms.

One other study refers to the effects of chlorpromazine on learning as one of the incidental findings. In describing the behavioural improvement in hyperactives receiving chlorpromazine, Freed & Peifer (1956) mention that learning also seemed to be facilitated. This statement, however, was apparently not based on systematic observations in an actual learning situation, but rather on the fact that most children received more favourable reports from their teachers while undergoing drug treatment. Considering how much of a nuisance a hyperactive child could be in a classroom, it is difficult to say whether these reports reflect the teacher's relief at a child being more quiet, or the fact that a calmer

child would have more opportunities for learning.

With respect to global measures of intellectual functioning, some improvement under chlorpromazine on the Wide-Range Achievement Test was also reported in the Freed & Peifer (1956) study. Since the results were only briefly referred to and the Ss served as their own controls, it is impossible to assess whether this finding represents practice effects, chance variation, or a reliable change due to medication.

Some information on the effect of chlorpromazine on cognitive processes is available from studies using acute doses of the drug on adult volunteers. Drug differences were found to be negligible on tasks involving a cognitive component, as opposed to simple sensorimotor tasks (Delay, Pichot, Nicolas-Charles & Perse, 1959; Lehman & Csank, 1957). When higher dosage levels were included, however, impairment was found on intellectual tasks, in addition to psychomotor retardation and drowsiness (Klerman & DiMascio, 1961).

Changes in IQ and other aspects of cognitive functioning following chlorpromazine treatment have been measured in a series of studies using either institutionalized mental defectives or hospitalized schizophrenic patients as Ss. Because of the particular severity and complexity of both these conditions, results of such studies remain difficult to interpret and contribute relatively little to an understanding of the effects of chlorpromazine on purely cognitive aspects of performance.

In a study which received wide attention at the time, Bair & Herold (1955) reported an increase in IQ following administration of chlorpromazine in their small sample of extremely hyperkinetic institutionalized mental defectives. The drug and placebo groups were not matched for severity of symptoms in this study, but the drug sample was made up of the ten most agitated and hyperactive patients in the

institution. As mentioned earlier, chlorpromazine was found to have a tranquilizing effect on these patients, so that they became more cooperative in the test situation. There were also indications that their muscle control and coordination, originally quite poor, were improved by the drug treatment. Two subsequent studies, using more representative samples of defectives (Isen, 1957; Durling, Esen & Mautner, 1956) failed to replicate the finding of increases in IQ. This suggests that the original IQ obtained on the Freed & Peifer patients was, in a sense, an underestimation of their potential. Possibly the effect of the drug was to allow them to function at their own optimal level by removing the spurious influence of their inability to sit still for a task, to execute movements requiring fine coordination, etc. The lack of significant effects on all the other, less agitated patients, strongly suggests that intellectual performance was not directly affected.

Among the studies on schizophrenic patients, the findings regarding the effects of chlorpromazine on intellectual functioning are quite contradictory. Improvements in IQ scores were reported in several studies (Kevitz, Carter & Addison, 1955; Petrie & LeBeau, 1956; Gilgash, 1957, 1961), while Abrams (1958) found that only the Similarities subtest of the Wechsler-Bellevue was significantly improved. These reports can be accepted only with considerable reservation, however, because of inadequacies in the treatment of the data which have been discussed in detail by Heilizer (1959). No drug effects could be demonstrated on most of the cognitive measures used in a series of other studies (Gibbs, Wilkens & Lauterbach, 1957; Daston, 1958; Grygier & Waters, 1958; Nikols, 1958), including an 8-item serial learning task (Whitehead & Thune, 1958). On the Porteus maze, decrements under chlorpromazine were reported by its originator (Porteus, 1957; Porteus & Barclay, 1957) but no significant drug changes were found in

two other studies (Mason-Browne & Borthwick, 1957; Grygier & Waters, 1958). Here again, the conclusion of the Porteus studies must be considered as only tentative because of a number of inadequacies in their execution (such as selecting the experimental and control patients from two different wards, adding subjects according to ill-specified and apparently varying criteria, and pre- and post-testing done by different experimenters). Finally, in a study by Vestre (1961), significant decrements were found in the retention of material learned under chlorpromazine, but acquisition was not affected.

In summary, the evidence on normal adult subjects is that acute doses of chlorpromazine do not affect intellectual performance, unless dosage is increased to the point of somnolence. Performance decrements were found on a paired-associate task, but not on serial learning, in one study using a mixed group of severely disturbed children. The evidence from studies on mental defectives and schizophrenics is far from conclusive, but tends to suggest the absence of drug effects on intellectual functioning.

The Present Investigation.

The favourable clinical reports on the action of chlorpromazine tend to suggest that this drug may be effective in reducing hyperactivity. Other reports, however, suggest that the drug may have no appreciable effect on behaviour. In view of the need for further evidence, the present investigation was designed to assess the action of chlorpromazine on a "target symptom" (Freyhan, 1959), hyperactivity, in a highly selected, homogeneous group of patients. Controlled evaluations of change were made in the overall project on a number of behaviour measures and psychological test scores. According to some clinicians (Freed & Peifer, 1956), any clinical improvement might

influence psychological functioning and drug effects such as reduced distractibility might lead to an improvement in learning ability. On the other hand, fears have been expressed (Eisenberg, 1959; Fish, 1960a) that tranquilization may be achieved at the cost of lowered mental activity. If this were so, the use of a tranquilizing drug on school-aged children could have serious consequences. One of the aims of the present study, therefore, was to assess the effects of chlorpromazine on the performance of hyperactive children on a concept learning task.

CONCEPT LEARNING

Concept learning was defined by Smoke (1932) as the process of developing a symbolic, but not necessarily linguistic, response, which is made only to members of a particular class of stimulus patterns and not to other stimuli. Developing the ability to distinguish exemplars from non-exemplars of the class one seeks to discriminate involves finding the predictive defining attributes appropriate in a given situation. In laboratory investigations of concept formation the appropriate classification is an arbitrary one chosen as correct by the experimenter.

Concept learning has been distinguished from ordinary rote serial or paired-associates learning because it does not lend itself to explanations based on a single-unit theory of S-R associations (Kendler, 1961, 1963; Kendler & D'Amato, 1955; Kendler & Kendler, 1959, 1962; Kendler, Kendler & Wells, 1960). A characteristic of concept formation is the learning of a common mediating response to a group of objects or situations (Osgood, 1953, p. 668). According to the mediation hypothesis, the external stimulus evokes an implicit symbolic cue in the subject. This, in turn, becomes the immediate stimulus leading to the overt classification or identification response.

In simple concepts the common characteristic may be a directly perceptual attribute of the stimulus such as shape, size or colour. In experiments using this type of concept the stimulus aspects to be responded to are imbedded in varying amounts of irrelevant information. The task requirement is therefore abstraction in the literal sense of "taking out", i.e. the singling out of the relevant stimulus attributes from the total configuration. Thus in Hull's (1920) classical study

using Chinese ideograms the subjects merely had to learn to discriminate instances which included a particular common radical (the "concept") from those which did not. Where relatively simple stimuli are used, (e.g. Suppes & Ginsberg, 1962), the subject may respond on either a rote or a conceptual basis. Consider, for example, a set of stimuli varying in colour (red and green) and in shape (circles and squares). A subject may respond correctly because he is choosing exemplars of the concept "red", or he may have learned a list of 4 paired-associate items (red circles and red squares require response 1, green circles and green squares require response 2). With more complex stimuli, involving several dimensions and several values along each dimension, correct responding on the basis of rote associations becomes increasingly difficult (Osler & Kofsky, 1964), since the memory load imposed by the total information available soon becomes overwhelming. Conceptual classification of the stimulus dimensions reduces problem difficulty up to a point, but, as the number of irrelevant dimensions is increased, concept formation also becomes more difficult (Archer, Bourne & Brown, 1955; Bourne, 1957; Bourne & Haygood, 1959; Bourne & Pendleton, 1958; Pishkin, 1960; Battig & Bourne, 1961; Meyer & Offenbach, 1962).

Efficiency of concept formation depends on the optimum utilization of information from two different sources: the stimulus display and the informative feedback following a response. In order to make proper use of the stimulus information, S needs the ability to single out dimensions or attributes of the stimulus complex, i.e. the ability for abstraction. Some dimensions must become temporarily salient, while responses to irrelevant cues inherent in the same stimuli must be inhibited. Saliency may be achieved by means of appropriate observing responses (Wyckoff, 1952; Kurtz, 1955; Atkinson, 1961; Wright, 1964), acquired

distinctiveness of cues (Rossman & Goss, 1951; Spiker, 1959), or the use of verbal labels, if available (Spiker, 1963; Norcross & Spiker, 1957). Ultimate success on a task, however, depends on S's ability to modify his responses as a function of task relevance, i.e. by taking informative feedback into account.

A theoretical analysis of discrimination and of concept learning has been made by a number of statistical learning theorists (Estes, 1950, 1964; Bush & Mosteller, 1951; Restle, 1955, 1962; Bower & Trabasso, 1963). These theorists consider learning as a stochastic process involving two distinct states: a learned state in which the correct response has a high probability approaching unity, and an unlearned state in which the correct response has only a chance probability of occurrence. The transition between these two states is seen as gradual by theorists who use the "linear operator model" (Estes, 1950; Bush & Mosteller, 1955; Bourne & Restle, 1959) and as discontinuous by those using an "absorbing Markov model" (Estes, 1960, 1964; Bower, 1962; Bower & Trabasso, 1963; Theios, 1963).

Several of these theories (Restle, 1962; Bower & Trabasso, 1963) assume that the S in a concept formation situation is selectively attending to or sampling cues from the stimulus display and that he is testing hypotheses regarding the relevance of these cues to the correct solution. This process resembles the "focus sampling" strategy (Bruner, Goodnow & Austin, 1956) which Ss were found to adopt when confronted with long series of different, complex stimuli. The advantage of the all-or-none as opposed to the incremental model in dealing with discrimination or concept learning is the allowance it makes for the availability of symbolic mediating processes to S. In addition, statistical theories have produced several techniques which have proved useful in the analysis of data

from concept formation experiments (Estes, 1964; Trabasso, 1963; Suppes & Ginsberg, 1963).

Consider a S in a concept formation situation who makes a response by choosing one hypothesis from the total set of strategies or hypotheses available to him. If the response is correct, the assumption is that S continues to use the same hypothesis. If the response is incorrect, S discards his hypothesis and resamples at random from the total set of hypotheses available to him (Restle, 1962). Whenever S makes an error, he has presumably not learned anything of relevance about the concept. The probability of his making a correct response on the next trial is still at the chance level, much as it was on the first learning trial. The probability of a correct response following an error is therefore constant throughout the learning sequence. As soon as S chooses the correct hypothesis, however, he should start on a criterion run of correct responses. Learning is thus terminated by the choice of a correct strategy. This means that, during precriterion trials, S's choices are based exclusively on two types of strategies. First, there are wrong strategies which would consistently lead to choosing the wrong stimulus alternative, such as "animals" instead of "flowers". Second, there are irrelevant strategies which may lead to either correct or incorrect responses depending on the extent to which their conceptual content overlaps with the concept correct in that particular situation (e.g. "things that are for girls" or "things that grow outside" for "flower"). It might be noted incidentally that a hypothesis may be irrelevant both because it is too specific ("two circles side by side" instead of "two shapes anywhere in the picture"), or because it is too general ("the smallest" or "the least" instead of just "two"). There is no <u>a priori</u> advantage to choosing more general or more "abstract" hypotheses in a concept formation task.

The representation of presolution errors as a stationary, independent binomial process includes the assumption that the S's memory of his past performance is seriously limited. In other words, S is sampling with replacement from the pool of hypotheses available to him (Restle, 1962). This assumption finds empirical support in a series of studies (Hovland & Weiss, 1953; Cahill & Hovland, 1960; Bourne, Goldstein & Link, 1964) where the majority of errors made in concept learning could be considered errors of memory, i.e. they were due to hypotheses incompatible with information provided by stimuli presented on earlier learning trials. This assumption seems particularly valid where, as in the present study, complex stimuli are presented in rapid succession. In other situations, however (Levine, 1963), the assumption of sampling without replacement may be more appropriate.

A slight modification of Restle's (1962) strategy-testing model has been proposed by Bower & Trabasso (1963). In this version concept learning is seen as depending on two main parameters. The first parameter reflects aspects of the S's perceptual processing of the stimulus information, including attention, and depends on such variables as the saliency of relevant and irrelevant cues, the discriminability of values of the relevant stimulus dimension, instructions, pretraining, etc. The second is the conditioning parameter which governs the association of particular stimulus values to responses and depends on variables such as completeness and immediacy of feedback information.

Under continuous reinforcement (CR) the critical feedback to S is provided by the non-reinforced (NR) trials, which are a signal to change his basis for responding. As for reinforced trials in the precriterion stage, they must be due to irrelevant hypotheses the concept content of which overlaps to some extent with the concept content of the correct hypothesis.

By leading to the repetition of an irrelevant hypothesis, reinforced trials thus merely retard the ultimate selection of the correct one. This prediction was supported in a study by Gormezano & Grant (1958) where increasing the partial validity of cues increased the number of reinforced responses to criterion, but had no effect on the number of errors.

Learning under CR should be facilitated by flexibility, or the readiness to discard a hypothesis after a minimum number of non-reinforcements (ideally - one). Having discarded the wrong hypothesis, S still has to decide what other hypotheses to use. The availability of different hypotheses, therefore, (or the ability to form them) should also have a facilitating effect on concept learning.

An analysis of concept learning under a partial reinforcement (PR) schedule has so far not been attempted by any of the statistical learning theorists. Under PR, errors consistently fail to produce reinforcement, but so do one half of the correct choices under a 50% schedule. Reinforced responses, when due to irrelevant hypotheses, retard the finding of the correct solution in the same way as under CR. But, in addition to this, non-reinforced trials also produce ambiguous feedback. If the NR was due to an error, the response strategy should be abandoned, but if the choice was based on a correct hypothesis, it should be repeated in spite of the NR. Since S has no way of distinguishing between these two possibilities, non-reinforcements are of little value in helping him reach the correct solution. Indeed, if S's performed strictly in accordance with the above learning models, concept learning under PR would be quite impossible.

One way of avoiding this difficulty is to inform S that correct responses will not necessarily be rewarded. Two basic strategies potentially leading to a correct solution now become possible. In the first strategy S does not discard his hypothesis after any single NR but instead continues

using it for an indeterminate number of trials. Eventually he would decide, on a probabilistic basis, whether the payoff rate is likely to indicate a correct or an irrelevant hypothesis on his part. Where, as in this study, S does not know what level of reinforcement to expect (i.e. what percentage of the correct responses are being reinforced), this strategy can easily lead to adopting an irrelevant hypothesis and a correct solution may never be reached.

The other possible strategy involves searching for any attributes that all the reinforced stimuli have in common, e.g. "every time I got it (the reinforcement) it seemed to be a flower, so I decided to pick flowers". The usefulness of this strategy is limited by the extremely rapid fading of the immediate visual trace (Sperling, 1960), but particularly by the limitations of the immediate memory span (Miller, 1956). Considering that, in the present experiment, a series of 150 different stimulus pairs were used to represent each concept, some form of encoding of the visual information presented clearly would be required in order to achieve a correct solution. Among Ss using this strategy, those able to encode information more rapidly would be more likely to reach a solution, other things being equal. Haber (1964) for example, has shown that the speed of encoding is positively related to accuracy. Learning should also be facilitated by the availability of verbal labels such as "flower", which would facilitate encoding.

A difficulty in analyzing the PR situation simply in terms of the processing of informative feedback is that the occurrence of non-reinforcements under PR has been repeatedly shown to produce a primary aversive motivational condition, frustration (Amsel, 1958, 1962; Amsel & Prouty, 1959; Amsel, Ernhart & Galbrecht, 1961). While the above were all runway experiments using rats as Ss, the frustrative effects of nonreward have been

demonstrated as well in token-reward situations with children (Lambert, Lambert & Watson, 1953; Kendler, Kendler, Pliskoff & D'Amato, 1958; Penney, 1960; Longstreth, 1960; Holton, 1961). According to Amsel (1962), a secondary form of frustration develops over a series of learning trials through a process of classical conditioning and is referred to as r_f, or fractional anticipatory frustration. This, in turn, is seen as producing two different effects which are in competition during the intermediate phase of the learning sequence: activating, or drive effects, and inhibitory effects producing a partial decrease in strength of the instrumental response. Under PR in the straight runway situation, these conflicting tendencies are resolved by the conditioning of r_f to the instrumental approach response. This results in increased vigour of responding in the later stages of learning and also provides a mechanism for explaining the increased resistance to extinction (the "Partial Reinforcement Effect") commonly found following PR training (Jenkins & Stanley, 1950; Lewis, 1960). In discrimination learning situations, which can be considered as a particular case of PR (100% reinforcement becomes possible only after the discrimination has been mastered), differential cues are available for the elicitation of approach and avoidance responses. The conflict mentioned above is simply resolved by increasing approach tendencies to the positive stimulus and increasing avoidance of the negative stimulus.

One of the conditions used in the present study involved conceptual discrimination under a PR schedule which, according to Amsel's theory, should generate a considerable amount of frustration. The discriminatory cues in the stimuli used, however, were more conceptual than perceptual in nature. Thus incremental conditioning of an approach response to the positive stimuli would be extremely difficult, if not impossible, because

of the lack of common perceptual elements. The inhibitory effects of frustration would be expected to remain dominant and to produce performance decrements in all Ss. Furthermore, since hyperactive children are considered to have a low frustration tolerance, this formulation would predict a greater performance decrement in hyperactive than in normal children.

The fact that acquisition proceeds less efficiently under PR than under continuous reinforcement has been established in a number of studies (Jenkins & Stanley, 1950; Lewis, 1960). The explanation in terms of frustration theory, however, is not the only possible one. As outlined earlier, the informative feedback available at the termination of each trial is considerably more ambiguous under PR than under CR. Both of the general strategies which make solution possible in these circumstances place an increased strain on S's memory and concentration. Whether the S is testing the same hypothesis over a series of trials, or is trying to discover what all the reinforced stimuli had in common, attention to task-unrelated stimuli would interfere with performance. Considering that distraction is also a symptom closely associated with hyperactivity, this formulation would also predict relatively greater performance decrements in hyperactive Ss under PR.

A possible way of separating the two effects would be to include a condition allowing greater opportunities for distraction, without the frustrating effects of a high rate of non-reinforcement. For this reason a so-called Delay condition was introduced in the present study, in which Ss received 100% reinforcement for correct responses, but the intertrial interval was doubled from 4 to 8 seconds. The argument was that, under relatively massed trials, hyperactive Ss would do reasonably well because the constantly changing stimulus situation would help to maintain their attention. Under more spaced trials, however, there would be increased opportunity for these children to engage in various task-irrelevant activities,

and performance decrements might be expected on the basis of interference. Performance decrements might also result from the forgetting or decay of relevant stimulus cues during the delay period (Bourne, 1957; Bourne & Restle, 1959). Recent work, however, has revealed a curvilinear relationship between length of intertrial interval and performance on concept formation (Bourne, Guy, Dodd & Justesen, 1965). Performance was found to improve, then worsen, as the intertrial interval increased from 1 to 29 seconds. The optimum point of this relation was found to depend on other factors such as level of task difficulty. The functional relationship between performance and intertrial interval thus appears considerably more complex than anticipated on the basis of the earlier studies.

Because the literature suggests that hyperactive children have difficulty with abstract, particularly number, concepts, two different types of stimuli were used in the present study. The one set consisted of familiar concept categories ("flowers" and "birds") which previous research had shown to be within the capabilities of children to solve (Osler & Fivel, 1961). The other set involved number concepts, which are said to be particularly difficult for hyperactive children (Burks, 1960; Clements & Peters, 1962) and have been reported to be generally more difficult for both children and adult Ss (Osler, 1962; Heidbreder, Bensley & Ivy, 1948), presumably because they are more "abstract" than ordinary "object" concepts.

Finally, as a corollary to the main aims of this study, a reversal phase was included following learning of each concept. One reason for obtaining reversal data was the common belief among clinicians that hyperactive Ss may have generalized perseverative tendencies in spite of, or in addition to, their marked distractibility (Bradley, 1955; Eisenberg, 1957; Clements & Peters, 1962). The reversal scores were also of possible interest as a

test for the presence of the PRE (partial reinforcement effect) in a concept learning situation. Reversal scores have been used as measures of extinction by several authors (Wike, 1953; Grosslight, Hall & Scott, 1954). The second hypothesis to be tested therefore, was whether or not reversal takes longer following learning under partial than learning under continuous reinforcement.

METHOD

Subjects

A total of 65 children diagnosed as "hyperactive" and 99 normal children, all from the Montreal area, participated in this study.

A. Clinical sample. The 65 Ss included in the clinical group had been referred to the Department of Psychiatry of the Montreal Children's Hospital, and were selected by two staff psychiatrists on the basis of criteria designed to make the sample as homogeneous as possible. Although the hyperkinetic syndrome includes a number of different symptoms, a chronically excessive level of activity appears to be the central, and most important one. For a child to be selected, therefore, hyperactivity had to be the major presenting symptom. In addition, the hyperactivity had to be chronic (present since early childhood), sustained (present throughout most of the day), and reported by both the parents and the school. In order to minimize the effects of major confounding factors, only children from 6 to 12 years of age and of at least dull normal intelligence were studied. The mean age for the sample was 8.6, with a standard deviation of 1.5. The mean IQ was 103.8 on the Wechsler Intelligence Scale for Children (WISC), with a range of 83 to 127. All but three of the clinical subjects were boys. Ss diagnosed as psychotic or primarily neurotic were excluded from the sample. Since evidence of brain damage is present in some hyperactive children and absent in others, Ss with definite indications of brain damage or epilepsy were also excluded from the sample, with the aim of further increasing the homogeneity of the group studied. The Ss were receiving neither drugs nor psychotherapy at the time of original assessment, and were living

at home with at least one parent. The only treatment they received during the course of the study was the administration of either drug or placebo.

B. Normal sample. The control Ss were students from schools in the city of Montreal and neighbouring suburban communities, who had their parents' permission to participate and were screened by the class teacher or school principal on the basis of the following criteria: a) academic performance and estimated intelligence level about average; b) normal progress in school, i.e. no record of failed grades; c) no indications or known history of behavioural problems or emotional disturbance.

The Vocabulary subtest of the Wechsler Intelligence Scale for Children was administered to the normal Ss, and they were chosen to match appropriate experimental subgroups of the hyperactive sample as closely as possible on both chronological age (CA) and Vocabulary scores. The normal children ranged in age from 6 to 12 years inclusive, with a mean of 8.9 and a standard deviation of 1.7. Their grade placement ranged from kindergarten to Grade 6, as was the case for the hyperactive Ss. Their mean scaled score on the WISC Vocabulary subtest was 12.0, with a standard deviation of 2.2. The mean Vocabulary score for all hyperactive Ss was 11.3, with a standard deviation of 2.8. The difference between the two overall samples was not significant on a two-tailed test ($t=1.80$, $df=157$). Separate means and standard deviations for age and Vocabulary scores are presented in Appendix A for all experimental subgroups.

Apparatus

The apparatus, shown in Fig.1, was designed and constructed in the Bio-Physical Division of the Department of Medicine, Johns Hopkins School of Medicine. It consists of a 12x12x18-inch grey metal cabinet of which a 12x12-inch panel faces the S. Centered in the upper half of this panel a rear-projection plexi-glass screen allows for the presentation of two contiguous 2 3/4 inch square stimulus pictures. A response key is located just below each stimulus picture. The marble rewards for correct responses are released through a 1 cm^2 opening at the lower left-hand corner. The marbles are caught on the left-hand side of a plastic tray attached by hinges to the base of the front panel. The remainder of the tray consists of 10 grooves capable of holding a total of 100 marbles.

The cabinet houses a slightly modified Bausch & Lomb Model 655 slide projector connected to a number of electrical relays and mechanical components. Four main functions are performed by this device:

a) stimuli are projected on the screen and remain there until the subject responds;

b) a marble reinforcement is dispensed immediately following a correct response. The reinforcement mechanism can be adjusted to operate on either a continuous or a partial 1:1 fixed ratio schedule;

c) immediately following S's response, and simultaneously with marble delivery where appropriate, the shutter of the projector is closed and the screen grows dark;

d) the next stimulus in the series is presented after a specified interval, which can be varied.

Fig. 1. Apparatus

Slide trays bearing the stimuli are introduced and removed through an opening in the front panel. Operation of the apparatus is controlled by means of three push-buttons and a crank-knob located on the right-hand panel. In addition, an inconspicuous remote-control block with silent switches can be set for either partial or continuous reinforcement, or reversal of reinforcement contingencies.

Stimuli

Four different concept problems developed by Dr. Sonia Osler were used, which were similar to concepts used by her in previous studies (Osler & Fivel, 1961; Osler & Weiss, 1962). Each concept was represented by a set of 150 unduplicated pairs of stimuli, mounted on 2x2 inch transparent slides. One member of each pair was the positive stimulus, i.e. it represented an exemplar of the concept, the other was negative and consisted of a non-exemplar of the concept. Left-right position of the positive and negative stimuli was controlled for each series of 150, by the use of semi-random series avoiding runs of more than 4.

Two different classes of stimuli were used: naturalistic pictures and geometric figures. Each pair of concepts representing these two classes of stimuli had been found in pilot studies to be of approximately equal difficulty (Osler, 1962).

1. Naturalistic pictures. Flower and bird were the two naturalistic concepts. On each slide a coloured picture of either a flower or a bird, constituting an exemplar of the concept, was paired with the picture of an object not belonging to the concept category. The two pictures in each pair were matched relatively closely for total area, colour

combination and brightness. Different exemplars of the same concept, however, differed widely in terms of shape, colour and total area. Examples of stimulus pairs for the flower and bird concepts are shown in Figs. 2 and 3 respectively. As pointed out by Osler & Trautman (1961), such stimuli have the advantage of involving a very large number of irrelevant dimensions without becoming excessively complex or unfamiliar. While variations in the stimulus dimensions are random rather than systematic, complications of unequal familiarity or availability of verbal labels, which might tend to favour older and more intelligent Ss (Osler & Fivel, 1961), are avoided.

2. Geometric figures. The two problems involving geometric figures represented the same concept, the number two, by means of two different types of exemplars.

The first, or black shapes, problem involved black geometric figures of approximately the same size, distributed in a 5x5 grid over the stimulus area. The figures varied in number (from 1 to 5) and in shape (circle, square, triangle, cross and star). Shape and position were irrelevant dimensions, being varied entirely at random. Only the number dimension was relevant, and two figures, regardless of their shape or position, always constituted the positive stimulus. The negative stimuli in this set consisted of a random assortment of either one, three, four or five black shapes. An example of the stimuli making up this concept can be seen in Fig.4a.

The second, or coloured dots, problem consisted of circular dots of equal size, also distributed over the stimulus space in a random manner. The dots varied in colour (red, yellow, blue, green and orange), but

Fig. 2. Sample stimulus pairs from the "flower" series.

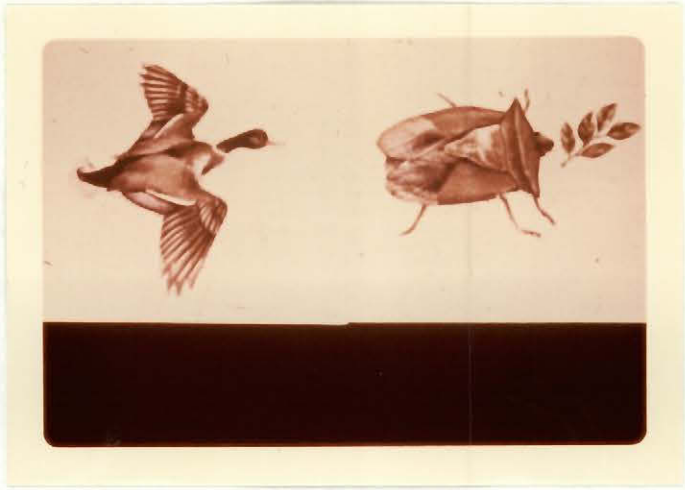

Fig. 3. Sample stimulus pairs from the "bird" series.

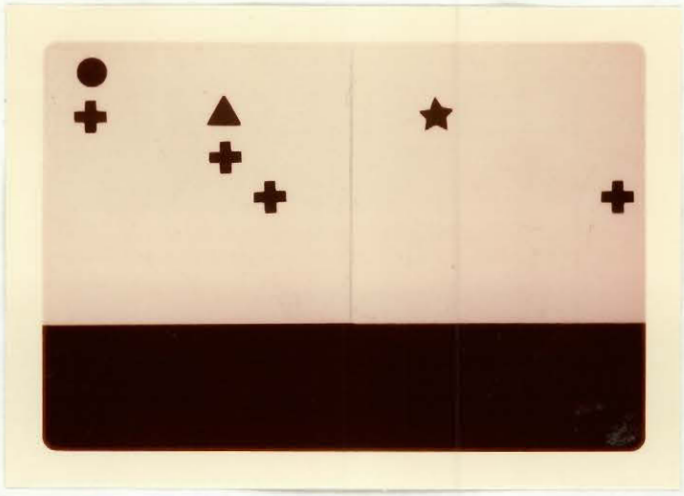

Fig. 4a. Sample stimulus pair from the "two black shapes" series.

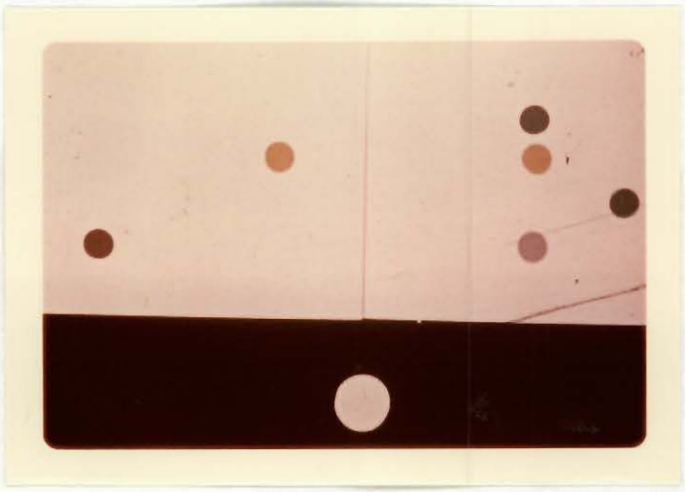

Fig. 4b. Sample stimulus pair from the "two coloured dots" series.

colour was an irrelevant dimension, being determined at random. The dots also varied in number from one to five, the number dimension being the only one relevant. The positive stimuli in this series consisted of two dots, regardless of colour or position. An example of the stimuli making up this concept can be seen in Fig.4b.

Procedure

Each S was tested individually in four separate sessions. The instructions given below were repeated at the beginning of each test session, the section in square brackets being omitted for Ss in the continuous reinforcement subgroups. The aim of these instructions was to reduce, so far as possible, the differential effects of intelligence on the concept learning tasks, in order to maximize the possibility of detecting any conceptual deficits peculiar to hyperactive Ss. The basic instructions were modeled on the specific instructions used by Osler & Weiss (1962) which resulted in the elimination of the effects of intelligence. Furthermore, in view of the finding that older and more intelligent Ss are more affected by a partial reinforcement schedule (Osler & Shapiro, 1964), additional instructions were given to Ss in the Partial groups, in an attempt to reduce the effect of these two variables.

Instructions:

> "This is a game we are going to play. Listen carefully and I will tell you how to play it. Here are two pictures, and here are two handles, one under each picture. In this game you will always have to choose a picture. Now, first of all, always make sure that you look at the pictures. Then, pick one of them and press the handle underneath it. If you pick the correct picture, you will get a marble, like this (demonstrate). If you push the handle under the incorrect picture, like this (demonstrate), you will not get a marble. Now here (third example), suppose you decide to choose this picture (point to it). Go ahead and push the handle. See how you get a marble? Pick up the marble and put it in one of these

grooves here. We will save it there until the end of the game when we will count up how many marbles you have won altogether.

The idea of this game is for you to get as many marbles as possible, as often as you can. If you look at the pictures very carefully, you will find that there is something in these pictures like an idea which will tell you which one to choose in order to get a marble as often as possible.

[Remember, there are two kinds of pictures in this game, correct and incorrect ones. The correct pictures are the only ones that ever give you marbles, but - they don't have to give you a marble every single time. The incorrect pictures never give you any marbles at all. So, in order to win the game, you will want to find out which are the correct pictures, the ones that ever give you any marbles, and choose them all the time.]

Now we will start the real game. What are you going to do first? (If S does not say: "look at the pictures", add:) If you look carefully and see which pictures give you the marbles, you will be able to win the game. At the beginning you may have to guess, but try and figure out which are the correct pictures as you go along."

The hyperactive Ss were tested by appointment at the Montreal Children's Hospital. The control Ss were tested in their respective schools during regular school hours. Additional instructions were therefore necessary for the control Ss, to the effect that the task they were about to perform was not a school test and was in no way related to their regular school programme.

Ss were tested until they reached a criterion of 10 consecutive correct responses or for a maximum of 300 trials (at which point each of the stimulus pairs would have been presented twice, since there were only 150 different pairs of stimuli for each problem). If a S had not reached the acquisition criterion by 150 trials, he was asked the following questions:

"Do you have any idea at this point which are the correct pictures? ... How have you been going about choosing the pictures?... How did you know which picture to choose each time?"

Depending on the child's answer, either the full instructions or only the second paragraph were repeated. If the child had not reached acquisition criterion by 225 trials, the above procedure was repeated once more.

Whenever a S reached the acquisition criterion in less than 300 trials, he was immediately switched to a second, reversal stage of learning. On the first trial following the acquisition criterion run of responses, the reinforcement contingencies were reversed by means of the silent remote-control switch, without any break in the procedure or any visible manipulation on E's part. For example, if a S had been learning the flower concept and proceeded to choose the picture containing a flower 10 times on a row, on the eleventh trial he would no longer get a marble for choosing a flower because the stimulus which was not a flower would now be reinforced. Testing was continued until a reversal criterion of 10 consecutive correct responses had been reached, or for a maximum of 300 trials since the beginning of testing (approximately one hour of testing). All Ss, including the Partial groups, received continuous reinforcement during reversal learning.

At the end of each test session (i.e. when S had reached reversal criterion or when 300 trials had been completed) S was told that he had won the game, the number of marbles won was counted (Ss had to return the

marbles to the apparatus), and each child was praised for his fine performance. Each S was then asked the following question, and the subsequent ones if necessitated by his answer:

"How did you go about winning all those marbles?... How did you know which picture to pick each time?... Do you have any idea what the correct pictures looked like?".

Finally, if the S did not spontaneously manifest his awareness of the difference between the acquisition and reversal stages in the procedure, he was asked: "Was this rule you used the same throughout the game, or were there different rules at different times?".

Design

The study was executed in two phases, aimed at answering two different sets of questions. In the first, or pretest phase, a comparison was made of the concept learning of hyperactive and normal children under two schedules of reinforcement and two different intertrial intervals. The second, or retest phase, was designed to assess the effects of chronic administration of chlorpromazine hydrochloride, as compared to an inert placebo, on the concept learning of hyperactive children.

1. Pretest phase. The basic design of the study was a 2x3x2 factorial with replication on the third variable. The two types of Ss, hyperactives and normal controls, were randomly assigned to either of three treatment conditions, Continuous, Partial or Delay, the only restrictions being that age and average IQ be kept comparable among the groups. The descriptive statistics for the different experimental subgroups are presented in Appendix A. T-tests comparing the means of hyperactive and normal Ss showed that none of the differencesin age were statistically significant. Comparisons of mean Vocabulary scores gave

nonsignificant results for all but the Delay subgroups, where the difference between the normal and hyperactive Ss was significant at the 5% level ($t=2.32$, $df=39$).*

Ss in the Continuous groups received 100% reinforcement for correct responses in a two-choice discrimination situation, with a 4 second intertrial (post-reinforcement) interval. The Partial groups received 50% reinforcement on a fixed ratio schedule (only every second correct response was reinforced, - again on a 4 second intertrial interval). Ss in the Delay groups were on a continuous reinforcement schedule, but had an intertrial interval of 8 seconds. All Ss under all conditions learned the same two concept problems in the same order: "flowers", followed by "two black shapes".

2. Retest phase. As soon as the initial assessment was completed, hyperactives from the Continuous and Partial groups were assigned to a "medication" condition by means of a double-blind procedure. (Data were also obtained for the hyperactive Delay group but were not used because of the small number of Ss in the drug and placebo subgroups). Approximately half the Ss received chlorpromazine hydrochloride and half a placebo identical in appearance (25 mg tablets were used). Medication was administered on an outpatient basis and dosage levels were individually adjusted according to the clinical judgment of the two staff psychiatrists. The procedure used in drug administration was thus the same as typically used in clinical practice. A maximum dosage of 6 tablets daily (150 mg) was imposed. The dosage range was from 37 to 150 mg daily for the

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* This failure in matching the Delay groups would make comparisons questionable if a significant relationship existed between Vocabulary scores and performance on the tasks used in the study. As can be seen from Appendix C, however, there was no evidence of such a relationship for either the hyperactive or the normal Delay groups.

chlorpromazine group, with a mean of 106 mg daily, and from 75 to 150 mg daily for the placebo group, with a mean of 140 mg daily. Medication was continued for a minimum of six weeks or until the clinical effects were considered by the psychiatrists to have become stabilized. The Ss were then retested while still receiving medication at the prescribed individual dosage level. As a check on whether or not patients had been taking their medication, a urine sample was taken at the time of retesting. This was examined (by a laboratory technician) for the presence of phenothiazine according to the method of Forrest, Forrest & Mason (1961). The usefulness of this test proved limited, however, by the occasional occurrence of false negatives, a difficulty others have noted (Gold, Griffith & Huntsman, 1962). The normal Ss were retested after an equivalent lapse of time. All Ss received the same two problems in the same order, "birds", followed by "two coloured dots".

A table giving the mean time intervals separating the administration of the different concept problems in each subgroup is presented in Appendix B.

3. Additional control samples. In the design described above, practice effects, or effects due to order of presentation, are confounded with possible differences in the difficulty level of the two problems administered. Counterbalancing at the problem level, however, was not attempted at the outset, since this would have necessitated a number of additional matched cells and only a limited number of hyperactive Ss were available. Preliminary analysis of the original data revealed significant differences on the problem variable along with an interaction showing these to be most pronounced under continuous

reinforcement. To check whether the observed differences were due to the order of presentation, differences in problem difficulty, or both, the problems were given in a counterbalanced order to additional samples of 22 normal and 10 hyperactive Ss. These Ss received continuous reinforcement with a 4 second intertrial interval, thus bringing to 4 the number of subgroups tested under these conditions:

		1st concept	2nd concept
Original samples	Normal Ss	Flower	Two shapes
	Hyperactive Ss	Flower	Two shapes
Additional samples	Normal Ss	Two shapes	Flower
	Hyperactive Ss	Two shapes	Flower

While these control samples were not introduced until later in the study, care was taken to select the additional Ss in the same manner and from the same sources as in the original experiment.

RESULTS

PART I: PRETEST COMPARISONS

A. Criterion Measures

Three response measures were used to compare the overall learning performance of hyperactive and normal Ss under the various experimental conditions: a) number of trials, b) number of errors, and c) number of reinforcements to a criterion of 10 consecutive correct responses or a maximum of 300 trials. Ss not having reached criterion within the maximum number of trials were assigned an arbitrary score of 300 on the trials measure. The distribution of solvers (Ss reaching criterion) and non-solvers for each experimental subgroup is given in Table 1, and can be seen to depend on both treatment condition and subject classification. The proportion of non-solvers was significantly higher among the hyperactive than among the normal children (27% vs. 9%, $\chi^2 = 14.55$, df = 1, $p < .001$). Furthermore, combining both types of Ss, there were increasing numbers of solvers in the Partial, Delay and Continuous subgroups (65%, 80%, 97%, $\chi^2 = 17.62$, df = 2, $p < .001$).

The use of 300 as an arbitrary score for the non-solvers has the effect of underestimating their performance decrement. Consequently potential differences between experimental subgroups will be underestimated in proportion to the number of non-solvers in a given group. Because of the high proportion of non-solvers among hyperactive Ss under partial reinforcement, comparisons involving this particular subgroup will yield conservative estimates of the group differences.

Correlations with age and IQ estimate. Product-moment correlation coefficients of the trials to criterion measure with chronological age and

WISC Vocabulary scores are presented in Appendix C. Significant negative correlations with age (older Ss requiring fewer trials to learn) were found for the Normal Continuous and Hyperactive Partial and Delay groups on the first concept. On the second concept, only the Normal Order Control and Delay subgroups showed a significant negative correlation between trials and age.

None of the correlations of Vocabulary scores with trials to criterion were significant for the first concept. On the second concept the correlation of number of trials with Vocabulary was significant for only the Normal and Hyperactive Order Control subgroups (with the brighter Ss performing significantly better on this concept, "flower", preceded by "two shapes").

It should be noted that the general lack of significant correlations with Vocabulary scores tends to confirm the effectiveness of the detailed instructions in eliminating the differential effects of intelligence on the concept learning scores. Chronological age was much more likely to affect level of performance.

Stage 1. Basic experiment. Means and standard deviations for the trials, errors and reinforcements measures are presented in Table 2. Inspection of the data suggested that the assumption of homogeneity of variance might not be tenable for these data, since there was a tendency for partial reinforcement to increase the variance. Furthermore, the standard deviations tended to approach the means in order of magnitude, particularly for the error measure. This is a fairly typical finding in concept formation experiments (Trabasso, 1962) and also agrees with Restle's (1962) formulation of the theoretical distribution of error scores in a learning task. F_{max} tests (Winer, 1962) were used to compare the variances and the size of the ratios obtained indicated that the variances were indeed not homogeneous.

A square root transformation was consequently applied to the data and resulted in a significant reduction in the heterogeneity of variance ($p > .05$ for every F_{max} ratio considered).

The transformed data were analyzed according to a fixed factor model analysis of variance (2 x 3 x 2 factorial design with repeated measurements on the last factor), with an unweighted-means correction for unequal cell frequencies (Winer, 1962, pp.337, 342). Summaries of the separate analyses for the trials, errors and reinforcements measures are presented in Table 3. To illustrate the interactions of the 3 variables, a graphical presentation of means of the transformed scores appears in Appendix D. As the results in Table 3 indicate, trials and errors are closely equivalent as response measures and therefore will be examined together, leaving a consideration of the reinforcements until later.

On both the trials and errors measures, the main effect for subject classification was significant at the 5% level. While the Ss x treatments interaction was not significant in these analyses, it can be seen from Appendix D that the overall Ss difference is due in a large measure to the notably poor performance of the hyperactive Ss under Partial reinforcement. Specific normal-hyperactive comparisons, therefore, were made separately for each treatment level, collapsing data across problems. The results showed that the hyperactive children did significantly more poorly than normal Ss under partial reinforcement ($F = 3.65$, $df = 1,126$, $p < .05$).* The difference between the two types of Ss was not significant under continuous reinforcement, i.e. either in the Continuous ($F = 0.09$, $df = 1,126$) or in the Delay condition ($F = 2.80$, $df = 1,126$).

The main effect for experimental treatment was significant well beyond the 1% level of confidence in the trials and errors data. Specific comparisons between the different levels, collapsing the data across problems,

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* The F values shown in brackets are all for the trials measure.

showed that Ss receiving 100% reinforcement for correct responses performed at a significantly higher level than those receiving partial reinforcement ($F = 45.87$, $df = 1,126$ for Continuous vs. Partial; $F = 13.42$, $df = 1,126$ for Delay vs. Partial, $p < .01$ in both cases)*. Concept learning under PR thus appears considerably more difficult for all Ss. It is particularly difficult, however, for the hyperactive Ss who are significantly worse than the control Ss under this condition.

No changes in the performance of normal children were produced by using an increased intertrial interval (Continuous vs. Delay comparison, $F = 0.02$ for the first problem and $F = 0.006$ on the second problem). Similarily, there were no significant differences between the Continuous and the Delay groups for the hyperactive Ss. There was a trend for poorer performance on the first problem for the hyperactive Delay group, but this trend did not reach statistical significance ($F = 1.57$ for the first problem and $F = 0.63$ for the second).

The overall difference between the two problems (i.e. the two different test sessions) was significant at the 5% level of confidence on the trials and errors measures. As can be seen from the cell means shown in Appendix D, there was a marked improvement in performance from the first to the second problem for hyperactive Ss in the Continuous and Delay groups, and a slight trend in the same direction for hyperactive Ss in the Partial group. Such differences between the first and second problem were not evident for any of the normal subgroups, a fact reflected in the significant Ss x Problems interaction term.

The main effect for problems and the Ss x Problems interaction were the only significant terms in the analysis of reinforcement scores (both at the 5% level). The overall difference between the two problems was not significant for the normal Ss. The hyperactive Ss, on the other hand, received a

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* The F values shown in brackets are all for the trials measure.

significantly smaller number of reinforcements while learning the second concept than while learning the first one (in other words, they learned the second concept significantly more quickly). Inspection of the cell means (Appendix D) suggests that this improvement is particularly marked in the Continuous and Delay conditions, but this trend (the triple interaction) did not reach statistical significance.

The main effects for treatments and for subject classification were nonsignificant in the analysis of reinforcement scores. This means that the average number of reinforcements received was essentially the same for all Ss, regardless of diagnostic category, reinforcement schedule, or intertrial interval. Since the relative proportions of solvers and nonsolvers varied among the different experimental subgroups (see Table 1), it appears that, given the same average number of reinforcements, Ss may or may not reach a criterion level of performance, depending on other factors. Thus of the 3 response measures used, trials and errors were sensitive to subgroup differences but reinforcements was not. Since trials is actually a composite measure (consisting of errors + reinforcements under CR), it is basically the number of errors that reflects the relative learning speeds of different experimental subgroups.

Stage 2. Order control data. While significant problem differences were found on all three response measures in the original experiment, they are difficult to interpret because of the confounding of practice effects (due to order of presentation) with the effects of problem difficulty. Counterbalancing for order of presentation was achieved at the continuous treatment level by testing two additional Continuous groups ("Order Control" groups) who received the two pretest problems in a reversed order. The data of the original and the "order control" samples were then combined into a Latin square design for purposes of analysis. Separate analyses

were done for normal and hyperactive Ss, with corrections for unequal sample size being made in each case. There were 26 Ss in the original Normal Continuous group and 22 Ss in the Order Control sample (mean ages and Vocabulary scores for both the normal and hyperactive children are shown in Appendix A). Only 10 additional Ss could be obtained for the Hyperactive Order Control sample, and their ages ranged from 7 to 9 years. For this reason only the 7, 8, and 9-year old Ss of the original Hyperactive Continuous group (a total of 13 Ss) were included in this analysis.

Because of the close equivalence of trials and errors as response measures found in the previous section, only trials to criterion will be used in these analyses. Mean trials to criterion as a function of the concept learned and order of presentation are presented in Table 4 for the normal and for the hyperactive Ss. Summaries of the Latin square analyses for both types of Ss are shown in Table 5.

The differences between the two separate samples were nonsignificant for both the normal and the hyperactive Ss ($F = 0.44$ and 1.15, respectively, $p > .05$ in both cases), indicating that the original and the order control samples are quite comparable. This was to be expected, since the Ss were selected in the same manner from the same sources, although at different times during the course of the study.

For the normal samples, the results showed significant effects due to both type of concept problem and order of presentation (both at the 5% level of confidence). The normal Ss thus show a significant improvement (positive transfer) in their performance on the second problem. The nature of the specific problems involved, however, also has a significant effect, since the "two" concept appears to be more difficult than the "flower" concept. It might be noted that for the original Continuous group the mean number of trials was quite similar on both of the pretest problems

(87.6 vs. 89.1 trials). Since in this case the flower concept was given first, followed by the two shapes concept, it would seem that any learning-to-learn effects resulting from solving the first problem were obscured on the second problem because of the greater difficulty of the two shapes concept for the normal Ss.

In the hyperactive data, on the other hand, the differences due to order of presentation were highly significant ($p < .01$), but there were no significant differences due to the type of concept ($F = 0.24$). Thus under continuous reinforcement, hyperactive Ss show a large amount of positive transfer from the first to the second concept, and this effect is in no way dependent on the particular concepts involved.

3. Reversal data. The reversal scores consisted of the number of trials to reversal criterion or a maximum of 150 reversal trials. In a concept formation situation only Ss who have reached the acquisition criterion can be meaningfully placed on a reversal schedule. As was seen in the previous sections, there were systematic differences in the number of Ss reaching acquisition criterion among the various experimental subgroups. As a result, reversal scores were available for more normal than hyperactive Ss and for more Ss under continuous than under partial reinforcement. Similarily, the number of reversal scores available for slow learners who did reach criterion was limited by the restriction of a maximum of 300 trials per session, (a S requiring 220 trials to learn the concept, for example, would obtain a reversal score only if he reached the new criterion within 80 trials).

A further complication in the analysis of reversal data arises because of the possibility of a functional relationship between acquisition and reversal trials. While direct evidence on reversal measures is not available, several studies (Lewis & Duncan, 1956; 1958) have shown that, the larger the

number of acquisition trials, the smaller the number of trials to extinction. Similarily, in two studies by Capaldi (1957, 1958), there was faster extinction following the larger number of acquisition trials. Since systematic differences in acquisition scores were found in the previous sections, correlations of the acquisition and reversal trials were calculated separately for the two pretest problems (using only Ss for whom both scores were available on each problem). These correlation coefficients are presented in Appendix E, where it can be seen that 3 out of the 6 subgroups showed a significant positive correlation between the number of acquisition and reversal trials on the first concept, and a fourth group showed a trend in the same direction. On the second concept, however, only the order control groups showed a significant correlation.

On the basis of these considerations only reversal data from Ss closely matched ($\pm$ 10 trials) on acquisition trials to criterion were used in the statistical analysis. Since correlations between acquisition scores on the first and second concepts were quite low for the normal Ss (see Appendix E), matching across all six experimental groups was done separately for each concept. 42 matched Ss were available for the flower concept, and 30 for the two shapes concept. Two separate two-way analyses of variance were done, comparing the two types of Ss, normal and hyperactive, and three treatment groups, Continuous, Partial and Delay. Summaries of these analyses are presented in Tables 6a and 6b. The results show that, with number of acquisition trials controlled, there were no differences in reversal scores between the normal and the hyperactive Ss. According to these data, the clinical Ss had no difficulty in switching their responses upon reversal of the reinforcement contingencies. The main effect for treatments was also nonsignificant, indicating that there was no PRE (partial reinforcement effect). Ss who learned a concept under PR

did not require more trials on reversal, so long as they were matched on number of acquisition trials. Since this study was not basically designed to study reversal, however, and because of the small number of matched Ss available, these findings must be considered with definite reservations.

B. Learning Curves and Response Sequence Analyses.

In addition to the criterion measures presented in the previous section, the response sequence data were analyzed in several different ways. These analyses were aimed at uncovering systematic differences in trial-to-trial patterns of responding that might provide additional information about the concept formation process in normal and hyperactive children. Only the pretest data of the original samples were examined in this manner.

1. Group Learning curves. Group learning curves were first obtained in the traditional manner, that is, by summing the errors made by all Ss in a block of trials, and dividing by the total number of trials in that block (i.e. dividing by number of trials in block x total number of Ss in group). The resulting curves are shown for the various experimental subgroups in Figs. 5 to 10, where they are identified by the caption "all subjects". As can be seen from the figures, these curves appear to be negatively accelerated functions, a type of function frequently obtained in plotting learning data (Hull, 1943, p.116; Osgood, 1953, pp.329-330). In other words, they present the picture of a more or less gradual decrease in errors over successive blocks of trials. In order to test the statistical significance of this decrease, the error data were combined over blocks of 100 trials. Blocks of trials were then used as the third variable in a 3-way analysis of variance involving again the two classes of Ss, normal and hyperactive, and the 3 treatment groups as the other two variables. Separate analyses, based on the same model as in the previous section, were made

for each of the two pretest problems. Because the assumption of homogeneity of variances was not satisfied by these data, a log x+1 transformation of the scores was used in the calculations. Summaries of the two separate analyses are presented in Table 7. Mean errors (transformed scores) as a function of blocks of 100 trials were plotted for all subgroups and are shown in Fig.13 in order to facilitate comparison between groups.

The decrease in errors over blocks of trials was highly significant on both concepts, but it was not uniform for all subgroups, as indicated by the significant interaction terms. Thus, on the flower concept, the reduction in errors over trials was significantly greater for the normal then for the hyperactive Ss. In addition, the decrease in errors over blocks was most pronounced for Ss in the Continuous groups and least obvious for the Partial groups, with the Delay groups being intermediate between the other two (Blocks x Treatments interaction significant at the 5% level).

As can be seen from these results, the group differences revealed by analyzing the change in errors over trials are essentially the same as those obtained from analyses of criterion scores. Both types of measures show that there are significant differences in the efficiency with which the different subgroups reach a criterion level of performance, whether this efficiency be expressed as a smaller number of trials or errors to criterion, or a smaller proportion of errors being committed by the group at each stage of the learning session. The reasons for this similarity lie in the manner in which the points on these curves are calculated. Since the number of errors made in a block of trials was divided throughout by the total number of Ss, successive points on these curves represent a composite of Ss no longer making errors (i.e. Ss in the post-criterion stage) and those still engaged in learning the concept (i.e. Ss in the pre-criterion stage).

Where, as in the present experiment, different Ss reach criterion at any time throughout the test session, the ordinary group learning curve becomes merely a pictorial representation of the relative efficiency with which groups master a problem. Strictly speaking, therefore, the all "Ss" curves in Figs. 5 to 10 would more properly be labeled curves of group performance, rather than curves of learning.

A further difficulty with average curves obtained in this manner is that they need not have the same shape as their individual components (Merrell, 1931). Indeed it can be shown that for the negatively accelerated function, the component curves could not be functions of the same nature (Sidman, 1952). Consequently these group performance curves can give no indication of the shape of the learning function for individual Ss, and cannot be expected to reveal differences in precriterion performance that might help to account for observed differences in learning efficiency among the different groups.

2. Precriterion curves. When errors as a function of blocks of trials were plotted for individual Ss, the resulting curves in no way resembled the group curves presented above. Examples of individual learning curves for 4 different Ss are given in Appendix G. Regardless of the number of trials necessary for learning, no gradual improvement in performance could be observed. This strongly suggests that learning the concepts was not accomplished by a gradual strengthening of associations between relevant aspects of the stimulus complex and the overt choice response. The proportion of errors over successive blocks of trials seemed to fluctuate randomly around the chance level, and the shift to a criterion level of performance was always sudden, occurring within a single block of trials. The shape of the individual learning curves was thus consistent with "all-or-none" descriptions of the learning process. Similar results have been found in

a number of studies (Suppes & Ginsberg, 1962; Trabasso, 1963; Trabasso & Bower, 1964 a, 1964b).

In order to make group comparisons, group learning curves reflecting the characteristics of the individual curves seemed desirable. Such curves can be obtained by plotting data from the precriterion sequence only, i.e. from the sequence of correct and incorrect responses made by S prior to his last error (Estes, 1964; Trabasso, 1963). For each block of trials the number of errors, summed over Ss, was divided by the number of precriterion trials, rather than the total number of trials, as for the "all Ss" curves. This has the advantage of having only Ss who are still actively learning represented on the curve. These are the upper curves shown in Figs. 5 to 10, where they are identified by the caption "precriterion Ss". It must be noted that the number of Ss in the precriterion stage decreases gradually over trials for most groups (as can be seen from the slope of the "all Ss" curves shown in the same figures). As a result, the number of Ss represented by each point on the precriterion curves decreases acccordingly. In order to eliminate extremes in the disproportionality thus introduced, the precriterion curves shown in the figures were truncated at the point where the number of Ss dropped to 5.

a) Tests for stationarity. As can be seen in the figures, the precriterion curves seem to remain essentially parallel to the x-axis throughout their course, with the exception of apparently random up-and-down fluctuations. A statistical technique for testing the stationarity of such curves has been developed (Suppes & Ginsberg, 1963) and was applied to the present data. Chi-square values were calculated for each curve by using the proportion of errors in any block of trials as the observed value, the over-all mean for the whole curve as the expected value, then summing these over blocks. Here again, the disproportionality in the number of observations at each point introduced

by the decreasing number of Ss would affect the statistic. Blocks of trials were combined, therefore, for analysis whenever the total number of trials in a block was less than 1/3 of the number of trials in the first block.

For curves stationary around their own mean, the chi-square obtained in this manner would be small and statistically nonsignificant. A large chi-square value, on the other hand, would mean that a number of the points on the curve deviate (in either direction) from the over-all mean value. The chi-square values obtained from the present data are presented in Table 8, under the heading "chi-square around own mean". These results show that most of the curves considered are stationary around their own mean. In other words they are essentially parallel to the x-axis throughout their course. For three of the curves, however, significant chi-squares were obtained. These were the curves representing the performance of the hyperactive Continuous group on the "Flower" concept and the normal Partial group on both the "flower and "two shapes" concepts. Judging from the shape of the curves in Figs. 6 and 9, this does not represent a systematic change over trials for any of these three curves, but rather a considerable amount of fluctuation in the proportion of errors.

b) Chi-squares around chance level. While the Suppes & Ginsberg technique provides a test of the stationarity of curves over trials, it does not necessarily indicate performance at a random, or chance level. Consider, for example, the curves for the NC group on the "two shapes" concept (Fig.5) and for the HP group on the "flower" concept (Fig.10). The chi-square values were nonsignificant for both these curves (see Table 8), indicating stationarity. Yet an examination of these curves with respect to the chance level shows that the majority of the points for one of the curves (HP "flower", Fig.10) lie above the chance level, whereas the converse is true for the other curve. (The probability of making an error on

the basis of chance alone = .5 in a two-choice situation). In order to assess the significance of such differences, a different set of chi-square statistics were calculated, this time substituting .5 for the group mean as the expected proportion of errors in each block of trials. The results are again shown in Table 8, under the heading "chi-square around chance level".

According to these analyses, a number of the curves deviate from a chance level of random performance to a highly significant degree (1% level of confidence). Examination of the mean proportion of errors for each group (Table 8), as well as inspection of the curves indicate three different patterns of deviation. First, the proportion of errors may be consistently smaller than chance expectation. This appears to be the case for the Normal Continuous group on the second concept, and for the Normal Partial group on both concepts. Second, the proportion of errors over blocks of trials may be consistently larger than would be expected on a random basis, as in the case of the Hyperactive Partial group on the first concept. Finally, in the case of the Hyperactive Continuous group on the first concept, the significant chi-square seems to reflect the excessive magnitude of the up-and-down fluctuation over blocks of trials.

c) Nonreinforcement data for Partial subgroups. The analyses reported above were all based on error data, an error being any choice on a nonexemplar of a concept. Under continuous reinforcement an error is equivalent to a nonreinforcement and a correct response to a reinforcement. In the PR condition, however, 50% of the correct responses were not reinforced. A number of the nonreinforcements thus stood for correct responses, indistinguishable from the errors on a feedback basis. As a result, data obtained under partial reinforcement can be dichotomized in two different ways, correct versus incorrect and reinforced versus nonreinforced responses.

Since the chi-square technique used in the previous sections was developed on data obtained under continuous reinforcement, and there is no precedent for extending this analysis to a PR situation, the reasons for choosing the correct-incorrect dichotomy will be considered briefly.

The main aim in plotting learning curves is to examine any changes in the frequency of correct responses over trials. Whenever the S has learned the correct concept, he will indicate this by choosing only exemplars of that particular concept category, regardless of the rate of reinforcement provided. The correct-incorrect dichotomy is thus the most meaningful one to use under PR, in spite of theoretical considerations which would attach a prime importance to the occurrence of a non-reinforcement (Atkinson, 1956; Bower, 1961; Estes, 1964). Furthermore, it is evident that the number of non-reinforcements received by a S under PR is primarily a function of the number of errors that he makes in any block of trials. To this is added a constant fraction (one half) of his correct choices which are also not reinforced. Thus

$$p_{nr} = p_e + 1/2 \ (1 - p_e)$$

where p_{nr} is the proportion of nonreinforcements per block of trials and p_e is the proportion of errors. The relationship to the chance level is therefore the same for non-reinforcement and for error curves, as can be seen by comparing the corresponding chi-square values in Tables 8 and 9. Thus the non-reinforcements curve for the hyperactive Ss on the flower concept is still significantly above the new chance level (.75), and the corresponding curve for the normal Ss is still below the chance level. The only change in the non-reinforcement data is with respect to stationarity, the up-and-down fluctuations in the curves becoming more attenuated. This is simply because the same deviations

(fluctuations in error) are now assessed at each point within a larger proportion (errors plus nonreinforced correct responses) of the total number of observations.

d) Mean proportions of errors. The mean proportions of errors to correct responses per block of 10 trials, which were used in the tests for stationarity, are shown in Table 8. Comparing the columns for normal and hyperactive Ss, the mean proportion of errors can be seen to be consistently higher for the hyperactive samples. This would have been expected only for the hyperactive Partial group, for whom the mean number of errors to criterion was significantly higher. The difference also holds, however, for the Continuous and Delay groups who were not significantly different on the criterion measures. Indeed, for the Continuous groups on the "two shapes" concept, the mean number of errors to criterion was twice as large as that of the normal sample, (see Table 2), although, as was seen earlier, this difference was not statistically significant. In short, it would appear that the hyperactive Ss produced a higher proportion of errors per block of trials regardless of the length of the precriterion sequence (i.e. speed in reaching criterion).

Finally, comparing the two concepts learned by each experimental subgroup, it can be seen in Table 8 that, for the hyperactive Ss, the mean proportion of errors was consistently lower on the second concept. For the normal Ss, a reduction in the proportion of errors occurs in the Continuous and Delay groups, but the Partial group shows an increase.

PART II: RETEST DATA

1. Chlorpromazine-Placebo Comparison.

All hyperactive Ss were retested while on medication, but only the data from the Continuous and Partial groups will be considered in this section. The Delay Ss were not included because the number of Ss available in the separate drug and placebo subgroups was too small for reliable comparison. As for the Order Control sample, they received a different kind of medication, being used for another study. "On drug" retest data were available for 19 of the original 20 Ss in the Continuous group and 18 of the original 20 Ss in the Partial group. Of the 3 cases for whom retest data were not obtained, one was due to the child's refusal to undergo more testing, the other two to the parents' not returning for retest assessment. In the continuous reinforcement subgroup, 10 Ss had received the drug and 9 the placebo. In the Partial reinforcement subgroup, both drug and placebo categories contained 9 Ss each. Mean ages, I.Q's and Vocabulary scores for these subgroups are given in Appendix A. T-tests comparing the drug and placebo samples on these three measures indicated that they were not significantly different.

All Ss received the same two retest problems in the same order, "bird", followed by "two coloured dots". The sequence in which the various concepts were administered throughout the study can be summarized as follows:

Pretest		Retest	
1st. session 1A	2nd. session 1B	1st. session 2A	2nd. session 2B
Flower	Two shapes	Bird	Two dots

It will be remembered that the "flower" and "bird" concepts used the same type of stimuli and had been found of approximately equal difficulty. The number concepts involved a different type of stimuli and were also considered to be equivalent. In order to illustrate the direction and magnitude of test-retest changes, mean difference scores for each type of problem (1A - 2A; 1B - 2B) are presented in Table 10 as a joint function of drug treatment and reinforcement schedule. For purposes of comparison the equivalent pretest data, separated into drug and placebo subgroups, are also included in this table. Statistical treatment of the data, however, was done by means of the analysis of covariance, since the analysis of difference scores tends to be less precise and reliable (Nash, 1960). Each criterion measure (retest score on a concept) was paired with a separate covariate measure (pretest score on the equivalent concept). Because adjustments were required by the repeated measures feature of the experimental design, separate calculations were made for the Continuous and Partial subgroups in order to simplify the analyses. The results for the hyperactive Continuous and Partial groups are summarized in Table 11. The drug-placebo comparison was nonsignificant in both cases, indicating that chlorpromazine had no systematic effect on the learning of the retest concepts. The differences due to type of concept problem were also not significant in these analyses.

2. Transfer Effects, Retest Comparisons.

Because of the absence of systematic effects due to medication, the retest data of the chlorpromazine and placebo subgroups were combined at each level of reinforcement, giving now a sample of 19 hyperactive Ss under continuous, and 18 Ss under partial reinforcement. These combined data were then used for a comparison of retest performance for

the hyperactive and normal Ss. Type of concept problem was the other variable, and separate analyses were done for Ss under continuous and those under partial reinforcement.

The normal Ss were retested after a period of 6 to 8 weeks without, of course, any intervening treatment. This time interval was chosen to match the estimated time it would take for the drug effects to become stabilized in the hyperactive Ss. In practice, however, a delay was introduced in the retesting of the clinical Ss due to the procedure of testing by individual appointments. The average time intervals between all test sessions are given in Appendix E and show that the test-retest interval was an average of two weeks longer for the hyperactive Ss. Because of the possibility of bias due to these differences, correlation coefficients were calculated between the test-retest difference scores and the time interval in days for all four experimental subgroups. The results, presented in Appendix F, show that there was no systematic relationship between the length of the time interval and the magnitude of test-retest change. Any bias due to the differences in the test-retest intervals is therefore highly unlikely.

The data were analyzed by means of analyses of covariance in the same manner as in the previous section. Retest scores on the two types of concepts constituted the criterion measures, with the equivalent pretest scores serving as covariates. The results of the separate analyses for Ss under CR and under PR are shown in Table 12. In both analyses there were no significant differences due to problem type for either normal or hyperactive Ss. The differences in retest performance between normal and hyperactive Ss were not significant under continuous reinforcement. Under partial reinforcement, however, the difference between normal and hyperactive Ss was significant at the 1%

level of confidence. Even with pretest differences controlled for, the hyperactive children still did significantly more poorly than the control Ss under PR. Indeed, the magnitude of the difference had increased (F significant at the 1% level, instead of the 5% level in the pretest phase). This was due to the fact that the performance of the control Ss improved significantly on the retest sessions, while the hyperactive Ss in the Partial group showed no evident improvement over their pretest performance.

Summary of Results

A. Pretest comparisons

1. In a standard concept formation situation, i.e. given continuous reinforcement with a 4 second intertrial interval, hyperactive children can reach a criterion level of performance as efficiently as normal control Ss. While both groups reached criterion equally quickly, differences in the shapes of their learning curves suggest possible differences between the groups during the pre-solution phase.

2. Under continuous reinforcement, the hyperactive Ss show positive transfer effects from the first to the second problem which are independent of the nature of the particular concepts involved. Transfer effects in the normal Ss, however, depend on both the nature of the problems and the order of their presentation.

3. Doubling the intertrial interval from 4 to 8 seconds had no effect on the performance of either hyperactive or normal Ss.

4. Learning under a 50% partial reinforcement schedule is more difficult for both normal and hyperactive Ss. The hyperactive Ss, however, perform significantly more poorly than the normal control Ss in this condition. Indeed, on the first problem, 65% of the hyperactive Ss failed to reach a solution within 300 learning trials. Precriterion learning curves show the hyperactive Ss to perform at a random level on the second problem and to make consistently more errors on the first problem than would be expected by chance. The normal Ss performed at a better than chance level even in the precriterion stages of both pretest problems.

5. There were no systematic changes in the proportion of errors over precriterion trials for any of the groups.

B. Drug results and retest comparisons.

1. The hyperactive Ss varied considerably in the amount and direction of test-retest change. No systematic differences could be found, however, between the hyperactive Ss treated with chlorpromazine and those who received an inert placebo. Chlorpromazine thus had no effect on concept learning in the present experiment.

2, There were no significant differences in retest performance between the hyperactive and normal Ss under continuous reinforcement. Under partial reinforcement, however, the hyperactive Ss still showed highly significant decrements as compared to the normal Ss.

TABLE 1

NUMBER OF SUBJECTS PER GROUP WHO REACHED CRITERION PERFORMANCE

Subjects	Treatment groups	Concepts	Solvers	Non-solvers	Total
Normal	Continuous	Flower	26	0	26
		Two shapes	25	1	26
	Partial	Flower	22	3	25
		Two shapes	20	5	25
	Delay	Flower	25	1	26
		Two shapes	23	3	26
Hyper-active	Continuous	Flower	19	1	20
		Two shapes	20	0	20
	Partial	Flower	7	13	20
		Two shapes	10	10	20
	Delay	Flower	11	4	15
		Two shapes	13	2	15

TABLE 2

PRETEST DATA

MEANS AND STANDARD DEVIATIONS FOR TRIALS, ERRORS AND REINFORCEMENTS TO CRITERION OR MAXIMUM OF 300 TRIALS

Subjects	Treatment groups	Problem 1 (Flower)			Problem 2 (Two shapes)		
			Mean	SD		Mean	SD
Normal	Continuous N 26	Trials	87.6	61.8	Trials	89.1	73.2
		Errors	37.6	29.5	Errors	35.0	33.9
		Reinf.	50.0	34.5	Reinf.	54.5	41.1
			Mean	SD		Mean	SD
	Partial N 25	Trials	162.6	86.1	Trials	154.5	100.9
		Errors	68.8	42.0	Errors	68.8	54.8
		Reinf.	47.9	26.0	Reinf.	48.3	25.5
			Mean	SD		Mean	SD
	Delay N 26	Trials	98.0	92.0	Trials	95.4	98.0
		Errors	44.0	46.2	Errors	40.9	49.3
		Reinf.	53.9	46.9	Reinf.	54.5	50.4
Hyper-active	Continuous N 20		Mean	SD		Mean	SD
		Trials	122.3	87.7	Trials	47.4	37.7
		Errors	57.4	45.2	Errors	17.6	20.3
		Reinf.	64.7	43.7	Reinf.	26.9	15.0
			Mean	SD		Mean	SD
	Partial N 20	Trials	221.4	113.7	Trials	201.9	110.2
		Errors	116.2	69.5	Errors	100.3	62.1
		Reinf.	53.0	25.0	Reinf.	51.3	27.3
			Mean	SD		Mean	SD
	Delay N 15	Trials	169.3	122.2	Trials	104.7	102.8
		Errors	85.9	74.5	Errors	47.0	56.3
		Reinf.	83.5	56.1	Reinf.	57.7	48.6

TABLE 3

ANALYSES OF VARIANCE OF THE THREE PRETEST CRITERION MEASURES
(SQUARE ROOT TRANSFORMATIONS)

Source	df	TRIALS		ERRORS		REINFORCEMENTS	
		MS	F	MS	F	MS	F
Between Subjects	130						
Ss classification (S)	1	363.86	4.24*	320.99	5.72*	20.79	0.71
Treatments (T)	2	1687.28	19.67**	1044.81	18.61**	40.46	1.37
S x T	2	142.04	1.66	92.75	1.65	47.45	1.61
Error between	125	85.78		56.14		29.48	
Within Subjects	131						
Problems (P)	1	535.38	8.74**	375.93	9.75**	113.27	4.70*
S x P	1	324.35	5.29*	200.79	5.21*	132.61	5.50*
T x P	2	43.46	0.71	34.02	0.88	24.72	1.03
S x T x P	2	87.92	1.44	41.16	1.07	35.94	1.49
Error within	125	61.27		38.54		24.11	

* $p < .05$
** $p < .01$

TABLE 4

MEAN TRIALS TO CRITERION FOR ORIGINAL AND ORDER CONTROL GROUPS UNDER CONTINUOUS REINFORCEMENT

Subjects	Original Continuous Group		Order Control Group	
	1st Problem Flower	2nd Problem Two shapes	1st Problem Two shapes	2nd Problem Flower
Hyper-active	134.4 N=13	51.7 N=13	99.4 N=10	36.4 N=10
Normal	87.6 N=26	89.1 N=26	113.9 N=22	42.4 N=22

TABLE 5

SUMMARIES OF LATIN SQUARE ANALYSES
ORIGINAL AND ORDER CONTROL GROUPS UNDER
CONTINUOUS REINFORCEMENT

A. NORMAL SUBJECTS

Source	df	MS	F
Groups	1	2,395.0	0.44
Error within groups	46	5,475.6	
Problem type	1	31,357.8	5.96*
Order of presentation	1	28,817.9	5.47*
Error within	46	5,265.5	

B. HYPERACTIVE SUBJECTS

Source	df	MS	F
Groups	1	7,143.7	1.15
Error within groups	21	6,208.7	
Problem type	1	1,095.9	0.24
Order of presentation	1	59,987.2	12.91**
Error within	21	4,645.3	

* $p < .05$
** $p < .01$

TABLE 6

SUMMARIES OF TWO-WAY ANALYSES OF VARIANCE
OF REVERSAL SCORES FOR SUBJECTS
MATCHED ON ACQUISITION TRIALS.

A. FLOWER CONCEPT

Source	df	MS	F
Ss classification	1	116.67	0.07
Treatments	2	1202.36	0.68
Interaction	2	1457.31	0.83
Within cells	36	1762.07	

B. TWO SHAPES CONCEPT

Source	df	MS	F
Ss classification	1	6394.80	2.45
Treatments	2	1256.23	0.48
Interaction	2	1988.10	0.76
Within cells	24	2608.02	

TABLE 7

ANALYSES OF VARIANCE OF LOG ERROR SCORES
OVER BLOCKS OF 100 TRIALS

A. FIRST CONCEPT - FLOWER

Source	df	MS	F
Between subjects	131		
S classification (S)	1	9.16	11.91**
Reinf. Conditions (R)	2	6.89	8.96**
S x R	2	0.26	0.34
Error between	126	0.77	
Within subjects	264		
Trial Blocks (B)	2	32.08	191.55**
S x B	2	0.83	4.96**
R x B	4	0.56	3.36*
S x R x B	4	0.35	2.11
Error within	252	0.17	

B. SECOND CONCEPT - TWO SHAPES

Source	df	MS	F
Between subjects	131		
S classification (S)	1	0.16	0.23
Reinf. Conditions (R)	2	12.28	17.22**
S x R	2	2.00	2.80
Error between	126	0.71	
Within subjects	264		
Trial Blocks (B)	2	30.32	195.04**
S x B	2	0.32	2.06
R x B	4	0.44	2.81
S x R x B	4	0.12	0.76
Error within	252	0.16	

* $p < .05$
** $p < .01$

TABLE 8

CHI SQUARE TESTS FOR STATIONARITY OF PRECRITERION ERROR CURVES

Treatment Groups	Concepts	NORMAL SUBJECTS				HYPERACTIVE SUBJECTS			
		Mean proportion errors	df	Chi-square around own mean	Chi-square around chance level	Mean proportion errors	df	Chi-square around own mean	Chi-square around chance level
Continuous	Flowers	0.484	13	17.1	18.2	0.512	19	45.8**	47.3**
	Two shapes	0.436	15	22.9	53.2**	0.471	7	10.1	12.6
Partial	Flowers	0.448	23	37.3*	78.7**	0.560	29	38.4	96.6**
	Two shapes	0.472	24	62.9**	73.8**	0.505	29	25.1	25.5
Delay	Flowers	0.497	17	23.4	23.5	0.545	28	16.4	36.2
	Two shapes	0.472	19	25.0	32.5	0.489	20	14.7	15.4

* $p < .05$

** $p < .01$

TABLE 9

CHI-SQUARE TESTS FOR STATIONARITY OF PRECRITERION NONREINFORCEMENT CURVES — PARTIAL REINFORCEMENT SUBGROUPS ONLY

Subjects	Concepts	df	Mean proportion nonreinfts	Chi-square around own mean	Chi-square around chance level
Normal	Flower	23	0.718	14.0	36.1*
	Two Shapes	24	0.728	25.7	36.5*
Hyperactive	Flower	29	0.772	13.0	43.7*
	Two Shapes	29	0.744	12.6	13.4

* $p < .05$

TABLE 10

TEST-RETEST COMPARISONS FOR THE TRIALS TO CRITERION MEASURE

A. HYPERACTIVE SUBJECTS

Reinforcement Condition	Medication	Naturalistic Concepts			Number Concepts		
		Pretest	Retest	Diff.	Pretest	Retest	Diff.
Continuous	Drug	101.2	27.5	+73.7	36.7	56.0	−20.7
	Placebo	135.4	42.8	+92.6	46.2	17.6	+28.6
Partial	Drug	203.1	176.4	+26.7	223.8	175.3	+48.5
	Placebo	207.0	184.2	+22.8	172.7	189.5	−16.8

B. NORMAL SUBJECTS

Reinforcement Condition	Naturalistic Concepts			Number Concepts		
	Pretest	Retest	Diff.	Pretest	Retest	Diff.
Continuous	87.6	21.7	+65.9	89.1	43.8	+45.3
Partial	162.6	75.8	+86.8	154.5	126.3	+28.2

TABLE 11

ANALYSES OF COVARIANCE FOR
DRUG EFFECTS IN THE HYPERACTIVE SUBJECTS, WITH
SQUARE ROOT TRANSFORMATION OF THE DATA.

A. CONTINUOUS REINFORCEMENT GROUP

Source of variation	SS	df	MS	F
Groups, Drug vs Placebo	59.18	1	59.18	3.37
Ss within groups	280.94	16	17.56	
Problem Type	2.19	1	2.19	0.07
Groups x Problems	94.22	1	94.22	3.03
Residual	497.91	16	31.12	

B. PARTIAL REINFORCEMENT GROUP

Source of variation	SS	df	MS	F
Groups, Drug vs Placebo	34.27	1	34.27	0.27
Ss within groups	1886.43	15	125.76	
Problem Type	0.51	1	0.51	0.01
Groups x Problems	0.35	1	0.35	0.00
Residual	1127.38	15	75.16	

TABLE 12

ANALYSES OF COVARIANCE COMPARING RETEST SCORES FOR NORMAL AND HYPERACTIVE SUBJECTS, WITH SQUARE ROOT TRANSFORMATION OF THE DATA.

A. Ss UNDER CONTINUOUS REINFORCEMENT

Source of variation	SS	df	MS	F
Groups (Normal vs Hyperactive)	17.89	1	17.89	0.99
Ss within groups	762.77	42	18.16	
Problem Type	83.09	1	83.09	3.14
Groups x Problems	14.67	1	14.67	0.55
Residual	1112.41	42	26.49	

B. Ss UNDER PARTIAL REINFORCEMENT

Source of variation	SS	df	MS	F
Groups (Normal vs Hyperactive)	663.68	1	663.68	8.00**
Ss within groups	3317.83	40	82.95	
Problem Type	161.85	1	161.85	2.22
Groups x Problems	131.10	1	131.10	1.80
Residual	2915.42	40	72.89	

** $p < .01$

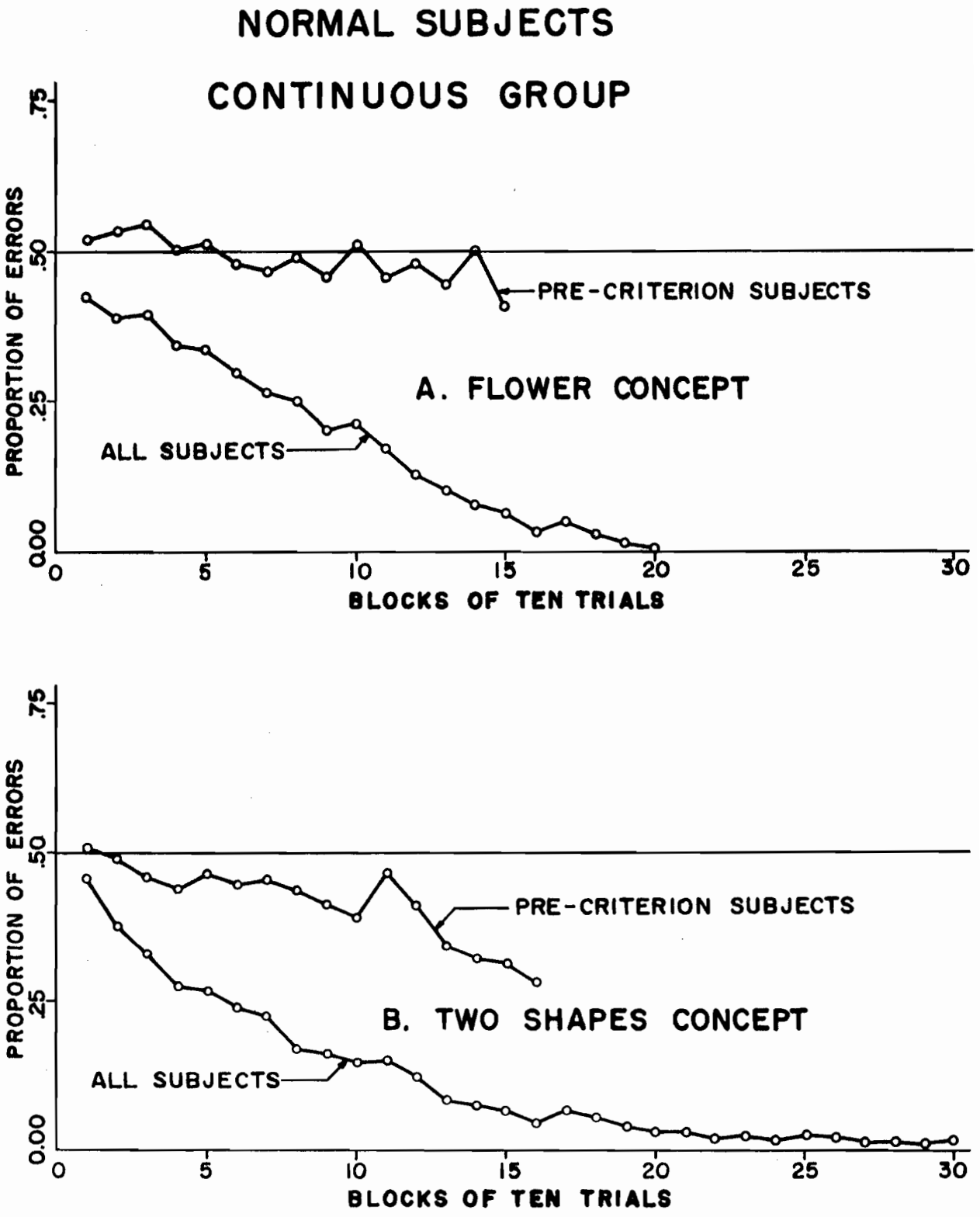

Fig.5. Group learning curves for normal subjects in the Continuous condition.

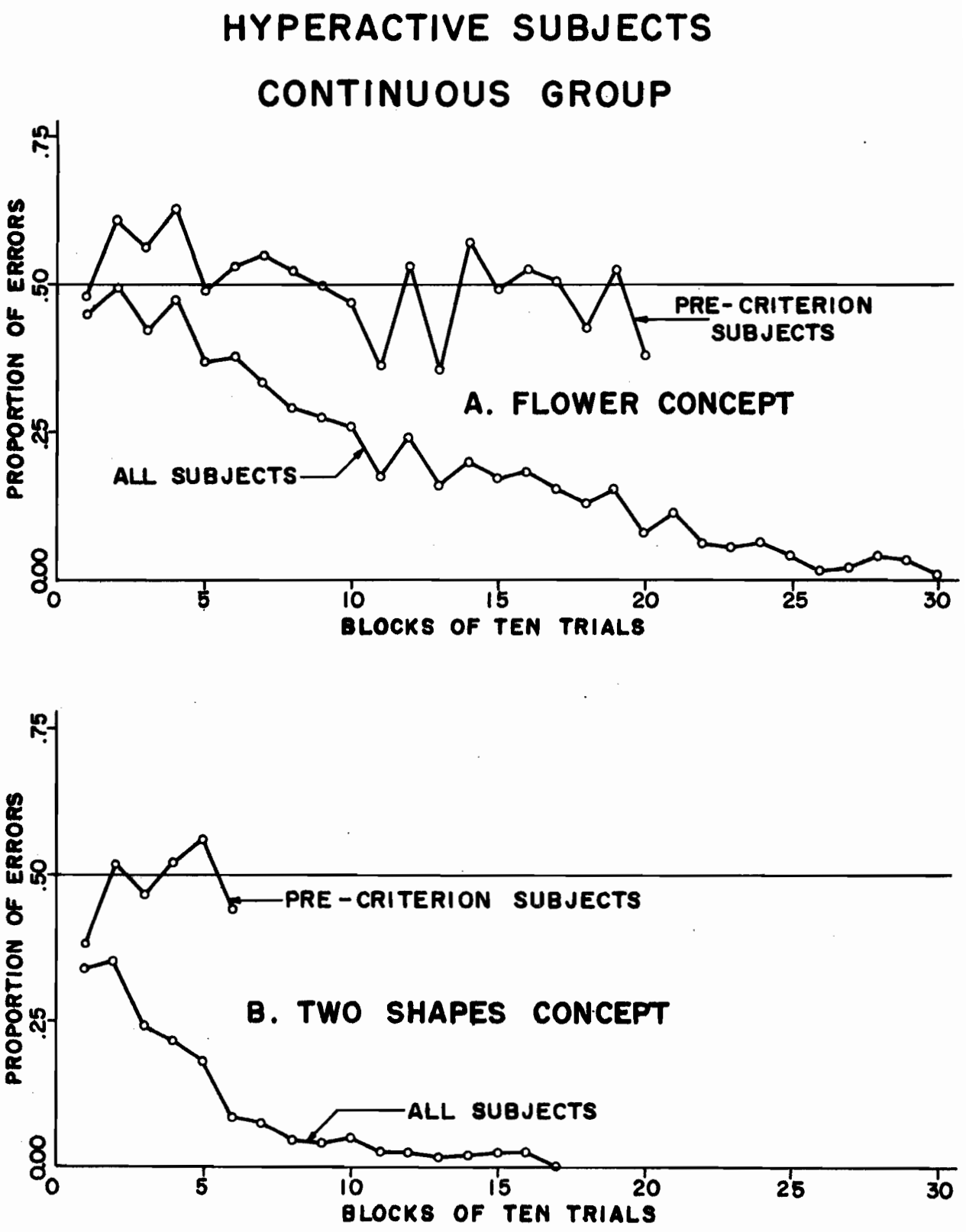

Fig.6. Group learning curves for hyperactive subjects in the Continuous condition.

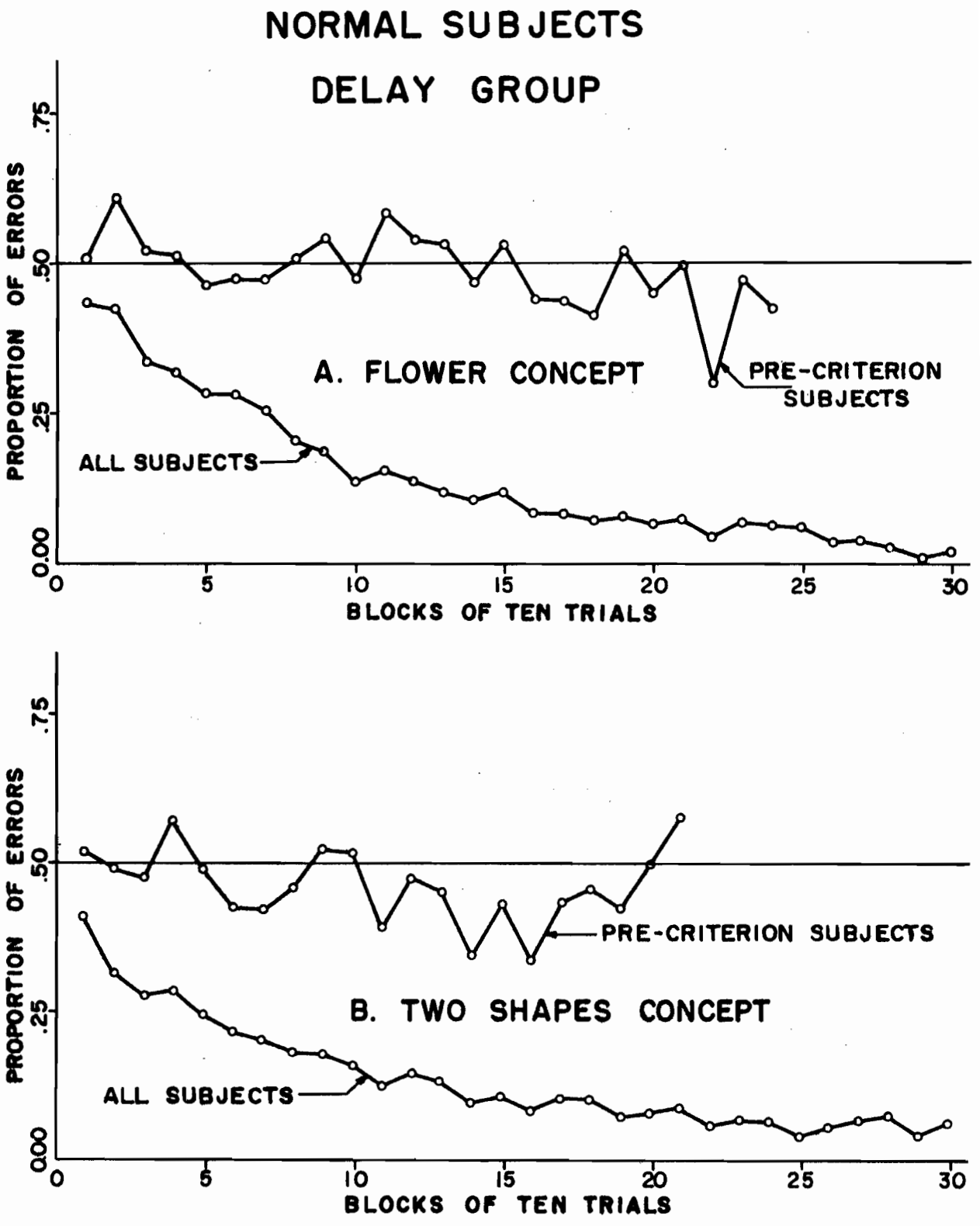

Fig.7. Group learning curves for normal subjects in the Delay condition.

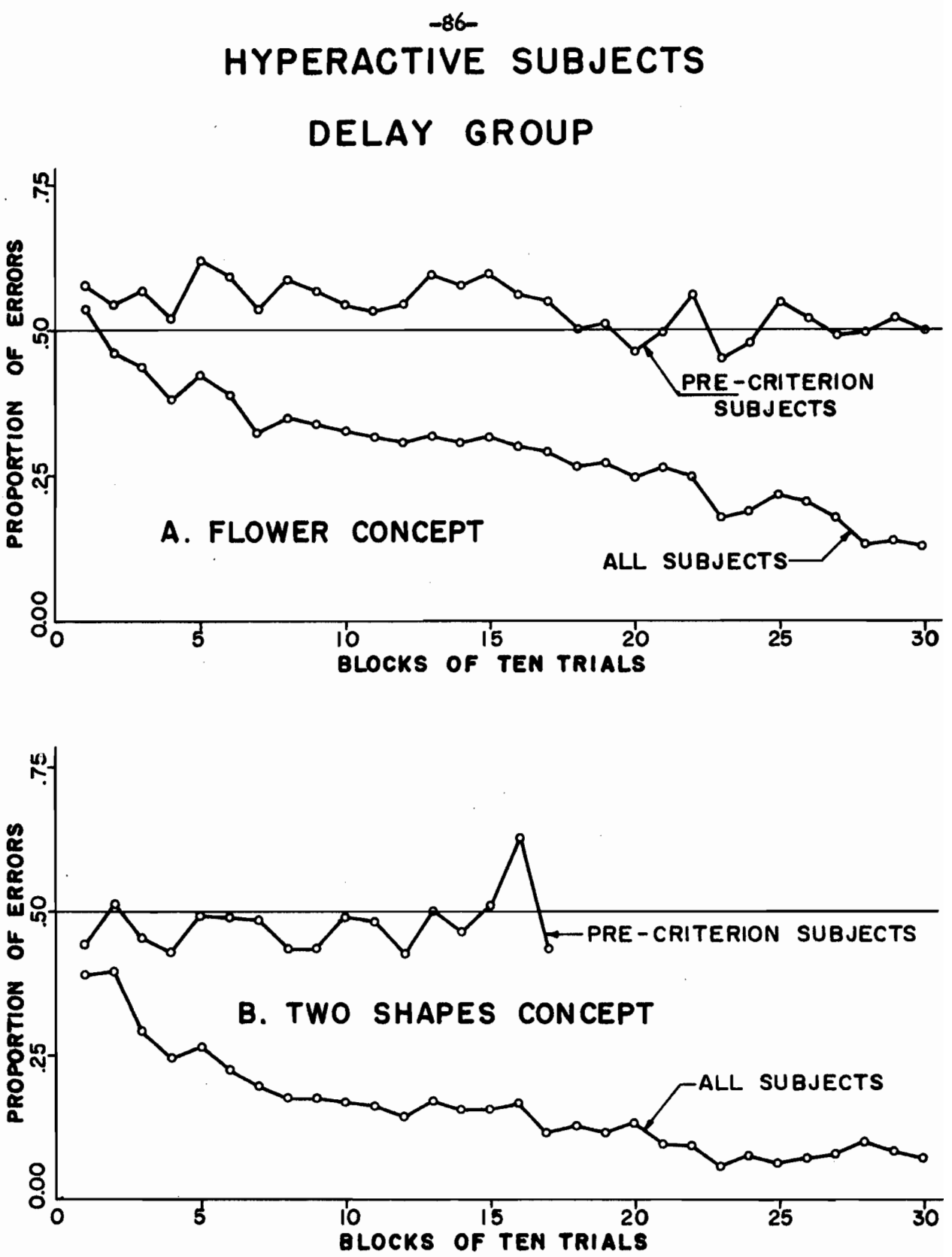

Fig.8. Group learning curves for hyperactive subjects in the Delay condition.

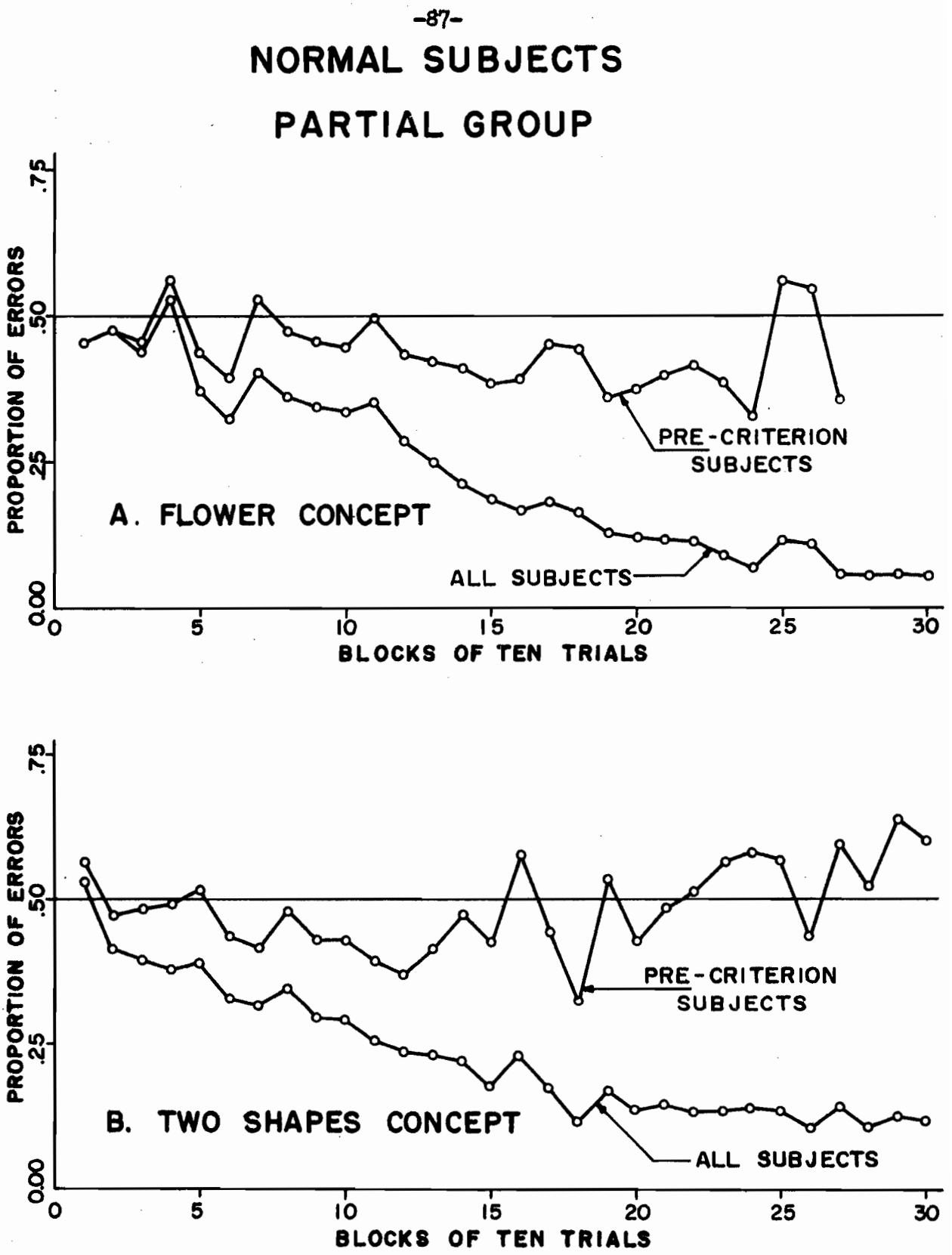

Fig.9. Group learning curves for normal subjects in the Partial condition.

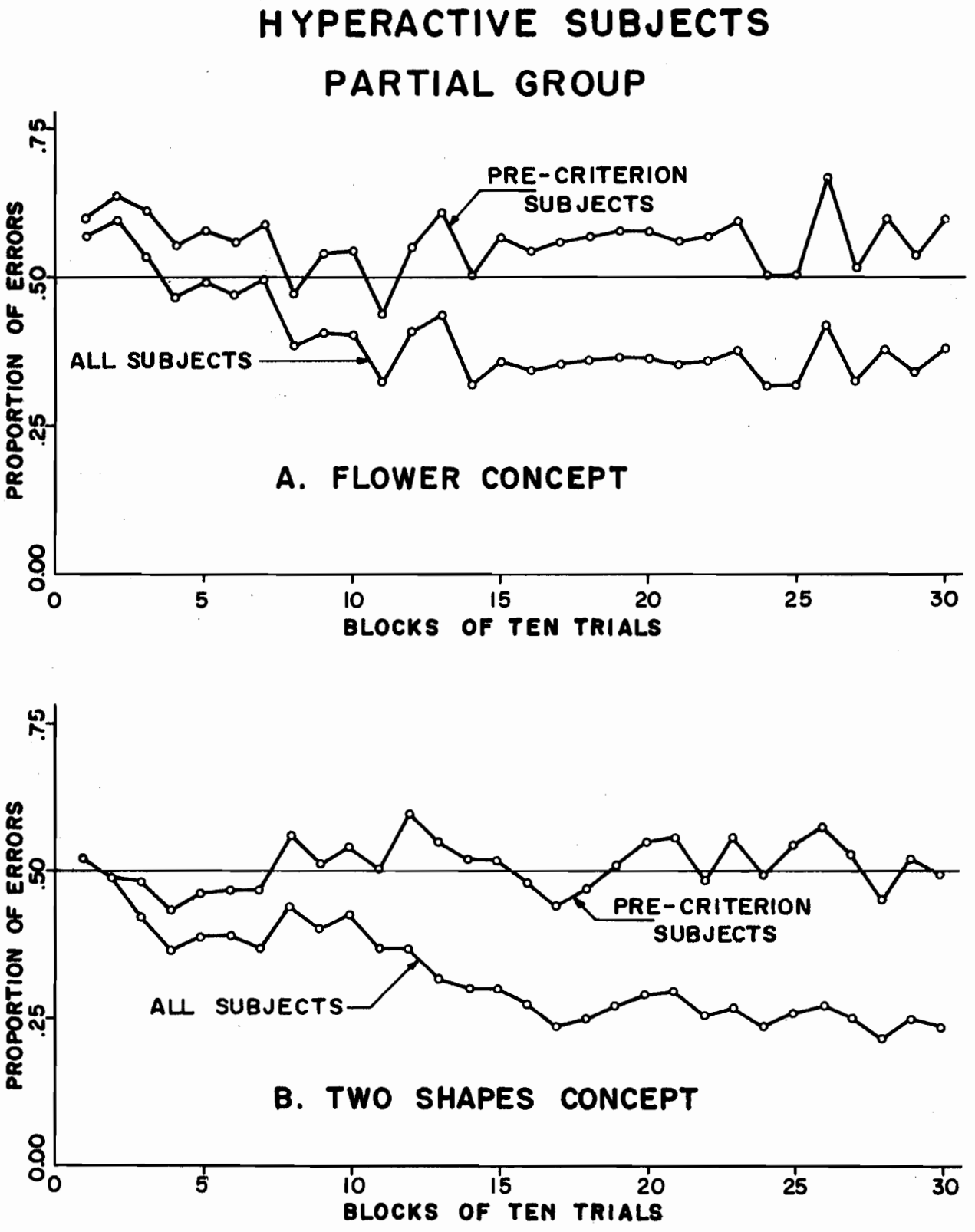

Fig.10. Group learning curves for hyperactive subjects in the Partial condition.

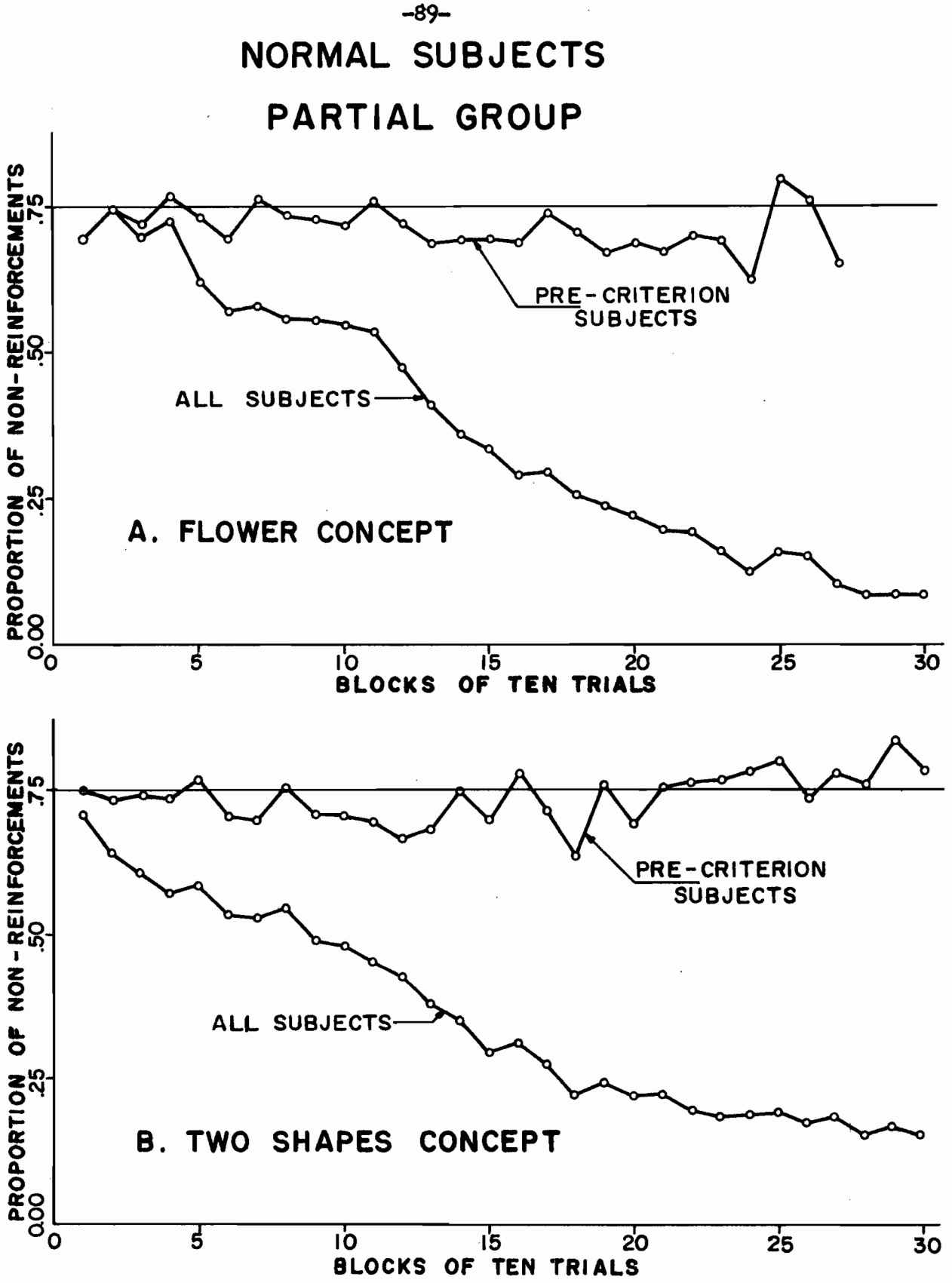

Fig.11. Non-reinforcement curves for normal subjects in the Partial group.

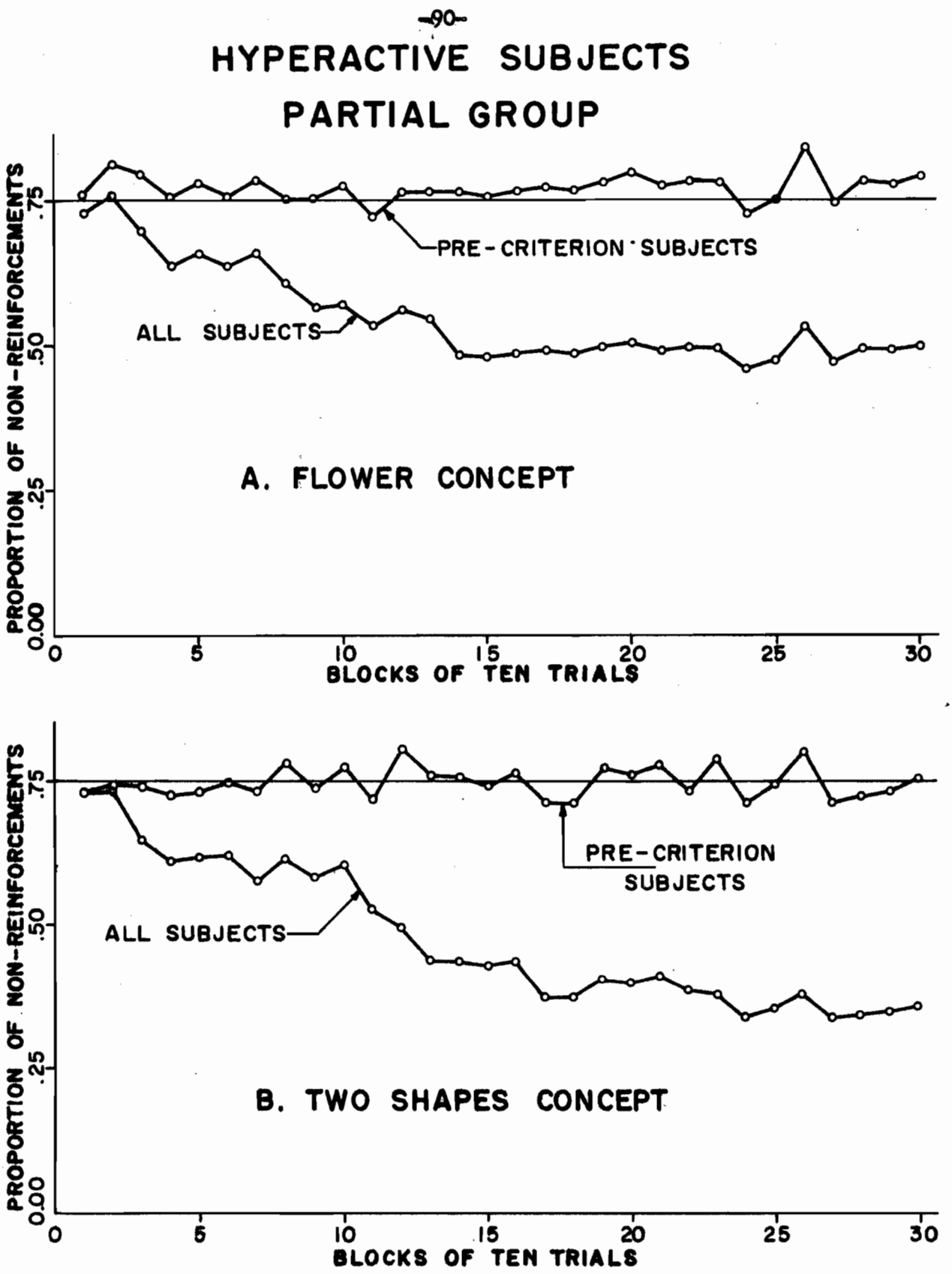

Fig.12. Non-reinforcement curves for hyperactive subjects in the Partial group.

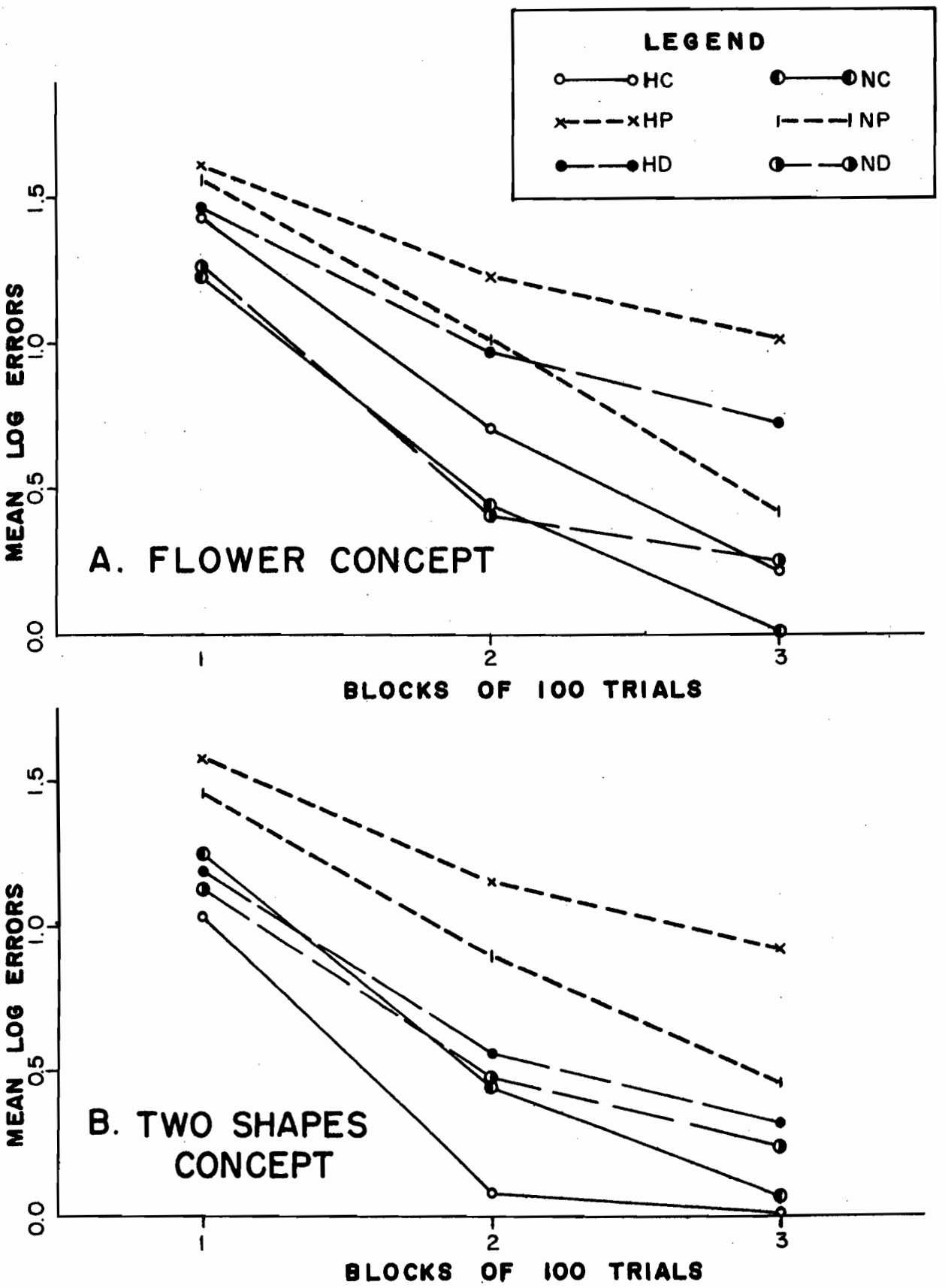

Fig.13. Mean log errors over blocks of 100 trials for the 6 experimental subgroups.

(H = hyperactive, N = normal; C = Continuous, P = Partial, D = Delay).

DISCUSSION

Considering first the drug results of the present study, the chronic administration of chlorpromazine hydrochloride was found to have no demonstrable effect on the concept learning of hyperactive children. These findings do not support the hypothesis that chlorpromazine therapy might improve learning by reducing distractibility in hyperactive patients. On the other hand, neither is there any indication that the tranquilizing action of chlorpromazine is achieved at the cost of impaired learning ability.

The present results are not in complete agreement with those of the Helper, Wilcott & Garfield (1963) study, where chlorpromazine was found to have no effect on a serial learning task, but produced a decrement on the later trials of a paired-associate task. It must be remembered, however, that in the Helper et al. study a severely disturbed, hospitalized sample of Ss was used, including psychotic cases. The task was also different, consisting of the repeated presentation of the same 8 stimuli for which names had to be learned. Most importantly, the maximum daily dosage was three times as high as in the present study (450 vs. 150 mg daily). The impairment observed, which the authors explained as a progressive loss of ability to attend to novel stimuli, might well be due to the higher dosage level.

The absence of drug effects on the concept learning task is consistent with the general findings of the over-all project of which the present study was a part. A total of 80 different measures, including psychiatric ratings, controlled behavioural observations, and a wide range of standard psychological test scores were analyzed in this investigation (Douglas, Werry & Weiss, 1965). Significant improvements under

chlorpromazine were found on clinical ratings of hyperactivity and overall evaluation of change in the child. This was supported by a significant reduction in the amount of undisciplined class-room activity, as rated in controlled observations. No differences were found, however, in clinical ratings of distractibility, aggressivity or excitability, or on any of the measures of intellectual or psycho-motor functioning. The action of chlorpromazine in small to moderate dosage thus seems to be confined to the level of motor activity, leaving learning ability and other psychological functions unchanged. These results, obtained after chronic administration over approximately a two-month period, are in essential agreement with the findings on normal adult Ss under acute doses (Delay et al., 1959; Lehman & Csank, 1957).

Before turning to a comparison of concept learning in hyperactive and normal children, some general comments about the concept learning process are in order. Concept learning has been distinguished from rote learning, largely because of the difficulty of explaining it by means of classical S-R learning theory. This difficulty is illustrated in the present data where no indications could be found (either in the normal or the hyperactive Ss) of incremental changes in the tendency to choose exemplars of the correct concept. On the contrary, there was consistent evidence that this type of concept learning is a discontinuous process, fitting all-or-none models of learning. A probable explanation for this is that, in the present situation, Ss were not forming concepts in the true sense of acquiring new conceptions such as "twoness" or "bird". Even the youngest Ss, being 6 years old, would have had sufficient opportunity to acquire a working collection of such basic concepts on the basis of their every-day experiences. The task of the S in the present experiment was mainly one of selecting the correct (i.e. task-relevant) concept

from the total repertoire of concepts available to him. Learning in this situation appeared to be sudden, possibly because it did not involve the establishment of new connections in the nervous system but the selective reinforcement of connections already capable of functioning (Hebb, 1949). The advantage of an all-or-none model is that it provides a useful basis for analyzing this type of selection process. How well such a model might describe the early learning by means of which basic concepts ("cell assemblies", Hebb, 1949) are acquired is another issue, and one beyond the scope of the present thesis.

A major aim of the present experiment was to obtain objective evidence with respect to the concept learning ability of hyperactive children. It has been suggested in the clinical literature that hyperactives would have difficulty in functioning at a conceptual level because of inadequate stimulus processing capabilities of their central nervous system (Burks, 1960; Clements & Peters, 1962). The results of this experiment indicate that hyperactive Ss may or may not show decrements on a concept learning task, depending on specific variables.

Turning first to the performance of the experimental subgroups receiving continuous reinforcement, no significant differences were found in this study between the hyperactive and the normal Ss on the criterion measures. Performance in a concept learning situation depends on two main types of variables, those pertaining to the processing of stimulus information, and those reflecting the ability to modify behaviour on the basis of feedback information. The fact that the hyperactive Ss under CR showed no impairment in their ability to discover the correct concepts indicates that they have no fundamental deficit in the ability to abstract the relevant information from complex, multidimensional

stimuli. Similarily, they do not appear to be deficient in their ability to shift from one hypothesis to another on the basis of information feedback. Additional evidence that hyperactive Ss do not seem to lack flexibility in responding to complex stimuli is provided by the finding that the reversal scores were not significantly different for hyperactive and for normal Ss. This finding is of particular interest because the clinical literature frequently describes hyperactive children as showing a tendency toward perseveration.

The experimental situation, it must be noted, had many features which would be expected to facilitate learning. The novelty of the special apparatus seemed to have a particular attraction for children. The mechanical noises accompanying the presentation of each stimulus probably helped to arouse interest and focus attention by signalling the appearance of the next stimulus. The use of a large number of attractive, colourful pictures would further serve to reduce boredom. Finally, the children were tested individually, in a samll room providing little distraction. Most important, however, appeared to be the fact that children in the Continuous and Delay groups received immediate, consistent and tangible reinforcement for every correct response made.

Although the hyperactive Ss under CR performed as well as the normal Ss on global criterion measures, it should be noted that analyses of the learning curves revealed some differences in the precriterion data. First, there were differences in the shapes of the learning curves. The precriterion curve for hyperactive Ss on the first concept under CR showed highly significant fluctuations around the chance level. It is possible that this reflects fluctuations in attention from task-relevant to task-irrelevant stimuli. Second, the mean proportion of errors was slightly

but consistently higher for the hyperactive than for the normal Ss. A higher proportion of errors during learning has been said to indicate a large number of irrelevant hypotheses in a S's response repertoire. (Restle, 1962). There is thus a suggestion in the precriterion data that the hyperactive Ss may be deficient in the ability to confine their attention to specific aspects of the stimulus situation (Atkinson, 1961). More generally, they may have difficulty, on the first test session, in adopting the set to examine the stimuli carefully (Vinogradova, 1959).

This suggestion is supported by striking and consistent differences in the test behaviour of the clinical and control Ss. Records were kept of the Ss' behaviour and verbalizations during the test sessions. These showed that about 75% of the hyperactive Ss were highly excited and spent a considerable amount of time engaging in task-irrelevant activities. This included asking countless questions about the apparatus, procedure and stimuli, continual handling of various parts of the apparatus, despite repeated discouragement by E, and manipulation of the accumulated marbles. None of the normal Ss asked more than three questions in a session, and none attempted to manipulate the apparatus, except as instructed.

Distractibility is one of the symptoms included in clinical descriptions of the hyperactive syndrome along with hypersensitivity, low frustration tolerance, etc. All of these symptoms, which were found to accompany hyperactivity in a considerable proportion of the Ss used in this study (Werry, Weiss & Douglas, 1964), could be considered as representing one fundamental difficulty, a chronic level of excessive arousal. This means that the hyperactive child would tend to have abnormally low response thresholds and, at being introduced into a novel situation, would respond

indiscriminately to a wide range of stimuli (Hebb, 1955). On each learning trial under CR, however, differential reinforcement is given for task-relevant responses. With 100% reinforcement for correct responses, the hyperactive child apparently learns very quickly the task-orienting sets that he may not have had at the outset, as evidenced by the significant improvement from the first to the second test session.

The most important finding of the present investigation is that concept learning is significantly more difficult for hyperactive than for normal children under a partial reinforcement schedule. Decrements under PR were found on both criterion and precriterion measures in the pretest sessions, and were even more marked on the two retest concepts. From the point of view of information feedback, less information is transmitted by any one trial under a PR than under a CR schedule, because of the ambiguity of non-reinforced trials under PR. In these circumstances the only strategy that can produce a correct solution involves remembering the stimuli which were previously reinforced, and maintaining a hypothesis in spite of non-reinforced trials. Judging from the present results, nearly half the hyperactive sample failed to develop the appropriate strategy, even after a total of four different test sessions. Two different explanations, one stressing cognitive, the other motivational variables might account for this finding.

Because the time interval separating successive reinforced responses is greater under PR than under CR, decrements under PR might be due either to a more rapidly fading memory trace or to interference from intervening stimuli. If either of these were major factors, however, some decrements would also have been expected for hyperactive Ss in the Delay subgroup. While there was a slight trend in this direction, it did not reach statistical

significance. Another possible basis for poor performance under PR would be a higher than average sensitivity to the frustrative effects of non-reward. According to Amsel's formulation, the primary frustration reaction leads to the development of two different components. The inhibitory component would be expected to lead to a rapid abandoning of any hypothesis that led to non-reinforcement, unless the S was able to keep in mind the instructions which explicitly stated that correct responses would not always be reinforced. Discarding hypotheses at the first non-reinforcement would make learning impossible under PR. In addition, frustration is considered as having an activating, or drive component. Thus the already high level of arousal of the hyperactive Ss would be further raised under PR. In the learning task used in this study, this excessive level of arousal would be expected to decrease the likelihood of task-relevant discriminations, by interfering with the cue function of stimuli (Hebb, 1955).

The frustration hypothesis receives support from both spontaneous and elicited verbalizations in the test situation. These verbalizations suggested that the hyperactive Ss were attempting to restructure the situation in such a way as to minimize its frustrative aspects. One reaction was to ignore the instructions, which stated that there was an "idea" in the pictures which would help in choosing the correct ones. Several hyperactive children stated, in spite of repeated instructions to the contrary, that there was <u>no</u> rule or "idea" and that the task was simply a game of chance. Others would say that the rules "changed all the time", again denying the possibility of a rational solution. A few other hyperactive Ss (but none of the normal Ss) took the position that they already had the correct answer, although the instructions stated

that E would inform them when they had "won the game". Thus one seven-year old hyperactive was jumping up and down and shouting that he was doing "better than anyone in the whole world" when, in fact, he was getting less than the 25% rate of reinforcement to be expected on a chance basis. These reactions resemble "denial", one of the "defense mechanisms" used in attempting to cope with frustration, and found to be particularly frequent in younger and in maladjusted children (Douglas, 1965).

The finding that PR produces such marked decrements in hyperactive children suggests the importance of training programs which would be specifically geared to overcoming this deficiency. This might be achieved by careful manipulation of reinforcement schedules, starting with 100% reinforcement at the beginning of training, and introducing lower rates of reinforcement very gradually.

In conclusion, the findings of the present study argue against the existence of any specific conceptual deficit in hyperactive children of at least dull normal intelligence. Significant and persistent decrements were found under partial reinforcement, but could be interpreted as representing motivational or attentional difficulties, rather than defects of an intellectual or cognitive nature.

SUMMARY

The performance of 65 hyperactive and 99 normal children was compared on a series of concept learning tasks under three different experimental conditions. Reinforcement schedule was found to be the major variable differentiating between the performance of normal and hyperactive subjects. Under continuous reinforcement there were no significant differences between the hyperactive and the normal samples on criterion measures of learning. Increasing the intertrial interval from 4 to 8 secs. under continuous reinforcement had no significant effect on the performance of either the normal or hyperactive groups. Although concept learning under partial reinforcement was more difficult for all subjects, the hyperactive children showed significantly greater performance decrements in this condition. These findings do not support the assumption that hyperactive children have deficits of a conceptual nature; they suggest instead that the observed decrements may be explained on the basis of attentional or motivational variables.

A second aim of this study was to examine the effects of a tranquilizing drug, chlorpromazine, on the learning ability of hyperactive children. No significant differences were found between Ss receiving the active agent and those receiving a placebo.

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APPENDIX A

DESCRIPTIVE STATISTICS ON EXPERIMENTAL SUBGROUPS

1. HYPERACTIVE SUBJECTS

Subgroup		No. of Ss	Age		WISC Vocabulary		Mean I.Q.**
			Mean	SD	Mean	SD	
Continuous	Pretest Ss	20	8.34	1.53	12.3	3.3	107.9
Original sample	Post-test Drug Ss	10	8.27	1.47	13.3	2.5	110.3
	Post-test Placebo Ss	9	8.56	1.70	11.3	4.0	107.1
Partial	Pretest Ss	20	8.87	1.66	11.1	2.9	104.4
	Post-test Drug Ss	9	9.31	1.43	12.1	2.4	100.8
	Post-test Placebo Ss	9	8.79	1.92	10.4	3.4	108.4
Delay (Pretest)		15	8.54	1.90	10.7*	2.3	100.7
Continuous, Additional control sample		10	8.67	0.83	10.8	2.3	98.9

2. NORMAL SUBJECTS

Subgroup	No. of Ss	Age		WISC Vocabulary	
		Mean	SD	Mean	SD
Continuous, Original sample	26	8.72	1.59	12.5	2.3
Partial	25	9.17	1.72	11.6	2.0
Delay	26	8.95	1.71	12.2*	1.8
Continuous, Additional control sample	22	8.79	1.80	11.9	2.6

* $p < .05$ in hyperactive - normal comparison

** Available only for hyperactive Ss.

APPENDIX B

MEAN TIME INTERVALS SEPARATING DIFFERENT TEST SESSIONS FOR EACH EXPERIMENTAL SUBGROUP

Subjects	Treatment Condition	Mean time interval in days			
		Pretest 1st to 2nd session	Retest 1st to 2nd session	Test-Retest 1st concept	Test-Retest 2nd concept
Normal	Continuous	6.9	4.1	53.4	50.6
	Continuous Order Control	3.0	-	-	-
	Partial	6.8	4.1	53.0	50.3
	Delay	4.0	-	-	-
Hyper-active	Continuous	6.6	3.2	66.4	62.5
	Continuous Order Control	2.0	-	-	-
	Partial	5.0	4.8	68.8	68.1
	Delay	3.0	-	-	-

APPENDIX C

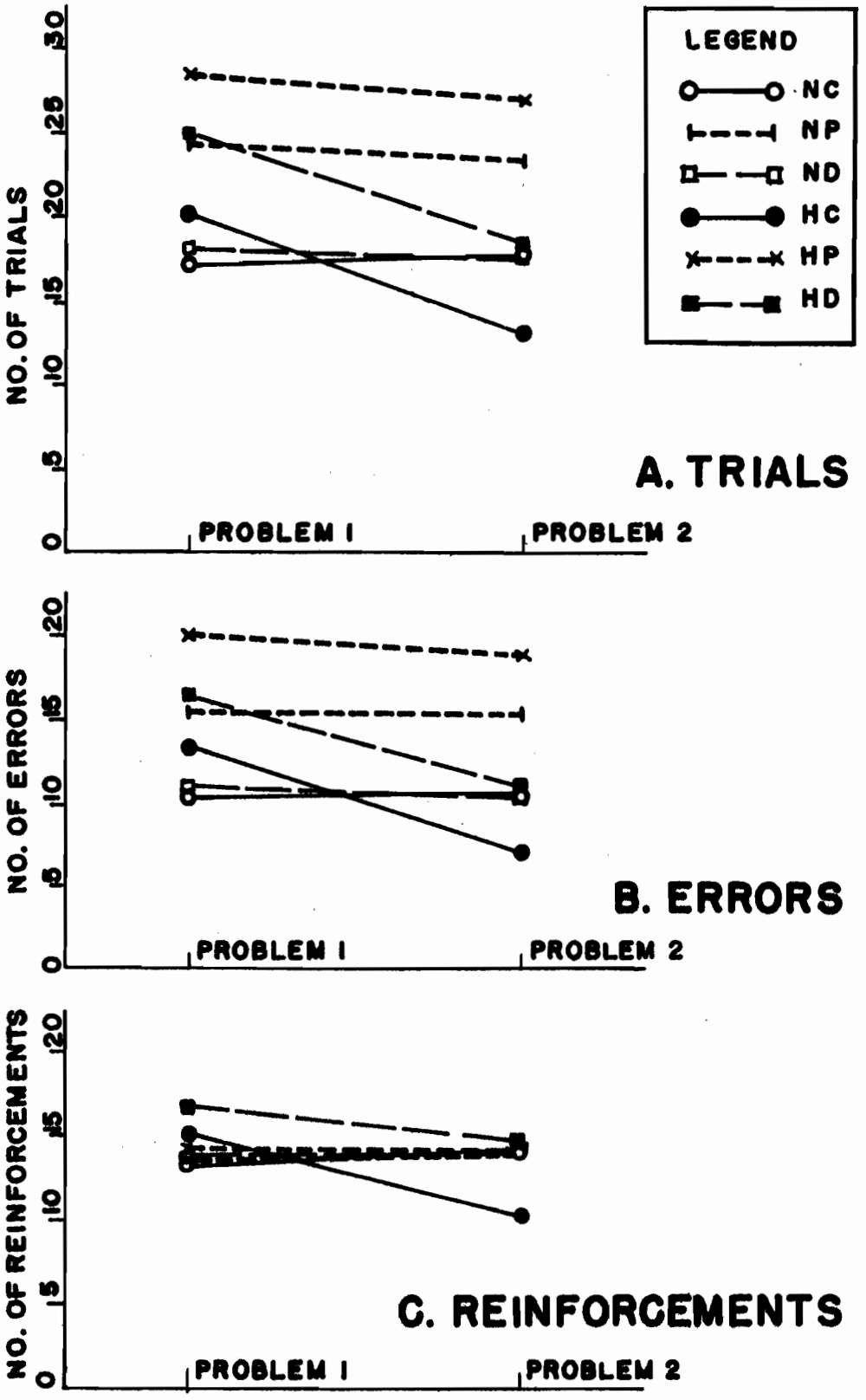
CORRELATIONS OF TRIALS TO CRITERION WITH WISC VOCABULARY SCORES AND WITH AGE (PRETEST ACQUISITION DATA)

Subjects	Treatment Condition	Correlation Coefficients			
		Vocabulary Score with		Age with	
		1st Concept	2nd Concept	1st Concept	2nd Concept
Normal	Continuous N = 26	.04	.03	-.42*	-.11
	Contin.Order Control N = 22	.03	-.72**	-.14	-.50*
	Partial N = 25	-.32	.05	.13	-.06
	Delay N = 26	.01	.13	-.33	-.55**
Hyperactive	Continuous N = 20	-.16	-.24	-.19	-.06
	Contin.Order Control N = 10	-.02	-.70*	-.21	-.54
	Partial N = 20	.23	.25	-.54*	.01
	Delay N = 15	-.20	.16	-.64**	-.41

* $p < .05$

** $p < .01$

APPENDIX D



Cell means from analyses of variance (Table 3) of the 3 criterion measures (square root transformation). Lines connect means of each subgroup on the 2 different pretest problems.

APPENDIX E

CORRELATIONS OF ACQUISITION AND REVERSAL SCORES ON THE TRIALS TO CRITERION MEASURE, PRETEST DATA. (1A = FIRST CONCEPT, 1B = 2ND CONCEPT)

Subjects	Treatment Condition	Product-Moment Correlation Coefficients			
		Acq. 1A with Rev. 1A	Acq. 1B with Rev. 1B	Acq. 1A with Acq. 1B	Rev. 1A with Rev. 1B
Normal	Continuous N = 26	.49*	.37	-.14	.06
	Contin. Control N = 22	.98**	.98**	.18	.35
	Partial N = 25	.17	.07	-.12	.35
	Delay N = 26	-.02	.15	.17	.02
Hyperactive	Continuous N = 20	.26	-.06	.35	.17
	Contin. Control N = 10	.14	.90*	-.04	.65
	Partial N = 20	.40	.05	.50*	-.06
	Delay N = 15	.66**	.30	.39	.07

* $p < .05$

** $p < .01$

APPENDIX F

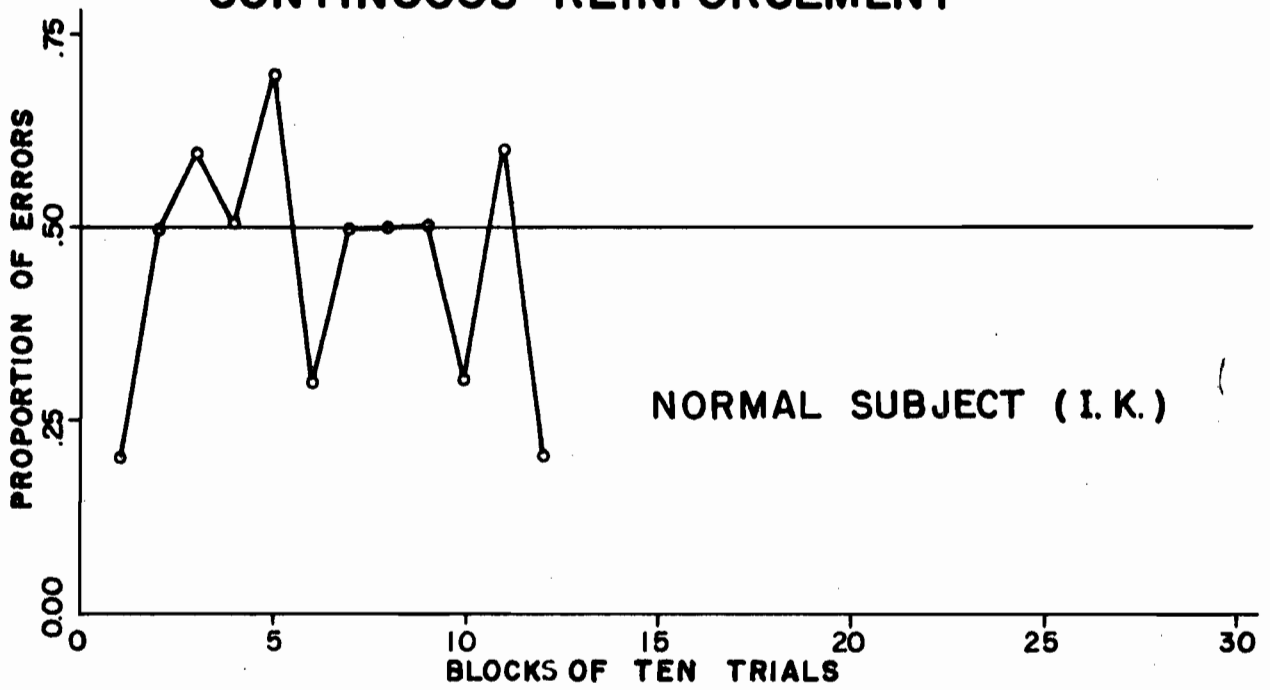
CORRELATIONS OF TEST-RETEST DIFFERENCE SCORES (TRIALS TO CRITERION) WITH TEST-RETEST TIME INTERVAL IN DAYS

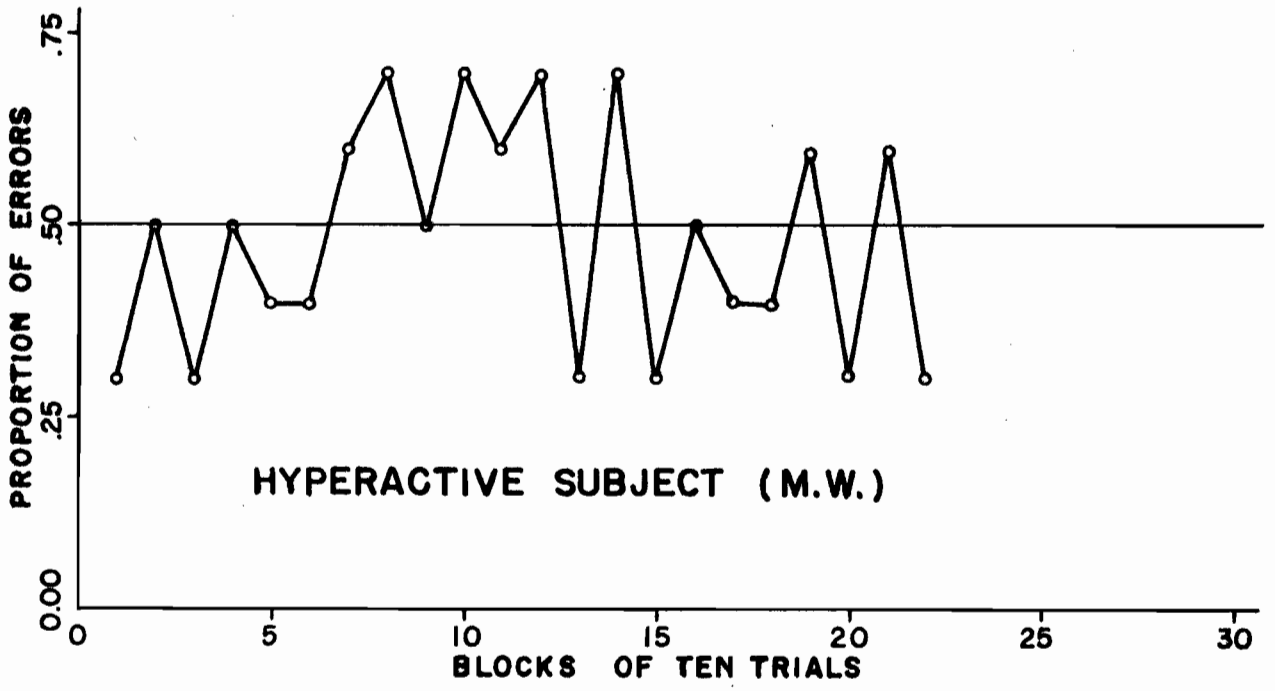
Subjects	Treatment Condition	1A-2A with T1	1B-2B with T2
Normal	Continuous N = 26	.15	-.19
	Partial N = 25	-.18	-.32
Hyperactive	Continuous N = 19	-.03	-.31
	Partial N = 18	.22	-.15

APPENDIX G

INDIVIDUAL LEARNING CURVES

CONTINUOUS REINFORCEMENT

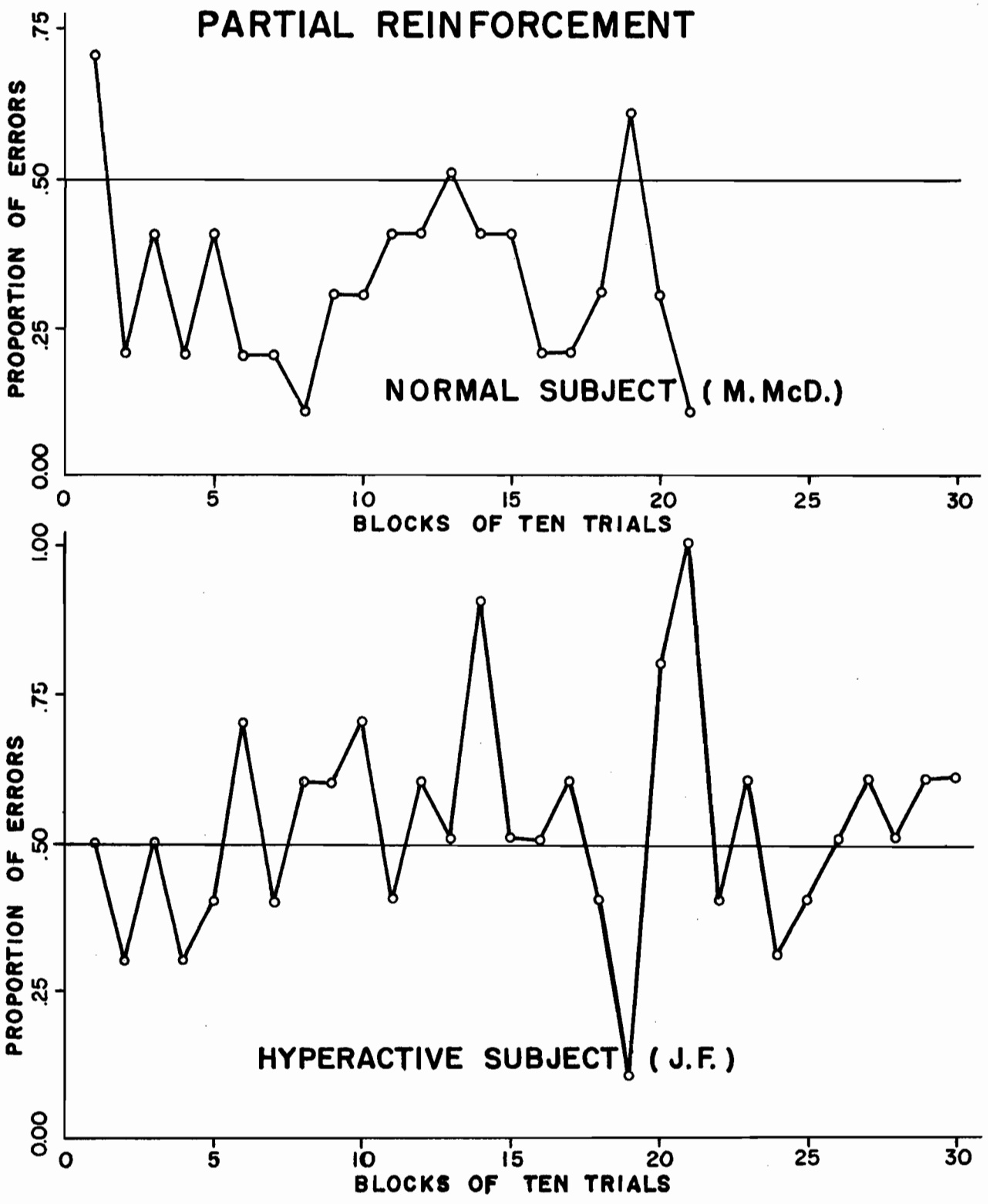




1. Learning curves for individual normal and hyperactive subjects under continuous reinforcement.

APPENDIX G

INDIVIDUAL LEARNING CURVES



2. Learning curves for individual normal and hyperactive subjects under partial reinforcement.