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TITLE OF THESIS....LOOKING BEHAVIOR IN NORMAL AND RETARDED CHILDREN DURING DIRECTED SEARCH TASKS AND DISCRIMINATION LEARNING

UNIVERSITY....ALBERTA....................

DEGREE FOR WHICH THESIS WAS PRESENTED....Ph.D..........

YEAR THIS DEGREE GRANTED......1971....................

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NL-91 (10-68)

THE UNIVERSITY OF ALBERTA

LOOKING BEHAVIOR IN NORMAL AND RETARDED CHILDREN DURING DIRECTED SEARCH TASKS AND DISCRIMINATION LEARNING

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

EDMONTON, ALBERTA

SPRING, 1971

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Looking Behavior in Normal and Retarded Children During Directed Search Tasks and Discrimination Learning" submitted by Walter Muir in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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Date: April 15, 1971

ABSTRACT

The Zeaman and House theory of discrimination learning suggests that retarded children are handicapped in learning by a visual-attention deficit. However, the theory has been criticized for the lack of an operational definition of the attentional construct. In the present study it was proposed that looking behavior, as measured by eye movements (EMs), could provide a useful definition of attention.

A sample of 20 functionally retarded Ss of CA 8 to 12 years was compared to a CA matched sample of 24 normal Ss with regard to looking behavior during directed search tasks and discrimination learning. The major hypotheses of the study predicted that retarded Ss would spend less time looking at stimulus areas of high information during visual search, and at the relevant cues of a discrimination learning task, than normal Ss. A secondary hypothesis suggested that the introduction of verbal information regarding the solution of the discrimination learning task would have no observable effect on the EM activity of retarded Ss, while normal Ss would respond with increased focussing on the relevant cues.

The results indicated general confirmation of the hypotheses and it was suggested that evidence in support of the Zeaman and House theory had been found.

It was concluded that the analysis of looking behavior was effective in providing objective evidence of a retardate visual-attention deficiency during visual-perceptual tasks and discrimination learning. The suggestion was made that further study of EMs during learning could provide objective evidence of mediational processes.

ACKNOWLEDGMENTS

Sincere thanks are extended: to the members of the supervising committee, and especially to Dr. F. J. Boersma, the chairman, for their guidance and support; to K. M. Wilton for his assistance in collecting the data; to the students, teachers, and principals of the participating schools for their cooperation; to Mrs. V. Niehaus for typing the manuscript; and to my wife, Joan, for several years of patience and encouragement.

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CHAPTER 1

Introduction

The purpose of this investigation was to relate selective attention and discrimination learning to visual activity in normal and retarded children. The primary means of doing so was through the evaluation of eye-movement (EM) behavior of two groups of subjects during their solution of specified tasks.

The human nervous system is capable of processing only a small portion of the great number of stimuli that impinge on the senses. The individual must, if he is to control his own behavior, develop a means whereby the important and useful information is recognized and the remainder is ignored. The majority of children gradually acquire the ability to select that which is relevant, but some, particularly retarded children, do not.

The difficulty that the retarded child has in directing and maintaining his attention has been recognized for over half a century, having been noted by Kuhlman (1904). Berlyne (1951) has stated that attention is an integral part of learning and that inadequate attention results in learning difficulties. And yet, according to Crosby and Blatt (1968), "despite the obvious educational importance of an alleged attentional deficit in the mentally retarded, the problem has not been adequately investigated." The lack of empirical evidence is also noted by Berkson (1963), Clausen (1967), Denny (1964), Rosenberg (1963), and Spivack (1963).

Berlyne (1960) has suggested that attention, as a construct, has had perhaps the most varied usage of any word in psychology, while Mostofsky (1968) has deplored the absence of any generally accepted definition of attention. It is not surprising, then, that research evidence of the nature of the attention deficit in retardates is sparse.

A growing body of literature from researchers in the USSR (Gal'perin, 1969; Luria, 1963a, 1963b, 1969; Lynn, 1966; Sokolov, 1963, 1969) has focussed on describing the physiological and intellectual components of the orientation response (OR). Several aspects of research in this area bear directly on the present study. Foremost among these are the concepts of "voluntary attention" as expressed by Luria (1969), and the "selective intellectual operation" of Gal'perin (1969). Each of these presents a promising framework within which to approach the study of learning difficulties. Both writers have attempted to extend Sokolov's concepts of the OR into the sphere of intellectual operations.

The act of learning intimately involves the auditory and visual senses. The learner must "tune-in" the appropriate receptor to the task at hand if learning is to occur. While both senses are important, it is not unreasonable to suggest that under normal circumstances the eyes are required to input the greater amount of information during learning. Therefore, if the retardate is deficient in the ability to direct his visual attention, objective evidence of the nature of the deficit should precede attempts directed toward improving his attentional behavior. The present study is based on this premise.

Instruments that can record EM activity accurately and with a minimum of interference to visual functioning have been developed quite recently (Alpern, 1962; Mackworth, 1967). As a result, an increasing number of studies relating EMs to intellectual processes have been reported. Very few of these studies, however, have involved retarded subjects. Consequently, a broad field of investigation lies open to those who are engaged in mental retardation research.

An area of study that is receiving considerable interest is the influence of attention on the discrimination learning of retarded children. Most of the studies reported have emerged from the work of Zeaman and House and their associates (House, 1964a, 1964b; House & Zeaman, 1963, 1967; Hyman, 1967; Zeaman, 1965; Zeaman & House, 1963) who have used the theory of Wyckoff (1952, 1954) as their point of departure.

Wyckoff's theory relates an "observing response" by the learner to his ability to perform discrimination learning tasks. He defines an observing response as an action that results in the exposure of stimuli to the learner, the probability of which can be determined for a given set of circumstances. Wyckoff (1952) has applied an instrumental learning model which permits the general hypothesis that exposure to discriminative stimuli will reinforce an observing response to the extent that the subject responds differentially, rather than randomly, to the stimuli. In other words, the probability of an appropriate observing response is associated with learning. This relationship follows from Skinner's (1938) suggestion that discriminative stimuli tend to have secondary reinforcement properties.

An additional hypothesis that can be derived from Wyckoff's theory suggests that when the differences between stimuli are small, and the probability of an observing response is also low, but not zero, the formation of a discrimination will be retarded for some interval. However, when appropriate observing responses begin to occur, learning will proceed rapidly. Wyckoff (1952, 1954) claims support for the theory in studies mainly on pigeons, and has presented a descriptive mathematical model of the relationships involved.

Zeaman and House have applied Wyckoff's model to their studies of visual discrimination learning in retarded children. Their major hypothesis states that discrimination learning is mediated by the perceptual mechanism of "attention." They propose a two-stage instrumental model in which the learner must attend to the relevant stimulus dimension before he can respond to its positive cue. Until appropriate attention occurs, learning does not take place.

The position is taken that the difficulties experienced by retardates in learning discriminations are more related to limitations in the first stage of the process than the second. Zeaman and House contend that once the learner begins to attend to the relevant dimension, learning is independent of his level of intelligence. The difference lies in the number of trials required before appropriate attention occurs.

Zeaman (1965, p. 110) states that "if our attention theory is correct, the poor discrimination performance of retardates is reversible to the extent that attention can be harnessed and properly directed." He suggests that the main factors that influence attention are intelligence, reinforcement (material and verbal), and properties of the stimulus such as color, size, symmetry, redundancy, and novelty.

However, Mostofsky (1968) has suggested that the Zeaman and House position is weakened by the lack of an acceptable definition of attention. In their theory, he argues, the existence of an "attention deficiency" is both inferred from and explained by the performance of retarded learners. As a consequence of this circularity, objective measures of the attention deficit have not been possible. In the absence of an operational definition, Wischner (1967) suggests, it must be concluded "that retardates are deficient in acquiring observing (attention) responses because they already have an attention deficit." What is required is an operational definition of attention that is independent of learning performance.

The research reported here is an attempt to provide at least partial answer to the problem. Several EM measures have been used as dependent variables in evaluating the perceptual and learning activity of normal and retarded children. Looking behavior, as manifest by EMs, has been applied as an operational definition of attention in an effort to determine whether the assumption of retardate attentional deficiency is tenable at this peripheral level of perception. By employing EMs, which can be objectively and reliably measured, the criticisms of Mostofsky (1968) and Wischner (1967) regarding the present circularity in the definition of attention can perhaps be countered.

Of additional concern in the study of discrimination learning is the nature of the mediational response. The "attention" mediator proposed by Zeaman and House is to a large extent a perceptual mechanism that permits the learner to select the relevant aspects of the stimuli. In contrast is the "verbal" mediator position of Kendler and Kendler (1962, 1970) which suggests that, for children who possess a degree of verbal fluency, the act of learning a discrimination is facilitated by covert verbal behavior. Firm evidence for or against either position has not yet been offered although it would appear that the attention theory has received more general support for its predictions of transfer learning (Wolff, 1967). Here again, the lack of operational definitions has made objective evaluation difficult. The present study has attempted, in a preliminary way, also to provide some objective evidence of the distinction.

CHAPTER 2

Review of Related Literature

Attention

Even the casual observer is aware of the vast amount of stimulation in his immediate environment. Since he is unable to respond simultaneously to all elements of this environment, he is obliged to select those elements to which he will respond. This act of selection, in a general sense, is what is commonly referred to as _attention_.

Mostofsky (1968, p. 13) describes attention as "a process, a state, or a relationship involving a subject reacting with and to his environment." Involved in the process are inputs to one or more of the senses to which selective responses are applied. The nature of the response is affected by such variables as development, maturation, reinforcement, and the response repertory of the subject.

Berlyne (1951, 1960) views attention as an integral part of perception and suggests that there are two components involved in its function. The _intensive_ component is associated with the organism's general level of alertness. As such, it reflects the "global" influence exerted by internal and external stimuli. The _selective_ component is related to the manner in which attention is distributed among specific elements of the stimulus field. Both components can be recognized as having an essential relationship to perception and learning.

An extension of Berlyne's position may be seen in the work of Soviet researchers (Luria, 1963a, 1963b; Sokolov, 1963, 1969) who have directed their efforts to the study of the orientation reflex or orientation reaction (OR). The terms are attributed to Pavlov's (1927) "what is it?" response and are usually considered to be synonymous. They seem to refer, generally, to the organism's holistic reaction to noticed stimulus change. Components of these reactions are described by Lynn (1966) as including dilation of the pupil, photo-chemical changes in the retina, changes in skeletal musculature, respiration, and heart rate, and, of particular relevance to the present study, changes in EM activity. Luria (1963a, p. 100) suggests that these reactions of the organism to its environment are of such importance that, "not one new temporary connection can be formed nor one new piece of knowledge or ability acquired without their participation."

In studying the OR, Soviet scientists have most recently relied on physiological measures, often during perceptual tasks, and have shown that two major types of responses exist (Lynn, 1966). The generalized OR is characterized by desynchronization of alpha rhythms over the entire cerebral cortex. The apparent function of desynchronization is to ensure that stimulus input quickly reaches a set of nerves at the optimum point in the cycle so that reaction time is minimum. The localized OR differs from the generalized in that alpha rhythm desynchronization is centered in the cortical area of the appropriate sensory modality (e.g., the visual cortex if the stimulation is through the eyes).

Sokolov (1963, pp. 116-118) describes the role of the OR as a "control of sensitivity" to stimulation. "The complex of the OR, aiming at an increased state of preparedness of the whole body, and at better perception of the stimulus is, in fact, a combination of two types of reflexes, tonic and phasic, which remain intimately interwoven." The tonic reaction is rather slower than the phasic and "persists for a longer time in the form of altered sensitivity." The phasic OR can be seen in the "form of rapid successive changes" of short duration, usually lasting no more than a few seconds, and tends to occur simultaneously with the tonic reaction. In situations of violent stimulus change, as with a sharp, unsuspected noise, the phasic reaction could, however, precede the tonic OR. When considered jointly, the two reactions complement each other such that the tonic OR provides a sustaining level of arousal upon which the phasic OR may be superimposed when a specific stimulus input is encountered.

Gal'perin (1969), also a Soviet, has described the general concept of orientation toward a task as the basis for the development of "mental acts." He suggests that there are basic types of orientation to a task and that each has a unique influence in the course of learning. In his formulation he assumes that all mental activity is influenced by a person's initial orientation to external and internal events. Gal'perin's conception of ORs as "intellectual operations" which select a specific problem solving approach differs from the physiological response interpretation of Sokolov. Cole and Maltzman (1969, p. 13), commenting on the apparent difference, suggest that "the measurement of this process and its relationship to the OR defined in terms of physiological responses or investigatory behavior is an important task which remains to be thoroughly explored."

Luria (1969, pp. 149-150) discusses the relationship of the OR and "voluntary attention" in the development of perception and thought. "By 'voluntary attention' we should understand a reflex act, social in origin and mediated in its structure, in the presence of which the subject <u>begins to guide himself by the very changes which he has produced in the environment</u>...." He describes a developmental trend in which the mediated activity is relatively unstable in the young preschool child such that stimulus changes resulting from his own activity were more likely to distract him than to facilitate his learning activity. The young school child (ages are not stated) was seen to exhibit a steady "externally mediated" attention that produced greatly improved performance over the preschooler. In older children, internal mediation in the form of subvocal speech had replaced external mediation. "Attention, which initially had an immediate character, acquired first an externally mediated structure and then, with the aid of speech, became a complex, organized functional system."

The theories of Sokolov, Gal'perin, and Luria suggest interesting parallels with those of Wyckoff, the Kendlers, and Zeaman and House. For example, Wyckoff's "observing response" and Zeaman and House's "attention" seem not unlike Gal'perin's "selective intellectual operation." These, in turn, can be perceived in terms of Sokolov's "phasic" component of the OR since all seem to refer, at least in part, to an initial short-term reaction to stimulus change. Extending the argument, the mediational features of the Zeaman-House and Kendler theories would seem to be similar to Luria's mediated "voluntary attention." Since, however, a mediational process logically follows an initial awareness of a problem and tends to occur over a period of time, a link between the mediational theories and Sokolov's sustaining "tonic" component of the OR emerges. It may be argued, therefore, that the attention theories exhibit a decided commonality in their description of the learning process and that their essential differences lie more in terminology than in definition.

In his consideration of individual differences in attention, Luria (1963a) has suggested that stimuli of low intensity which evoke ORs in normal children fail to elicit similar responses in retarded children, and that when ORs do occur in retardates, they tend to extinguish more rapidly than in normals. In addition, the ability of normal children to control and direct their attention ensures that irrelevant stimuli will not evoke ORs, whereas retardates, being less able to select and focus on what is relevant, tend to exhibit ORs to more extraneous stimuli. The logical outcome of this lack of control is the ineffective intake of information by the retardate. Additional support for this point of view is offered by Berlyne (1960), Hagen (1967), and Heal and Johnson (1970), all of whom suggest the presence of an inadequate inhibitory mechanism in the retardate.

When the position of Zeaman and House (1963) is compared to that of Berlyne (1951, 1960), and to physiological theories associated with the OR, a logical theoretical parallel seems to emerge. Berlyne's selective component and the phasic component of the OR appear to be somewhat related to "attention to the relevant dimension" on which the Zeaman and House theory is predicated. Inadequate development of Berlyne's inhibitory mechanism, and of the phasic OR, results in a heightened distractibility in which the learner responds indiscriminately to a wide range of stimuli; a situation which corresponds very closely to that described by Zeaman and House (1963) as occuring during pre-solution trials of a discrimination learning task. Berlyne's intensive component and the tonic component of the OR also seem related in that both appear to refer to a general state of arousal or readiness to receive information. An optimal level of arousal, moreover, would be necessary for effective learning to take place. Such a state of readiness is a factor which Zeaman and House (1963) appear to assume and one which logically seems to precede the selection of stimuli.

What the above discussion appears to suggest, with some unanimity, is that retarded learners are deficient in the selection of those stimuli which carry useful information. As a result of this deficiency, information input is of reduced utility and learning effectiveness minimized. Since orienting behavior (attention) is, in part, a learned phenomenon, it might be argued that a "cumulative attention deficiency" in the retardate could occur if appropriate attentional behavior is not developed.

While the broader definition of attention includes reactions to inputs through all of the senses, this investigation is directly concerned only with those entering through the eyes. The eyes probably provide the organism with more stimulation per unit of time than any of the other senses. As a consequence it is in the visual mode that the greatest need for appropriate stimulus selection occurs.

Eye Movements

The importance of the visual receptors in perception and learning has pointed to the need for better understanding of the relationships involved. Physiologists, such as Davson (1962), have provided a large body of literature that describes the functioning of the eye as a sensory input mechanism; much less research is related to the functions of the eye during the process of learning.

Movements of the eyes (EMs), both voluntary and involuntary, are essential to the visual process (Alpern, 1962). Voluntary EMs permit the viewer to focus the image of momentary interest upon that small area of the retina, the fovea, which contains the greatest concentration of receptor cells. It is via the fovea that a clearly defined image is received and transmitted to the visual cortex. These movements, controlled as they are by the viewer, vary in amplitude from a few minutes of arc to several degrees, depending upon the field of view. In the context of the previous discussion, voluntary EMs would seem to be related to Berlyne's selective component, Sokolov's phasic OR, Wyckoff's observing response, and in part to Zeaman and House's conception of attention. (The latter position, however, seems to also include the intensive and tonic components.) Involuntary EMs are described by Alpern (1962) as being of several types, each of which serves an essential function in maintaining the integrity of the retinal image.

The development of sensitive and reliable instruments for the measurement of EMs is quite recent (Alpern, 1962; Levy-Schoen, 1969; Mackworth, 1967; Yarbus, 1967). Methods of observation, as reported in the literature, vary from a subjective estimation of eye position by an independent observer, to the placement of a tiny mirror on the eyeball by means of a suction cup (Alpern, 1962; Yarbus, 1967). The former is probably the simplest, least obtrusive and least precise method reported, whereas the latter, while very precise, quite obviously prevents vision through the eye on which the measurement is taken. According to Alpern (1962, p. 66), "the most popular method of objectively estimating eye position is by photographing light from a small source after it is specularly reflected from the convex surface of the cornea."

The corneal reflectance method, as described by Mackworth (1967), offers an acceptable level of precision while avoiding the intrusion of a foreign object to the surface of the eye, and is the method used in the present study. Briefly stated, a point light source of medium intensity is reflected from the cornea of a subject's (S) left eye. Since the radius of the cornea is smaller than that of the eyeball, movement of the eye is described by the light reflected from the cornea. It is a matter then of merging the reflected light from the cornea with the image of the field of view and photographically recording the two simultaneously. According to Mackworth (1967, p. 120), the method produces recordings that are accurate to within one degree of arc.

Several writers have reported studies designed to determine parameters of EMs in various contexts. Alpern (1962) notes that if a target is completely fixated, objects will disappear from the field of view after about 5 seconds. Maintaining the image, therefore, requires that the eye be almost constantly in motion. Alpern describes 3 types of EMs that appear to serve such a function. High frequency tremor, slow drifts, and saccades combine to keep the eye in a dynamic state. Tremor and drift are so imperceptible that they may be observed only on the most sensitive instruments. Saccadic movement is the characteristic scanning activity that is largely determined by the nature of the field of view and the purpose of the search. Ditchburn and Foley-Fisher (1967) and Gould (1967) have indicated that the interval between successive saccades (i.e., fixation duration) is in the order of 250 to 400 milliseconds, again somewhat dependent upon characteristics of the observer and of the field of view. These EMs, controlled as they are by the viewer, provide a useful means of objectively measuring perceptual activity.

EMs and Developmental Differences

A number of studies describe the development of EM activity in children. Zinchenko, van Chzhi-Tsin, and Tarakonov (1963) studied the EMs of children 3 through 6 years and found that the 3 year olds tended to fixate longer, made little attempt to search for the distinctive features of the display, and stayed within the area of the figure rather than search the more informative outer contours. The 6 year olds, however, displayed briefer fixations, seemed to look for the distinctive features, and showed movement along the contours. They concluded that EM activity in the growing child develops toward locating the distinctive features of visual stimuli.

Zaporozhets and Zinchenko (1966) report a similar study with Ss 3 to 6 years of age. They concluded that only the 6 year old children showed "fully-formed" methods of perceptual activity. This was interpreted to mean that, by the sixth year, most children have learned which characteristics of an object are most informative. "The development of perceptual activity proceeds along the line of isolating a specific sensory content which is increasingly more commensurate with the material presented and the task with which the subject is faced" (p. 398). They note, however, that this developmental trend is very closely related to the complexity of the stimuli presented. When children were shown pictures of familiar content, such as illustrations to popular fairy tales, no essential differences in EMs were observed. The writers suggested that specially designed perceptual training may result in an acceleration of the developmental sequence.

In a later paper, Zaporozhets (1969) describes supporting research by himself and others in the USSR regarding the effects of sensory training on the acceleration of learning. In the paper he formulates a general theory of perceptual and cognitive development based primarily on an increasing internalization of perceptual models by the learner. The developmental sequence, the theory states, proceeds from a rather general orientation to the size of the object by children of 3-4 years, toward a more specific orientation to the configuration of the object by children of 6-7 years. Visual search behavior by the older group is characterized by rapid EMs directed toward relating individual parts of the figure, whereas there are fewer EMs and virtually no relational attempts by the younger children.

Vurpillot (1968) provides additional evidence of EM development in children. She studied the EMs of children of ages 3 through 9 years as they performed a task requiring judgment as to the similarity or difference of paired stimuli. It was found that children under 6 years scanned only part of the stimuli and tended to make judgments on insufficient information. She found also that the 9 year-old children made virtually no errors, and concluded that scanning for information improved with age. This finding, the writer suggests, is in accord with Piaget's theory of development.

Mackworth and Otto (1970) used the wide-angle EM camera described by Mackworth (1968) to compare the "visual orienting response" (VOR) behavior of 29 children of ages 2 through 7 years. The task required that subjects fixate on a 4x4 matrix of simple white shapes one of which, the "test circle", was capable of being changed from white to red and back to white. In this manner, novelty was introduced into the stimulus situation. The VOR was compared across 3 age groupings (2-3, 4-5, & 6-7) to determine the effect of novelty and habituation. The VOR was measured in terms of a "fixation index"; "the percentage of motion-picture frames showing a fixation falling on the test circle within a block of frames." It was found that the 2-year-olds were as effective in their VOR behavior as the 7-year-olds, an indication that as long as the rules of evaluation are simple, age is not a significant factor in processing and interpreting visual displays. In addition, no significant differences in the rate of habituation were observed across ages. It was stressed, however, that no elaborate searching of the simple display was required; thus, a situation was presented that was quite different from that reported by Vurpillot (1968). The writers concluded that studies of the VOR "allow us to follow the formation of a neural model of the environment and its subsequent use in reaching decisions."

The need for similar studies on more complex stimuli was noted. On the basis of this study, however, it would appear that even very young children have an ability to control, at least partially, their EM behavior during the observation of visual displays.

O'Bryan and Boersma (1970) studied the EMs of 92 girls 6 through 10 years in their performance of Piagetian conservation tasks of length, area, and continuous quantity (solid and liquid). They found that those Ss identified as "conservers" showed greater perceptual activity in the form of scanning behavior than did the "non-conservers." The data, they suggest, "appear to support a theory of perceptual activity leading to decentration and to indicate a change in viewing strategy associated with change in conservation status."

Mackworth and Bruner (1970) compared the EMs of adults and 6 year-old children during inspection of displays and found significant scanning differences between the two groups. Adults showed greater facility than children in the selection of informative areas, "a process which called for a delicate balance between central and peripheral vision,... a skill which is controlled by a cerebral program not always fully developed in the six-year-olds." Moreover, adults showed "cognitive attempts" to relate important areas of displays by long leaping EMs, and tended to have shorter fixation durations than did children. The writers concluded that the analysis of EMs illustrated a greater ability in adults to apply "stored internal experience" to the recognition of visual stimuli.

Mackworth and Bagshaw (1970) report a series of experiments that compared the VORs of adults, children of 6 years, and monkeys. They found that each group was able to find the novel and informative areas in a complex display, although children were less effective than adults in doing so. Monkeys were found to exhibit EMs similar to children although of lesser intensity in terms of a VOR. They concluded that children can process pictorial information almost as quickly as adults and that "6-year-olds have...reached almost their final level in pictorial skills."

Drake (1970) compared the EMs of 18 third grade children with those of 16 college students during solution of the Matching Familiar Figures test. The college students had significantly more fixations and covered more area of the pictures with their EMs than did the younger Ss. This finding differs somewhat from the conclusion of Mackworth and Bagshaw, above, by suggesting that visual search behavior in children may not reach a stable state until after the age of 8 years. What is needed is a more comprehensive description of the development of visual search strategies.

The literature contains very few studies of non-normal populations. Tyler (1969a) reports an EM study of 2 adult male patients with lesions of the frontal lobe. He found that while their mean fixation times of 260 to 300 msec. were within the normal range, there was a tendency for the Ss' gaze to leave the viewing area after 10 seconds. He found, also, little attempt to relate different areas, while recognition was piecemeal or on the basis of limited information.

A second study by the same author (Tyler, 1969b) describes the EMs of 19 patients classified according to 3 types of aphasic disorder: "receptive", "primary expressive", and "amnestic" (naming). The receptive aphasics were found to scan in a "purely passive manner" with no attempt to accumulate information or to relate different parts of the display. The primary expressives showed initial "normal" scanning but did not continue their exploration of the field and failed to make a "sophisticated perceptual judgment." The author suggests that the verbal deficiency of expressives would be of reduced importance to a "pure visual process." The amnestics, whose major difficulty is in the production of verbal labels, appeared to scan "normally." This, Tyler suggests, enhances the notion that the amnestic aphasic has little problem with his thought processes, but does have difficulty in "recalling the model from memory."

Only 2 studies were found that compared EMs of normal and retarded children. O'Connor and Berkson (1963) compared the EMs of "mongoloids", "nonmongoloid imbeciles", and normal children. They found that the mongoloids showed more EMs than the others but concluded that this could have resulted from a notable apprehensiveness by the mongoloids to the experimental situation. Winters, Gerjuoy, Crown, and Gorrell (1967) compared the EMs of "adolescent educable retardates" with CA and MA matched normal children during a tachistoscopic presentation of alphabetic and geometric displays. The correlations between EMs and verbal reports of what was seen were significantly higher for normals than for retardates. In addition, retardates who were "more consistent" in their organization of EMs and verbal reports gave significantly more correct responses and scored higher on a reading test than retardates who were less so.

In summary, the research evidence indicates that during normal development there is a sequence in EM behavior from relatively undifferentiated fixations on a stimulus field toward a controlled and increasingly efficient search for information and meaning. The control of search behavior by the child does not normally seem to occur before age 6, and by age 9 or 10 has reached a high level of effectiveness. The rather sparse research on non-normal Ss appears to suggest either an arrested development in early childhood, or as with patients having frontal lobe injury, a reversion to a childhood level of functioning. These latter observations must remain tentative until much more research has been conducted on non-normal populations.

EMs and Cognitive Behavior

A survey of the research in which the corneal reflectance method of recording EMs was employed reveals a recent interest in the role of EMs during cognitive tasks.

Luborsky, Blinder, and Mackworth (1964) studied the EMs of 18 adults during a search task and found that those Ss having the greater number of fixations were better able to recall the content of perceptual images. Teichner and Price (1966) presented a serial sequence task to 10 male college students in which the S was required to determine the next letter in the sequence. They concluded that correct solution of the task was associated with a reduction in scanning and an increase in attention to the detail of the sequence.

In a series of studies designed to establish the parameters of adult EM behavior during pattern recognition tasks, Gould and his associates (Gould, 1967; Gould & Brown, 1967; Gould & Schaffer, 1965; Gould & Schaffer, 1967) have reported a quadratic relationship between the amount of information contained in the stimulus and the duration of fixation. The major conclusion of the studies was that duration of fixation is influenced by the amount of "cognitive activity" associated with the specific task.

Tikhomirov and Poznyanskaya (1966) analyzed the EMs of master chess players during a chess match. The most important finding, they suggested, was that a chess move is preceded by repeated investigations of the critical elements, with EMs searching through the alternative moves. It was concluded that "the dynamics of search thus emerge as the perpetual transformation of the conditions of a problem...we interpret this transformation as the result of positive search activity open to objective analysis." Williams (1966) has suggested that the specification of a target creates a "perceptual structure" and that the study of EMs is, in effect, the study of that structure.

Several studies are reported which investigated relationships between EMs and the construct of "cognitive style." Conklin, Muir, and Boersma (1968) found that "field-independent" Ss fixated with significantly greater frequency in high information areas of pictorial displays than did "field-dependent." It was concluded that the field-independent Ss employed more effective search strategies. Boersma, Muir, Wilton, and Barham (1969a) compared the EMs of 16 field-independent and 16 field-dependent Ss on an "embedded figures" task and found that the field-independent Ss exhibited significantly more refixations or shifts between the target figure and the optional figures among which the match to the target was to be found. A second report in which the same Ss responded to an anagram task (Boersma, Muir, Wilton, & Barham, 1969b) indicated that the field-independents required significantly less time to scan the 5 letters of the anagram than did the field-dependents.

Drake (1970) compared the EMs of "impulsive" and "reflective" Ss during the solution of the Matching Familiar Figures test and found that by the time of response, the reflectives had looked at a larger area of the figures than had the impulsives. The conclusion was that the reflectives' approach to the task required that they gather more information about the stimuli, and that it be gathered more "carefully." Impulsives were more inclined to "take a stab at a decision" before all the evidence had been acquired and tended to be less concerned with rechecking the information before making a decision. Drake's basic assumption, that a S's EMs reflect his cognitive approach to the task, appeared to be supported.

The above studies show that EMs do indeed reflect individual differences during the solution of cognitive tasks. The measures used in most of the studies, (e.g., fixation duration) tend to be rather general descriptors of cognitive behavior, therefore, it would seem desirable to apply a measure that would provide a more specific index of cognitive functioning. A number of studies, discussed below, appear to have been designed with this purpose in mind.

Several studies have reported the application of an "information search" variable to perceptual tasks in which the subject is required to scan for and report on information contained in a pictorial display.

Mackworth and Bruner (1970) in comparing the EMs of 6-year-old children and adults on a search task, divided the stimulus field into 1-inch squares and had each square rated according to its relative informativeness by a panel of judges. Fixation frequencies were weighted accordingly and the summation across all cells provided a numerical index of each S's search performance. In comparing the means of the two groups it was found that the children were less likely than adults to search out the high information regions of the display.

Validation for the procedure is provided by 2 recent studies. Mackworth and Morandi (1967) compared the subjective ratings of 20 adults to the regions of the same display actually fixated by another 20 adults. They found a high correspondence between the rated and fixated areas of the display. Pollack and Spence (1968) specifically attempted to validate the procedure using a sample of 22 university students. They found a high correlation between ratings assigned to each region and the speed with which each region was searched. The areas of high information were scanned more rapidly than those of low information where, presumably, information was more difficult to perceive. They concluded that "the concept of the apparent information of real pictures is supported."

The same procedure was used by Conklin et al. (1968) in the comparison of field-independent and field-dependent Ss, noted above. The results of the study suggested that field-independent Ss employed more effective search strategies, a finding that was predicted by cognitive style theory.

In summary, it appears that meaningful information relative to individual differences in search behavior can be obtained through the study of EMs. One of the more promising variables in terms of sensing reliable differences in search behavior seems to be that of information search proposed by Mackworth and Bruner. To date, however, no studies based on this variable have been reported for non-normal populations. An objective of the present investigation was to apply the information search variable to the study of normal and retarded populations.

EMs During Learning Tasks

Two types of studies in which EMs were analyzed during learning tasks are reported. McCormack and his associates (Haltrecht & McCormack, 1966; Hannah & McCormack, 1968; McCormack & Haltrecht, 1965, 1966; McCormack, Hannah, Bradley, & Moore, 1967; Moore & McCormack, 1968) have focussed on EM behavior of college subjects during paired-associate learning tasks. These authors have investigated Underwood's (1960) two-stage learning model in which the initial stage involves "response-learning" which is followed by the "association" of appropriate pairs. Their studies comprise the majority of EM research during learning and have provided general support for the postulated two-stage model. In addition, they report that slow learners tend to take longer in the first stage and experience more difficulty in the second (Haltrecht & McCormack, 1966); that the EMs of high anxious subjects differ from those of low anxious (Hannah & McCormack, 1968); and that, as learning progresses, time spent scanning the response decreases (McCormack & Haltrecht, 1965, 1966; Moore & McCormack, 1968).

A second type of EM learning study is reported by White and Plum (1962, 1964). They studied the EMs of 16 nursery school children during the learning of easy and hard discriminations and found that "interesting and distinctive" stimuli resulted in greater EM activity than did difficult stimuli. An additional finding, of particular importance to the present study, was that EMs tended to become more active with the onset of learning and then decreased to remain at an "optimal" level for the solution of each succeeding trial. This finding, they concluded, provided evidence of sudden learning similar to that described by Zeaman and House (1963). The writers suggest, however, that their results must be considered tentative since the observed differences failed to achieve statistical significance.

Schroeder (1970) investigated the effect of reinforcement on the EM behavior of 15 college students during their solution of simultaneous discriminations. He found that when Ss were reinforced for their choice of stimulus they "most often fixated those stimuli they had been reinforced for choosing." He also found, as did White and Plum, that after the discrimination had been learned, there was a gradual decrease in the number of fixations on the discriminanda. This was interpreted to reflect the effect of practice during which observing responses decreased to a level of "maximum efficiency" for the solution of the task.

It seems quite evident that EM activity is an extension of the individual's search for information. As such, the evaluation of EMs offers a promising means of studying perceptual and learning behavior. Most of the reported studies are very recent and virtually all of them conclude with a statement of the need for further research. In response to this, the present study has attempted to relate EM activity to discrimination learning in normal and retarded children.

Discrimination Learning

Discrimination is defined by Fellows (1968) as "the process by means of which an organism responds to differences between stimuli." Studies of the discrimination process have their origins in the work of Lashley (1929) who suggested the method as a means of studying learning. Early studies of discrimination learning were directed mainly toward animal behavior, but more recently learning in children has become a central theme.

Recent discrimination learning studies have been directed toward answering two major questions (Shepp & Turrisi, 1966). The properties of covert mediating responses by the learner have been examined in an effort to determine the extent to which these responses are verbal or non-verbal in character. A second class of experiments has compared the performances of different CA and MA groupings with the purpose of describing learning characteristics and parameters during child development. Many of these studies have compared retarded and normal children as a means of identifying the nature of the learning deficit in retardates.

One of the most promising theories of retardate discrimination learning is that of Zeaman and House. Two articles (Zeaman, 1965; Zeaman & House, 1963) provide the major statements of the theory. The writers suggest that their efforts constitute an attempt to uncover the regularities in the learning behavior of retardates. They assume the position of "behavioral engineers" who are primarily interested in describing manipulable variables. The discovery of unique laws of learning occupies a secondary position in their work (Zeaman, 1965). They believe that the learning behavior of retardates differs in amount but not in kind from that of their more "normal" counterparts. As a consequence, they suggest, the prospects for improving the learning characteristics of retarded children are bright.

The Zeaman and House theory, briefly stated, postulates the chaining of two responses in the solution of a visual discrimination problem. The first response is that of <u>attention</u> to the relevant "dimension" of the stimuli which is followed by an instrumental response to the positive "cue" of the relevant dimension. The typical experiment used in testing the theory employs a simultaneous two-choice discrimination with reinforcement in the form of candy or trinkets. Learning is achieved when a preset number of successive correct trials has been reached. The differences that are observed between bright and duller subjects in the rate of learning are considered to reside in the attention deficit of the slower learners. The effect of this deficit is to prolong the initial flat segment of the learning curve during which the learner responds at a chance level of success. Once appropriate attention begins, however, learning curves for various IQ groupings exhibit a similar shape which suggests that the learning process does not differ markedly across intelligence levels.

Several studies have indicated support for the theory. House and Zeaman (1960) reported that the transfer of a discrimination by retardates is more efficiently accomplished when preceded by a sequence of easy to difficult trials on the relevant dimension than when Ss are trained on difficult trials only. Cunningham (1965) applied the concept of successive approximations in shaping the attention responses of normal and retarded nursery school children and found that training in this manner facilitated both learning and transfer. She concluded that, the most outstanding finding was an increased efficiency of retardate performance as a result of training with attention focusing procedures.

A study by House and Zeaman (1962) showed that novelty, as defined by a change of cue from a previously constant condition, resulted in a highly discriminable dimension. This finding supports Berlyne's (1960) position on the attentional value of novel stimuli and also the notion that attention or observing responses can be manipulated.

Hyman (1967) studied the effect of redundancy in dot patterns on 8 institutionalized retardates, and found that increasing the number of features that could be used to discriminate between stimulus patterns made the task more difficult. He concluded that attention to the relevant aspects of the stimuli was impeded by the increase in information available for processing.

Spitz (1969) studied the effect of information reduction on a matching task and found that both institutionalized adolescent retardates and fourth grade normal children were less able to cope with the loss of information than were seventh grade normal children. He suggested that the performance difference resulted from an attention deficit in both the retardates and fourth graders that was not evident in the seventh graders. This finding, when compared to that of Hyman (1967), would suggest that an attention deficit interacts with the difficulty of the task, as represented by either a deficiency or a surplus of information, to prevent the low MA learner from successfully completing the task.

The literature does seem to support the Zeaman and House contention that the learning difficulties of retardates are dominated by an attentional deficiency. Normal children, it would seem, exhibit attentional behavior that is appropriate to the learning tasks at each stage of their development, whereas retarded children do not. As a consequence, the retarded child becomes progressively less able to perform the learning tasks expected of him, and a "cumulative attentional deficit" ensues.

To date, the influence of the deficit has been inferred from observed differences in the configuration of learning curves; it does not appear, however, to have been validated independently of this rather subjective assessment. The main reason for this would seem to be associated with Zeaman and House's failure to provide an operational definition for the attentional construct (Mostofsky, 1968).

In their formal statement of the theory (Zeaman & House, 1963), the term "observing response" is used extensively as a synonym for attention. The term follows from that defined by Wyckoff (1952) as a "response which results in exposure to the pair of discriminative stimuli." However, Wyckoff's observing response was an observable act, whereas Zeaman and House (1963, p. 167) state that "none of these responses is directly observable, neither the instrumental approach responses nor the observing responses." It must be concluded, therefore, that the term does not hold an identical meaning for the two positions, a point noted by Reese and Lipsitt (1970).

Kendler and Kendler (1970, p. 71) offer some clarification of the distinction by suggesting that "this attending response could be interpreted as having observing, filtering, and encoding properties." Viewed thusly, attention emerges as a complex set of operations of which only the first bears resemblance to the "observing response" of Wyckoff.

Also of interest in the study of discrimination learning is the nature of the mediational response. In the Zeaman-House formulation attention plays a selective role in determining the dimensional cue toward which the instrumental response is to be made (Reese & Lipsitt, 1970; Shepp & Turrisi, 1966). On the other hand, Kendler and Kendler (1962, 1970) have proposed that, depending upon the developmental level of the individual and the nature of the task, either attentional <u>or</u> verbal mediating responses can perform a similar function. The Kendlers (1970, p. 80) suggest a developmental sequence in the mediation process as follows:

> In the <u>preverbal stage</u> the child does not possess words appropriate to the discrimination task. In the <u>verbal deficiency</u> stage appropriate words are available but are not used in solving the discrimination problem. In the final <u>verbal mediation stage</u> linguistic processes control the discrimination-learning behavior.

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Since characteristics of the mediation process are important to both the Zeaman-House and Kendler positions, a brief review of the literature would seem to be warranted. Unfortunately, the comparability of results is hindered by differences in populations and tasks, a situation noted by Goulet (1968). Most of the studies associated with the Zeaman-House position have been directed toward retardate populations, whereas the majority of the Kendlers' work has been based upon samples of normal nursery school and kindergarten children.

Kendler and Kendler (1959) compared the shift performance of "fast" and "slow" kindergarten children and found that the slow learners exhibited response behavior similar to that observed in rats while the fast learners appeared to respond in the manner of college students. It was suggested that the slow learners were responding in a "single-unit" manner whereas the fast learners were using verbal mediators to solve the discrimination.

In a study comparing the "cue function" of words for children of ages 4 and 7, Kendler and Kendler (1962) formed 3 treatment groups for each age level. One treatment required that the S verbalize the relevant cue (e.g., large) to which he was responding, a second required that the irrelevant cue (e.g., black) be named aloud, while the third required no verbal response. The results indicated that while both ages were hindered by verbalizing the irrelevant cue, the effect was greater for the 7-year-olds. Saying the relevant cue aloud facilitated the performance of the 4-year-olds more than that of the 7-year-olds. The performance of the 7-year-olds was equivalent under the relevant and non-verbalization conditions. The writers interpreted this to suggest that the 7-year-olds were able to make the response themselves and outside help seemed to be of little use. However, the introduction of inappropriate verbalizations tended to inhibit the learning of those who had acquired the ability to "spontaneously" generate correct ones.

O'Connor and Hermelin (1959) compared the learning and transfer of 10 institutionalized "imbeciles" to 10 MA matched normal children and found that the retardates had greater difficulty in learning the discrimination but showed greater facility with the reversal task. They concluded that the lack of verbal facility in the low IQ sample resulted in unstable motor responses that were more easily reversed than the combination of motor and verbal responses in the normal children.

House and Zeaman (1962) reported an attempt to validate the efficacy of Wyckoff's "observing response" theory. Their interpretation of the original learning and shift performance of 3 groups of institutionalized retardates (Mean IQ = 50) suggested that the Wyckoff theory could predict most of the results. However, it was suggested that the test of the theory was not sufficiently rigorous and the results were considered to be tentative until further evidence of the parameters (e.g., response weights) were established. It was conceded that a verbal mediation hypothesis could also have been applied to the data; a reflection of the ambiguity of the findings.

Milgram and Furth (1964) studied position and dimensional reversals in educable retardates and normal children. They found that the dimension reversal task, which was the more difficult, was less effectively solved by the retardates and younger children of 6 years than by normal children of 9 years. The simpler position reversal task, however, was accomplished equally by all Ss. They concluded that verbal mediation deficiencies were reflected in the dimensional reversals but not in the position reversals. Support for a hypothesis of verbal mediation deficiency in the younger CA and lower MA groups was suggested.

Scott (1964) compared the discriminative and verbal responses of 40 "moderately retarded" children to questions of "sameness" or "difference". He found that most Ss could respond adequately to sameness but not to difference. The conclusion was that verbal mediating responses were not used even when available.

Recent reviews of research in discrimination learning (Mackintosh, 1965; Shepp & Turrisi, 1966; Wolff, 1967) have attempted to place the distinctions between the attention and verbal mediation theories into perspective. All three reviews concluded that the attentional model of Zeaman and House has been better supported than the verbal model of the Kendlers. The attentional model, for the present, appears to be the more promising of the two.

Mackintosh (1965), however, seems to have underlined a major problem by suggesting that the precise nature of the mediational response has not been clearly specified with the consequence that strong arguments for or against either of the positions cannot be made. Extending his argument, Mackintosh states the need for a more general theory of discrimination learning and suggests that Zeaman and House have made a start in this direction.

Shepp and Turrisi (1966) have suggested that the learning processes of normal and retarded children may be differentially affected by the same variables, in which case the Zeaman and House contention that the learning characteristics of the two are similar could be questioned. Wolff (1967), on the other hand, has noted the possibility that retarded children are either not as deficient in verbal mediators as many have supposed, or that verbal mediating responses are not involved in discrimination learning.

In summary, it may be concluded that the theory of Zeaman and House appears to offer the more parsimonious explanation and is better supported by the research than that of the Kendlers. There are, however, obvious deficiencies in its theoretical framework, the most prominent being the lack of an operational definition of attention. As a theoretical construct, attention offers much for the description of discrimination learning behavior, but its usefulness is restricted by this lack of definition. The question of verbal mediation in discrimination has not yet been resolved.

In short, it appears that because of poorly defined constructs, the two positions may contain more similarities than differences.

> To view these competing conceptions as being mutually exclusive would be in error. They represent disagreements about the relative importance of different psychological processes and about the preference for a learning or perceptual model. We...have not suggested that behavior can be properly analyzed without reference to both learning and perceptual processes. (Kendler & Kendler, 1970, p. 85)

What is needed at this time is research directed toward operationalizing the construct of attention as it is applied to discrimination learning. The present study is an attempt in that direction.

CHAPTER 3

Rationale, Definitions and Hypotheses

Rationale

The theory of discrimination learning proposed by Zeaman and House (1963), concerned as it is with the attention deficit of slow learners, offers a promising framework within which research into the learning difficulties of retarded children may be conducted. Strong empirical support for the theory would permit the development of perceptual training programs designed to enhance the abilities of slow and retarded learners.

At the present time, however, while a considerable amount of research has been conducted by Zeaman and House and their associates, the findings are subject to Mostofsky's (1968) criticism of the lack of an operational definition of attention. The failure to provide such a definition essentially weakens the results published to date.

The studies supporting the Zeaman and House position have assumed that the correct choice of a visual discriminandum is dependent upon "attention" to the relevant cue of the correct dimension. While this may be true, alternative explanations are not ruled out. Among the alternatives that might be applied is the suggestion of Kendler and Kendler (1962, 1970) that verbal mediation serves to assist the learner in the solution of a discrimination task. Until an attempt is made to operationalize the definition of attention, the circularity of the Zeaman-House position will bring to question the results of research directed toward evaluating their theory.

Inasmuch as the Zeaman-House theory is based on the visual-perceptual activity of the learner, it would seem logical to consider EM behavior as a basis for the definition of visual attention. To the extent that EMs can be objectively and reliably measured, a definition of visual attention based upon EM behavior should avoid the question of circularity in that it would be independent from the act of learning.

The present study has employed <u>looking behavior</u>, as measured by EMs, as the definition of attention. It is recognized that this definition might be limited to a sensory aspect of attention, however, the assumption has been made that cognitive activity also is reflected by EM activity. It was expected that an analysis of the EMs of normal and retarded children during perceptual and discrimination learning tasks would provide objective evidence of differences in their attentional behavior.

With regard to the choice of samples, Baumeister (1967) has indicated that comparative studies of normal and retarded <u>S</u>s are particularly susceptible to the effects of confounding variables. Foremost among these are the controls applied in the selection of the samples. In most studies comparing normals and retardates, <u>S</u>s are matched with regard to MA, CA, or both of these, in the absence of a qualifying statement. Baumeister and others (Goulet, 1968; Spitz, 1969) have questioned the usefulness of MA matches on the grounds that MA is not a "pure" measure. Baumeister (1967, p. 873) concludes that "the CA match is the more straightforward procedure. Here the experimenter is interested in constituting groups which have had equal opportunity to mature biologically. If a difference in performance arises, it is clearly correlated with IQ." The present study has assumed this position.

The review of literature has indicated that the EM behavior of normal children becomes well developed between the ages 6-9 years. Consequently, an initial investigation, such as the present one, would logically include Ss who had reached that age range but had not yet entered adolescence. Retarded children placed in elementary level special classes fall into this category as do children attending grades 4, 5, and 6 in regular classrooms. These groups constitute the populations toward which the present study was directed.

Specific Objectives

A major purpose of the present study was to estimate the effectiveness of EMs as a basis for evaluating the attentional construct of the Zeaman-House theory of discrimination learning. Three main aspects of the problem were investigated:

1. whether retarded Ss differed with regard to EM activity from age-equivalent normal Ss during their search of pictorial displays (Study 1);
2. whether retarded Ss differed with regard to EM activity from age-equivalent normal Ss during the presentation of a 2-choice discrimination learning task (Study 2);
3. whether the introduction of verbal instructions designed to assist in the solution of the discrimination learning task would be used with equal effectiveness by retarded Ss and

age-equivalent normal Ss (Study 2).

It was expected that the information obtained from these investigations would serve to clarify some of the ambiguity surrounding the Zeaman and House theory.

Definitions

General Terms

Looking behavior. - the recorded movement of a S's eyes during the visual scanning of perceptual stimuli.

Frame. - a single exposure of 16 mm. movie film which would normally contain a corneal reflection superimposed on an image of the field of view.

First 30 frames. - the first 30 frames of EM data recorded at the rate of 10 frames per second; the initial 3 seconds of EM recording during a stimulus presentation.

Fixation. - one or more successive corneal reflections, recorded at the rate of 10 per second either: within the same circular area subtended by 30 minutes of arc in the stimulus field (Study 1); or judged to lie within the area subtended by 1 degree of arc centered on a stimulus element (Study 2).

Learning criterion. - a series of 8 consecutive correct responses to the discrimination learning task.

Stimulus element. - a component of a perceptual display that can be identified and described.

Dependent Variables for Study 1

Information Search Score. - the summation of corneal reflections over the first 30 frames weighted according to the relative information content of the stimulus area in which each reflection occurs. Reflections that occur beyond the boundaries of the stimulus receive a zero weight.

Mean Fixation Duration. - the mean elapsed time in seconds, of all fixations during the first 30 frames.

Track Length. - the summation of the angular displacement in degrees of arc, of a S's corneal reflections over the first 30 frames.

Dependent Variables for Study 2

Percent Frames on Relevant Cues. - the percentage of the first 30 frames in which a corneal reflection is judged to have been located on one of the stimulus elements (i.e., a dot) relevant to the solution of the discrimination.

Percent Frames on Irrelevant Cues. - the percentage of the first 30 frames in which a corneal reflection is judged not to have been located on one of the stimulus elements relevant to the solution of the discrimination.

Percent Unscorable Frames. - the percentage of the first 30 frames in which a corneal reflection is not visible.

Number of Fixations. - the total number of fixations by a S during the first 30 frames.

Hypotheses

Study 1: Specific Objective 1

Berlyne (1960), Hagen (1967), Heal and Johnson (1970), Luria (1963a), and Zeaman and House (1963) have indicated that retardates tend to have difficulty in directing their attention. Berlyne, Hagen, and Heal and Johnson describe the problem in terms of an inadequate inhibitory mechanism, while Luria attributes the difficulty to a failure in the emission of appropriate ORs. Zeaman and House, without attempting to describe the nature of the deficit, have suggested that it is a major factor in the learning difficulties of retarded children. As a consequence it seems reasonable to predict that the visual-attentional behavior of retardates would be less directed and controlled than that of normals of comparable age.

Several studies relating to developmental trends in EM behavior (Drake, 1970; Mackworth & Bruner, 1970; O'Bryan & Boersma, 1970; Vurpillot, 1968; Zaporozhets, 1969; Zaporozhets & Zinchenko, 1966; Zinchenko, et al., 1963) have demonstrated that the efficiency or effectiveness of visual search improves with age. Retardates, assumed to be functioning at a lower developmental level would, therefore, be expected to display less efficient EM behavior than their normal counterparts. It follows from this that the retardate, when directed to search for information in a pictorial complex, should have greater difficulty directing his visual search to stimulus areas of high information content than the normal child of a similar age.

Another variable related to visual search is the average duration of a fixation. Fixations that are too lengthy will result in a reduced coverage of the stimulus, whereas those that are too brief will permit only partial information to be derived. Consequently, there appears to be an optimal period of fixation which is most conducive to the efficient intake of information. No studies have been reported with respect to differences between normal and retarded children on this variable, but it seems reasonable to assume, especially on the basis of the Berlyne (1960), Hagen (1967), Heal and Johnson (1970), Luria (1963a), and Zeaman and House (1963) articles, that the average length of fixation would be shorter for retardates because of their attentional difficulty.

A further indication of the relative efficiency with which visual search tasks are performed may be reflected in the linear movement (track length) of the eye as it moves over the surface of the stimulus. It seems reasonable to surmise that the acquisition of information from a display is rather closely related to this variable. However, no studies were found in which track length was employed as a dependent variable in normal-retardate comparisons. An investigation of track length with respect to normal and retardate performance may reveal meaningful information. The following hypotheses are based on the above discussion.

Hypothesis 1: Retarded children will tend to be less efficient in their intake of information when given specific directions to search pictorial material, and will have a shorter mean duration of fixation than normal children of the same age. A retardate-normal difference also may be evident in terms of track length.

Hypothesis 1.1 Retarded Ss will exhibit significantly lower Information Search Scores on visual search tasks than will age-equivalent normal Ss.

Hypothesis 1.2 Retarded Ss will exhibit significantly shorter Mean Fixation Durations on visual search tasks than will age-equivalent normal Ss.

Hypothesis 1.3 Retarded Ss will not differ significantly with regard to Track Length on visual search tasks from age-equivalent normal Ss.

Study 2: Specific Objective 2

The Zeaman and House (1963) theory of discrimination learning postulates an attentional deficit in retarded children. Furthermore, it suggests that such children are more distractable than normals. Berlyne (1960), Hagen (1967), Heal & Johnson (1970), and Luria (1963a) have also noted that retardates have difficulty directing and maintaining their attention.

If looking behavior, as manifest by EMs, reflects an essential attentional component, as it appears to, distinct EM differences should be observed between normal and retarded children during the solution of a visual discrimination learning task. Specifically, retardates should show more evidence of difficulty in directing and maintaining their visual search towards the relevant cues than normals. An analysis of percentage of frames on relevant and irrelevant cues, as a function of trials over a constant time base, should indicate whether the above supposition has merit.

In the event that some retarded Ss are able to learn the discrimination and some normal Ss fail to do so, it might be revealing to evaluate the data in terms of a learner-nonlearner dichotomy. In doing so it should be stated that no inference as to similarities between retardates and normals, other than the fact of either learning or not learning the specific task, would be made. In other words, there would be no suggestion of a similar etiology for retardate and normal learners.

Another variable which may reflect an attentional difficulty is the percentage of unscorable frames. Several factors appear to contribute to frames in which the corneal reflection is not visible. Among these are: visual inspection by S of objects that are off the stimulus field, head movements, eyeblinks, and poor calibration of the EM recorder. At the time of coding, it is often impossible to determine which one of these factors has resulted in the loss of the reflection. But based on attention theory it seems reasonable to assume, that since retardates appear to be more distractable, they will also be more susceptible to unscorable data. Again, an analysis of learners and nonlearners with respect to this variable might be particularly interesting.

Also of relevance to the present study is a comparison between normal and retarded children with regard to the relative number of fixations that occur during discrimination learning trials. Such information should provide some indication of the amount of EM activity during learning. Moreover, this variable seems logically to be related to the acquisition of visual information. Only one study has investigated this variable with retardates, and its results were inconclusive (O'Connor & Berkson, 1963). However, it seems reasonable to assume that the EM activity of normals, and perhaps learners, might be different from that of retardates, and nonlearners.

Finally, an investigation which attempts to evaluate aspects of a theory should do so on the basis of a task which is not unlike that used by the theorists themselves. Zeaman and House (1963) suggest that in their experiments learning occurs suddenly, perhaps in a single trial, following a succession of trials in which correct responses are at a chance level. This type of learning is described by Atkinson, Bower, and Crothers (1965) as exhibiting the principle of "stationarity", in which the sequence of pre-learning responses results from independent trial outcomes. Atkinson *et al*. (1965) have proposed a statistical test under which stationarity may be evaluated. It seems reasonable to suggest that evidence of stationarity in the learning data of the present study would provide an indication of task similarity. The following hypotheses are based on the above discussion.

Hypothesis 2: The discrimination learning task used in the present study, to be considered similar in terms of the type of learning that occurs to that described by Zeaman and House, should result in stationarity of pre-learning response sequences.

Hypothesis 2.1 Analysis of correct choices as a function of trials will reveal stationarity for the following: (a) retarded learners; (b) retarded nonlearners; (c) normal learners; (d) normal nonlearners.

Hypothesis 3: Retarded children will have fewer frames on those stimulus elements which are relevant to the solution of the visual discrimination learning task, and conversely, more irrelevant and unscorable frames, than will normal children of the same age.

Hypothesis 3.1 Retarded Ss will exhibit significantly lower Percent Frames on Relevant Cues during the visual discrimination learning task than will age-equivalent normal Ss.

Hypothesis 3.2 Retarded Ss will exhibit significantly higher Percent Frames on Irrelevant Cues during the visual discrimination learning task than will age-equivalent normal Ss.

Hypothesis 3.3 Retarded Ss will exhibit significantly higher Percent Unscorable Frames during the visual discrimination learning task than will age-equivalent normal Ss.

Hypothesis 4: Retarded children will be expected to exhibit a higher level of EM activity during the visual discrimination task than will normal children of the same age.

Hypothesis 4.1 Retarded Ss will exhibit a significantly higher Number of Fixations during the visual discrimination learning task than age-equivalent normal Ss.

Hypothesis 5: The analysis of EM data in terms of the learner-nonlearner dichotomy could provide additional insight into the role of EMs during discrimination learning. Specific hypotheses cannot be directly derived because similar analyses have not been reported. Several tentative hypotheses, however, seem feasible.

Hypothesis 5.1 Intergroup differences will be present between learners and nonlearners during visual discrimination learning trials with learners having significantly: (a) higher Percent Frames on Relevant Cues; (b) lower Percent Frames on Irrelevant Cues; (c) lower Percent Unscorable Frames; than nonlearners.

Hypothesis 5.2 There will be no significant difference between learners and nonlearners with respect to Number of Fixations.

Study 2: Specific Objective 3

Kendler and Kendler (1970) have described 3 verbal developmental stages; preverbal, verbal deficiency, and verbal mediation. In this framework, the pre-adolescent retardate, deficient in verbal fluency, would have progressed to the second stage whereas his normal age mate would have arrived at the third. Studies by House and Zeaman (1962), Kendler and Kendler (1962), Luria (1969), Milgram and Furth (1964), O'Connor and Hermelin (1959), and Scott (1964) have tended to support this premise. Scott's finding, that moderately retarded children did not use verbal mediators even when they were available, is of particular interest here.

The present study will investigate 2 types of instructions. The first (Treatment 1) will consist of telling the S which dimension is relevant and will be presented after the 10th trial. The second (Treatment 2) will tell the S which of the 2 cues is negative, that is, the cue associated with the incorrect response. By describing the negative cue of the relevant dimension it is considered that a more sensitive discrimination of the verbal abilities of the 2 samples will result. Treatment 2 will be presented after the 20th trial. It is expected that retarded Ss, because of their verbal deficiency, will not be able to use the instructions as effectively as normal Ss. The instructions, then, should result in an improved efficiency of EMs for normal Ss, but have little effect on the EMs of retarded Ss.

Hypothesis 6: When compared before and after the presentation of specific verbal cues relative to the solution of the visual discrimination learning task, retarded children will exhibit no differences in EM behavior, whereas differences will be observed in normal children.

Hypothesis 6.1 Comparisons with regard to Percent Frames on Relevant Cues before and after the presentation of specific verbal cues will reveal: (a) no significant differences for retarded Ss; (b) significantly higher values for normal Ss after the presentation.

Hypothesis 6.2 Comparisons with regard to Percent Frames on Irrelevant Cues before and after the presentation of specific verbal cues will reveal: (a) no significant differences for retarded Ss; (b) significantly lower values for normal Ss after the presentation.

Hypothesis 6.3 Comparisons with regard to Percent Unscorable Frames before and after the presentation of specific verbal cues will reveal: (a) no significant differences for retarded Ss; (b) no significant differences for normal Ss.

Hypothesis 7: When compared before and after the presentation of specific verbal cues relative to the solution of the visual discrimination task, retarded and normal children will be expected to exhibit approximately the same level of EM activity.

Hypothesis 7.1 Comparisons with regard to Number of Fixations before and after the presentation of specific verbal cues will reveal: (a) no significant differences for retarded Ss; (b) no significant differences for normal Ss.

CHAPTER 4

Method

Subjects

Two samples of elementary school children were selected. The first was representative of the population of familial educable mental retardates which, for the purposes of this study, was designated as *functionally retarded children* (FRC). This sample was composed of 20 students (10 boys, 10 girls) in regular attendance in opportunity rooms of the Edmonton Public School system, whose IQ's when measured by the full scale of the *Wechsler Intelligence Scale for Children* (WISC) were in the range 50 to 80, and whose medical history showed no evidence of organic defect or severe emotional upset. The mean CA of the FRC sample was 10 years and 5 months.

The second sample, which was matched approximately according to CA and sex with the FRC sample, was drawn from the population of *normal children* (NC) in grades 4, 5 and 6 of the same school system. The NC sample was composed of 24 students (13 boys, 11 girls) whose full scale IQ's, as measured by the WISC, were in the 100-135 range, and whose educational progress had been continuous. The mean CA of the NC sample was 10 years and 7 months. A test of the difference between the mean CA's was not significant.

All *Ss* attended schools located in middle socio-economic areas. In addition, all *Ss* had uncorrected visual acuity that permitted clear vision for objects at 26 inches, the distance between the *S*'s eye and the plane of the viewing screen of the EM recorder.

Tests of significance between sexes within each sample indicated no differences with regard to either CA or IQ. Statistics descriptive of the samples together with tests of significance are reported in Table 1.

Apparatus

The Eye Movement Recorder

The EMs of Ss were recorded by means of a Polymetric Eye Movement Recorder (Model V-1164-1). The instrument employs the principle of a corneal reflection superimposed on a photograph of the stimulus field to provide a permanent record of the S's visual search behavior. EMs were recorded by a Pathé 16 mm. single lens reflex movie camera at exactly 10 frames per second. Mackworth (1967, p. 120) has suggested that accuracy to within 1 degree of arc (approximately equivalent to the area covered by a 25 cent piece when held by an adult at arm's length) is possible when the field of view is restricted to an area no greater than 20 degrees wide and 20 degrees high. The recorder used in the present study provided a viewing area of about 8 degrees by 8 degrees.

The recording procedure required that S be seated comfortably with his head firmly secured from movement by an adjustable headrest and a bite bar coated with dental impression compound. A spot light source was reflected from the cornea of the left eye into an optical system leading to the focal plane of the the camera. Simultaneously,

Table 1

Description of the Samples

	FRC n = 20			NC n = 24					
	$\bar{X}$	sd	Range	$\bar{X}$	sd	Range	*t*	df	p
Age (months)	125.3	11.8	95-145	126.8	11.0	98-143	0.4	42	ns
WISC (Verbal)	73.2	7.9	60-87	111.2	7.9	100-128	15.6	42	<.0001
WISC (Performance)	74.6	8.1	57-86	112.7	10.9	97-135	12.7	42	<.0001
WISC (Full Scale)	71.2	7.4	54-80	113.0	8.8	100-131	16.6	42	<.0001

the image viewed by S was transmitted to the camera by means of a semi-plated mirror. The combined inputs were then recorded on high speed black and white reversal film which resulted in a spot of light describing the location of the stimulus field at which S was looking.

All stimuli were presented on 35 mm. slides, rear projected by a random access Kodak Carousel projector (Model, RA950) onto an opaque surface with a 7.5 inch square viewing area. The viewing area was 26 inches from S's eyes. Figure 1 provides an illustration of the EM recorder.

Audio System

All instructions were recorded on tape and presented to S over earphones. This was done to provide a standard set of instructions and to control for extraneous sounds. Included in the system were an amplifier, three earphone sets, two microphones, and two tape recorders. Both E and an assistant who controlled the tape recorders wore headsets to monitor the audio system. E was able to communicate with S by means of a microphone input to the system. The second microphone and tape recorder were used to record S's verbal responses.

Response Indicator

Study 2 required that S indicate his choice, either left or right, of the discriminanda. A spring loaded pressure switch was placed under each of S's thumbs so that he could indicate his choice. Pressing the switch closed an electrical circuit to one of a pair of low intensity lights in front of E, who then recorded the response.

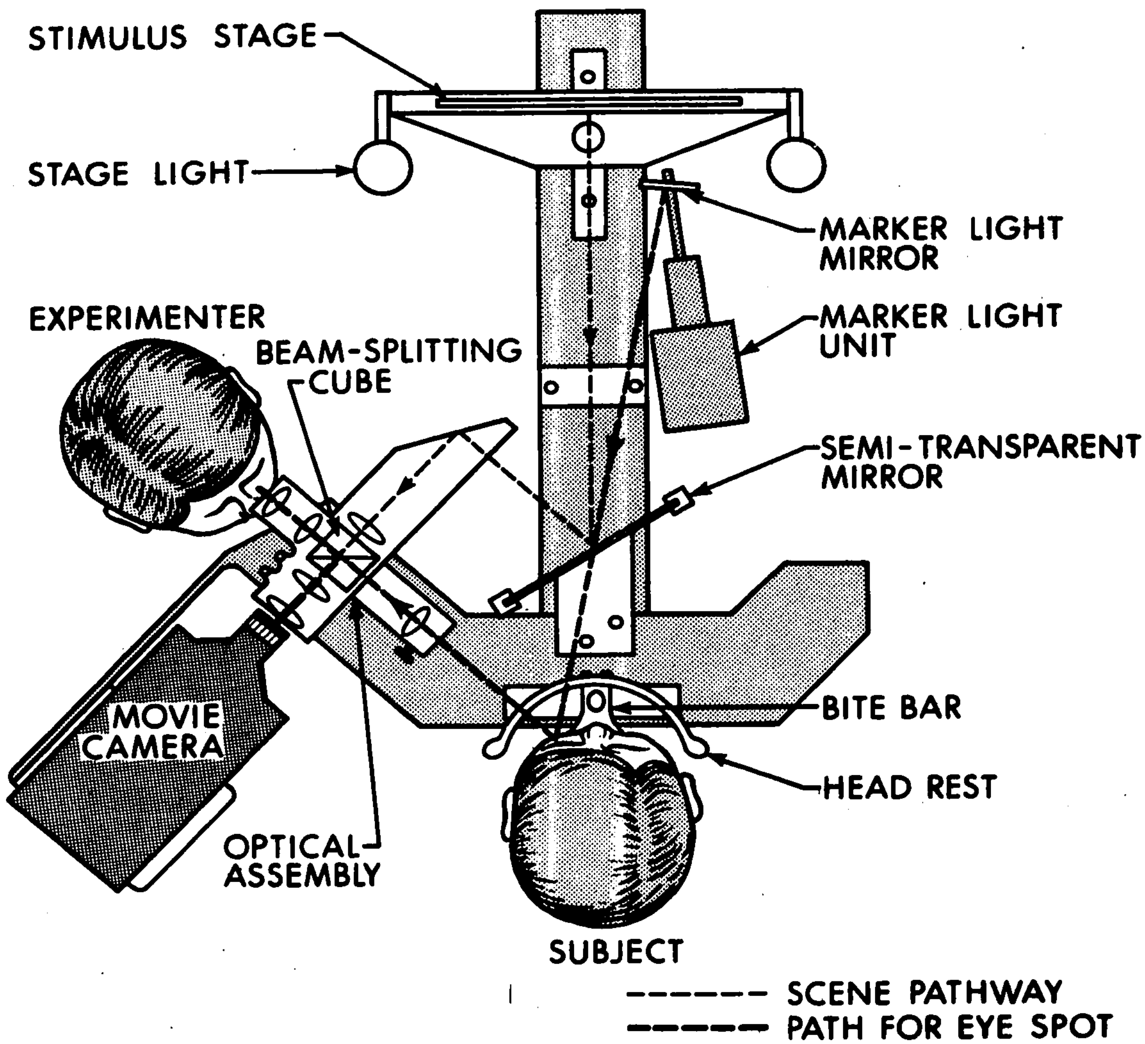

Fig. 1.

SCHEMATIC VIEW OF EYE MOVEMENT CAMERA

The Laboratory

Recording was conducted in a sound attenuated, light controlled, air conditioned EM laboratory. The laboratory is situated in the Faculty of Education Building of the University of Alberta.

Analysis Apparatus

Since the type of data recovered from the two studies differed, two descriptions are required.

Study 1. The film records were digitized according to relative X-Y coordinates of the reflected spot by means of a custom built plotter. A L-W Photo Inc. (Model, 224A) photo-optical data analyzer was used to project, frame by frame, the film recording of each S onto a ground glass screen. The coordinates of the points of interest were then converted to voltages after being located by a cursor placed on the target by the person engaged in scoring. The voltages obtained from two potentiometers were then converted by a Hewlett-Packard Digital Voltmeter (Model, 3440A) to paired digits of four figure accuracy and output through a modified IBM keypunch onto computer cards.

Study 2. The film records were projected, frame by frame, onto a movie screen by a L-W Photo Inc. (Model, 224A) photo-optical data analyzer. The location of the reflected spot was then numerically coded and recorded on data sheets.

General Experimental Procedure

The Ss were brought in pairs to the laboratory by taxi where they were met by E who made every effort to familiarize them with the surroundings and put them at ease. Then one S was given the WISC by a qualified examiner in a separate room while the other was brought to the EM laboratory.

On entering the laboratory S was shown, under normal lighting conditions, the equipment to be used. A games-like situation was described so that S would not feel he was being tested, and he was given a package of "Smarties" (M&M's).

After S was comfortably seated in an adjustable chair, a heated bite bar was mounted on the recorder and S was brought on to the bite bar to make the required impression. The S was then encouraged to eat 1 or 2 Smarties to sweeten the unfamiliar, though not offensive, taste of the impression compound. He was then instructed to return to the bite bar so that the headrest could be adjusted and the initial calibration carried out. For a detailed explanation of the calibration procedure see Boersma and O'Bryan (1970).

To ensure that S would have no visual difficulty, that the audio system was at an adequate level, and that he would be able to understand the instructions, an initial familiarization task was presented. The task required that S select from four simple figures the one which was identical to a centrally located target figure. Four trials, each with a different set of figures, were presented. The S's EMs were recorded during a 10 second exposure of each set. After each trial S was brought off the recorder and asked to indicate the position of the matching figure. He did this by pointing to its location on a 5 by 8 inch card upon which the relative positions were shown in outline. Regardless of the correctness of his response, S was encouraged for his effort but was not told whether he was right or wrong in his selection. The task was adequately performed by all Ss.

All Ss were very cooperative and none appeared to have difficulty in adapting to the apparatus. The mean time required for the two studies was approximately 30 minutes with a standard deviation of 7 minutes.

Study 1: Information Search

Stimulus Materials. Two sets of 4 stimuli, displaying black figures on white backgrounds, were photographed and mounted on 35 mm. slides. One slide in each set was used as a sample item with the remaining 3 used as the task stimuli.

The first set (Task 1: Specific Search) was selected to allow S to search visually and respond to the question, "What is wrong in the picture?" Three of these stimuli were selected from the Picture Absurdity items of the Stanford-Binet (S-B), Form L-M, (Terman & Merrill, 1960), and the fourth was from the Picture Completion subtest of the Wechsler Adult Intelligence Scale (WAIS), (Wechsler, 1955).

The sample stimulus was Card E, Year VII, of the S-B Picture Absurdities I. This picture showed several mice and a cat playing together. The first item was Card D of the same subtest. In it, a man and woman were shown sitting in the rain (Rain). The second item was the picture of a man casting his shadow toward the sun from Picture Absurdities III, (Year XIII) of the S-B (Shadow). The final item was the picture of a barn in which new fallen snow covered all top surfaces except a prominently located woodpile. This was Item 20 of the Picture Completion subtest of the WAIS (Barn). These items were presented in the above order and reflected an increasing subtlety in the error that S was required to detect.

The second set (Task 2: Non-specific Search) was selected to allow S to search visually and respond to the question, "What is happening in the picture?" The sample item was Card B of the Picture Absurdities I subtest of the S-B. This picture, which normally shows a man sawing a log with the saw's teeth pointing upward, was modified to remove the absurdity by redrawing the saw teeth to the proper position. The other items of Task 2 were Cards A, B, and C of the Response to Pictures, Level II, of the S-B. These pictures, which showed respectively, an elderly woman telling a story to 3 children (Story), 3 children going to a birthday party (Party), and a woman chasing a dog on washday (Washday), were presented in that order. The amount of detail in each of the pictures was approximately equivalent.

Task 1 was designed to permit the evaluation of EMs during specific directed search. The increasing subtlety of the 3 items allowed, to some extent, a comparison of EM activity over 3 levels of difficulty. Task 2 was also a directed search task inasmuch as a reason for the search was stated in the instructions, however the lack of a specific purpose for the search allowed S to scan the picture without the constraint of finding a particular element. In addition, the approximate equivalence of the items in content permitted comparisons of a replicative nature.

Study 1 Procedure. The sample item was projected onto the viewing screen of the EM recorder and the tape recorded instructions presented over earphones. The S remained off the bite bar during this period so that he could ask questions if necessary. The specific instructions for each of the Tasks were as follows:

> Task 1. Now, do you see the picture on the screen? I want you to tell me what is wrong in the picture. (pause) That's right, cats and mice don't play together. The cat would be eating the mice. (pause)
> Now, I am going to show you another picture in which something is wrong. When the machine stops, I want you to come off the mouthpiece and tell me what you think is wrong in the picture.
>
> Task 2. Now, do you see the picture on the screen? What can you tell me about the picture? (pause)
> I am now going to show you some more pictures. When the machine stops, I want you to come off the mouthpiece and tell me about the picture.

When S had indicated that he understood the task he was brought onto the bite bar, the recorder was calibrated, and the first item presented. All items for both tasks were terminated at the end of ten seconds. After each item S came off the bite bar and stated his answer. Regardless of whether the answer was correct or not, S was verbally reinforced by E.

The procedure for Tasks 1 and 2 differed only with respect to the instructions given and the questions asked. The period between items was approximately 15 to 30 seconds; the mean duration for both tasks was approximately 10 minutes with a standard deviation of 2 minutes.

Scoring of Study 1 Film Records. The film records for Study 1 were digitized and recorded on computer cards by means of an electronic coordinate plotter. Only the first 3 seconds of recorded film were analyzed since pilot research had indicated that this period contributed to good differentiation between subject groups. In addition, previous experience with the EM recorder (Boersma, et al., 1969a) had shown that the reliability of the data decreased with the increase in recording time. The initial 3 to 5 seconds was found to be the best recording period for the EM recorder used in the present study.

The quality of film records was generally very good with approximately only 5% of the total number of frames containing no visible reflected spot. Eyeblinks and, to some extent, gross head movements were the main contributors to unrecordable frames. Gross head movements could be identified during scoring and resulted in the deletion of some data.

A check on the consistency of the plotter output revealed slight variations in the fourth digit. Since 2 digit accuracy was sufficient, the effect of this variation was considered negligible.

Information Search Scores (ISS). Each of the 3 items of Tasks 1 and 2 was divided into equal area rectangles of approximately 1 inch by 1 inch. Ten judges were requested to rate the "information content" of each cell within each picture on a 6 point scale (0-5). This provided 10 estimates of the information content of each cell. The mean of the 10 ratings for each cell became the "information weight" for that cell. The specific instructions for the rating procedure are presented in Appendix A. Internal consistency coefficients for the ratings of the 6 items yielded values that ranged from .95 to .98, indicating a high degree of correspondence between judges both within and across items.

The ISS for each S was calculated by a computer program which accepted the cards produced by the plotter, identified the cell within which each reflected spot occurred, applied the appropriate information weight, and summed these values over 30 consecutive frames.

Data Analysis. Hypotheses for Study 1 were tested by means of independent t tests between FRC and NC samples. In instances where the assumption of homogeneity of variance could not be met, the procedure of Welch (1947), as described by Winer (1962, p. 36), was applied. In addition, intercorrelations between the dependent variables were calculated for each group.

Study 2: Discrimination Learning

Stimulus Materials. Extensive pilot testing of 2 promising discrimination learning tasks with FRC and NC indicated that both groups were able to respond appropriately to one of the tasks. It was important that the tasks be neither too difficult for the FRC nor too easy for the NC. The actual task used, together with the order of item presentation is shown in Figure 2. In this task, Ss were required to select the rectangle or "box" containing either 1 or 3 dots in its corners. In addition, a sample stimulus having a plus (+) sign in one rectangle and a minus (-) sign in the other was used to introduce S to the task.

The stimuli, composed of black figures on a white background, were photographed and mounted on 35 mm. slides which, when rear-projected

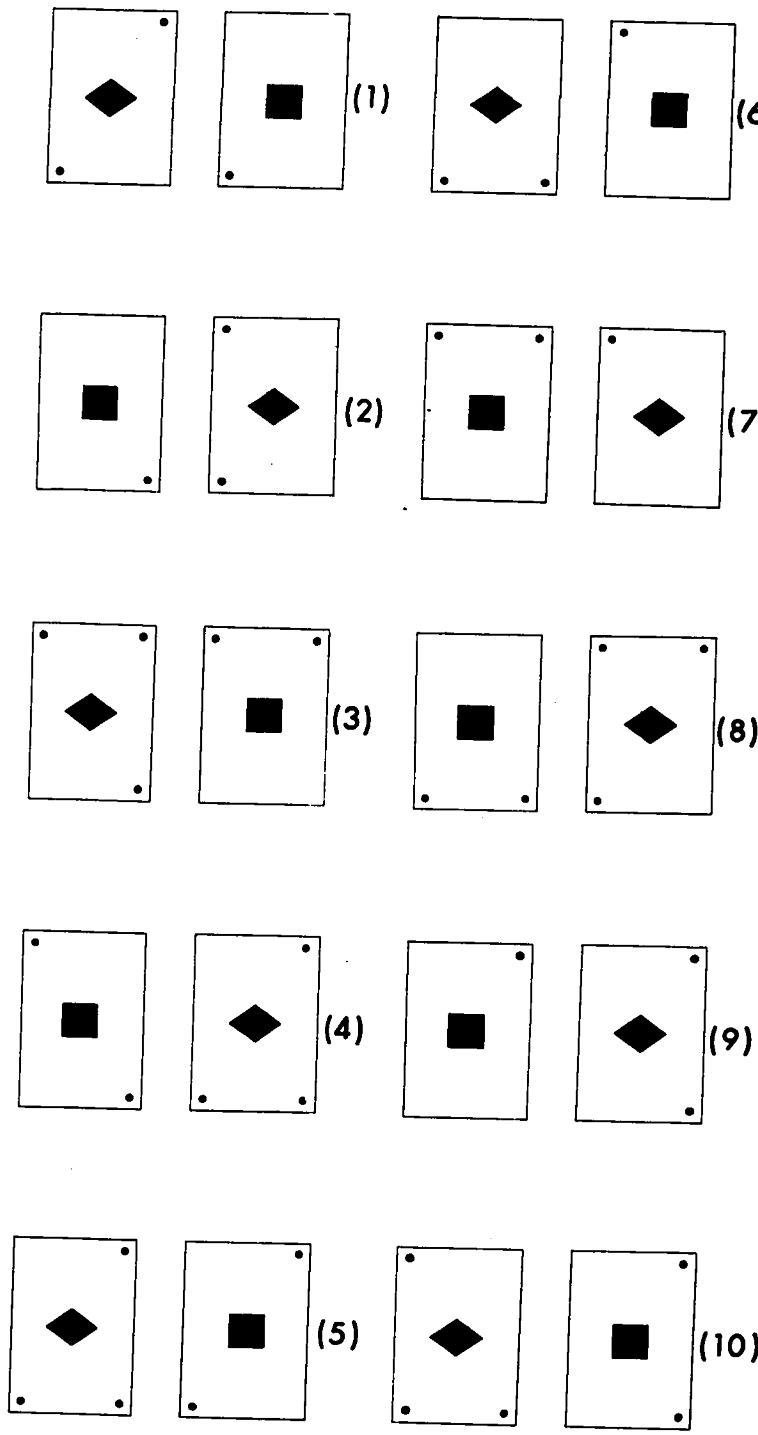

Fig. 2. Stimulus cards for Study 2.

onto the viewing screen, presented S with a choice of 2 well defined figures. Underlying the design of the Study 2 stimuli was the need to provide sufficient separation between elements so that active EM behavior by the S would be encouraged, and in addition, ambiguities in locating the reflected spot during analysis would be minimized.

The stimuli contained 3 basic discriminable dimensions; position, form, and number. The relevant dimension was number (of dots) and the appropriate cue was odd (1 or 3). It should be noted that the stimuli also contained 4 irrelevant compound dimensions; number and position, position and form, number and form, and the triple compound of number, position, and form. As a consequence, the stimuli presented S with a task of rather high complexity.

Study 2 Procedure. The procedure for the study was carefully pretested on 4 retarded and 2 normal children. The results indicated that both samples would be capable of performing the tasks. The procedure was as follows.

First, S was shown how to operate the response buttons. Two buttons were used, one at S's right hand to indicate a right preference, and the other at his left hand to indicate a left preference. The sample stimulus was first shown on the viewing screen and the tape recorded instructions given. The instructions were presented with S off the bite bar and were as follows:

> Do you see the two boxes on the screen? You will see that one box has a plus sign in it and the other box has a minus sign in it. (pause)
> One of the boxes is the correct one and the other box is the wrong one. You can tell me which one you think is correct by pushing either the button in your left hand,

if you think the box with the plus sign is correct, or by pushing the button in your right hand if you think the box with the minus sign is correct. Now, tell me which box you think is correct by pushing either the left hand button, if you think the box with the plus sign is correct, or by pushing the right hand button if you think the box with the minus sign is correct. (pause)
(Positive verbal reinforcement was given by E regardless of S's choice.)
Now, when you have made your choice, I want you to keep pushing on the button until I tell you to stop.
Keep biting on the mouthpiece and try not to move your head.
I will tell you when to stop pressing the button, and when to come off the mouthpiece.
Now, I am going to show you some more boxes. Remember to hold the button down when you have picked the one you think is the correct box. Do not come off the mouthpiece until I tell you to.

The discrimination learning task then commenced. The task was divided into 3 parts such that Treatment 1 occurred after trial 10 and Treatment 2 after trial 20. The duration of each trial was carefully timed at 5 seconds by an assistant who manually interrupted the projected image with a piece of cardboard. The timing procedure operated very effectively and with acceptable accuracy as indicated by the film records. The intertrial interval normally varied from 15 to 30 seconds, with recalibration after every trial occupying approximately the last 5 seconds of the interval.

The same discriminanda were repeated for each part and were presented in the random series "RLLRLRRRLL" as suggested by Gellerman (1933). The EM recorder and the selection and presentation of the stimulus slides were controlled by E who also recorded S's responses on a checklist. A learning criterion of 8 successive correct trials, as suggested by Grant (1947), was applied. If and when criterion was met, S was taken off the bite bar and asked if he could tell which was the correct "box" and his answer recorded.

At the conclusion of the first 10 trials (Part 1), S was told to relax for a few seconds and asked whether he knew how to tell which of the "boxes" was the correct one. His response was recorded as a check on criterion performance. Then the instructions which constituted Treatment 1 were presented. These instructions were as follows:

> Now, I want you to look carefully at the dots in the corners of each box.
> Only the dots will tell you which box is the correct one.
> Remember, look carefully at the dots in the corners of each box because, only the dots will tell you which box is the correct one. (The underlined words were emphasized.)

At the completion of trial 20, S was brought off the bite bar and again asked if he could tell which was the correct "box". A negative response resulted in the presentation of the instructions for Treatment 2, which were as follows:

> Now, I will tell you how you can tell which box is the correct one, every time.
> I want you to count the number of dots in the corners of each box.
> The wrong box always has the same number of dots, every time.
> Remember, you can always tell which box is the wrong box because the wrong box always has the same number of dots every time.

At the conclusion of trial 30, S was again asked if he knew which was the correct "box", and if he did know, why? At this point, regardless of whether learning had occurred, trials were terminated.

The mean elapsed time for the Study 2 procedure was 19 minutes, with a standard deviation of 7 minutes.

Scoring of Study 2 Film Records. The film records were projected, frame by frame, onto a screen by the analyst projector. Two assistants, one coding the location of the reflected spot according to a preset code, and the other recording onto computer data sheets, transcribed the data for processing by computer.

The film records of five Ss were chosen at random at different times during the coding process to provide a reliability check on the coding procedure. An error rate of 3.8 percent was found when the 2 sets of records were compared. This value was based upon approximately 7,000 pairs of data points. A 7 point code, as follows, was used to describe the location of the reflected spot in each frame.

1 Fixation on the single dot.
2 Fixation on 1 of the 2 dots of the "box" having only 2 dots.
3 Fixation on 1 of the 3 dots of a "box" having 3 dots.
4 Fixation on any corner which does not have a dot in it.
5 Fixation on either of the central objects (square or diamond).
6 Fixation anywhere but on the above.
7 An unscorable frame in which a spot is not visible.

The codes 1-5 were applied when the reflected spot fell within the area subtended by 1 degree of arc centered on the stimulus element. The coded categories were then modified to provide the dependent variables of the study. The percentage of frames coded 1, 2 or 3, of the total of 30 successive recorded frames for each trial, was calculated and designated Percent Frames on Relevant Cues (PFRC). Similarly, the percentage of total frames coded 4, 5 or 6 was calculated and designated Percent Frames on Irrelevant Cues (PFIC). The percentage of total frames coded 7 was designated Percent Unscorable Frames (PUF).

The Number of Fixations (NF) was determined by the number of differently coded frame sequences over 30 successive recorded frames. One or more identically coded successive frames constituted a fixation.

Data Analysis. The data were treated statistically and graphically. Analyses of variance and *t* tests (independent and correlated) were used to test the hypotheses of the study. Graphical figures of forward and backward performance curves were used to illustrate variations in the dependent variables over trials. Intercorrelations between the dependent variables were calculated for each group.

CHAPTER 5

Results and Discussion for Study 1

Results

Task 1: Specific Search

Information Search Score (ISS). Comparisons between the FRC and NC samples with regard to ISS are displayed in Table 2. The results show that the FRC were significantly lower on ISS for each subtask as well as on the Combined ISS of the 3 subtasks. (The Combined variables represent the mean values on the total Task for all Ss with complete data for the 3 subtasks.) Two FRC Ss experienced head movement during recording and their data were deleted from the subtask in which the movement occurred.

Figure 3 has been included to illustrate Task 1. In it, the information weights for the Barn subtask are shown in brackets. It may be seen, for example, that the cell (E5) in which the answer to "what is wrong in the picture" occurs has been assigned the greatest weight (4.9 of a possible 5). On the other hand A1, in which no part of the display is to be seen, received a weight of 0.0.

The unbracketed numbers in Figure 3 denote the percentage of total reflections that occurred in each cell for FRC and NC groups. From this it is evident that the FRC sample tended to have fewer reflections in areas of high information and more in areas of low information than did the NC; hence the significant differences in ISS for the Barn subtask.

Table 2

Summary of Independent *t* Tests for Task 1

	FRC			NC					
	$\bar{X}$	sd	n	$\bar{X}$	sd	n	*t*	df	p[a]
ISS (Rain)	102.42	24.74	20	118.85	8.78	24	2.82†	23	.005
ISS (Shadow)	72.71	26.34	19	86.12	21.43	24	1.80	41	.04
ISS (Barn)	79.34	18.76	19	88.74	11.57	24	1.91†	28	.03
ISS (Combined)	86.30	13.39	18	97.90	9.37	24	3.22	40	.001
MFD (Rain)	.22	.05	20	.27	.10	24	2.46†	37	.02
MFD (Shadow)	.20	.03	19	.21	.04	24	1.24	41	NS
MFD (Barn)	.20	.03	19	.25	.06	24	3.33†	37	.002
MFD (Combined)	.21	.03	18	.25	.05	24	3.26†	38	.001
TL (Rain)	69.28	17.28	20	61.55	18.95	24	1.20	42	NS
TL (Shadow)	110.71	25.39	19	109.90	35.20	24	.08	41	NS
TL (Barn)	70.54	14.29	19	66.68	17.02	24	.77	41	NS
TL (Combined)	82.77	14.62	18	79.38	17.77	24	.64	40	NS

[a] ISS: 1 tailed
MFD & TL: 2 tailed

† Welch *t*'

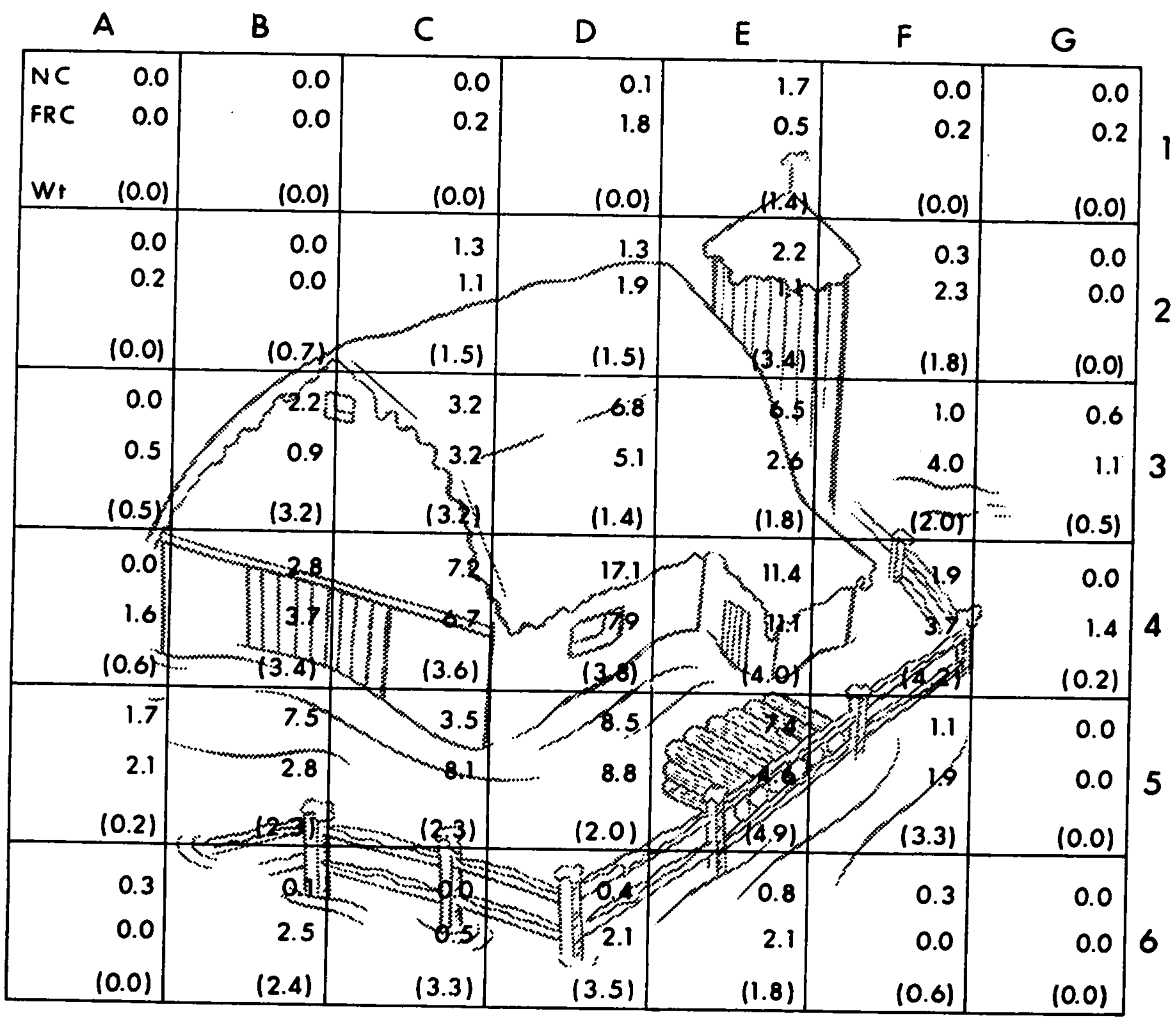

Fig. 3. Information weights, and percent reflections in each cell of the Barn subtask for total samples.

It should be mentioned that in their performance of the Barn subtask the FRC directed 1.9% of their reflections beyond the border of the stimulus, whereas only 0.3% of the reflections of the NC were similarly recorded. For Task 1 in total, the FRC sample had 5.2% of their reflections off stimulus, and the NC 1.9%; a ratio of approximately 3 to 1.

Mean Fixation Duration (MFD). Reference to Table 2 indicates that the MFD for the FRC sample was significantly shorter on 2 of the 3 subtasks when compared to the NC sample. The difference on the Shadow subtask, while not significant, was also in the same direction. The Combined MFD indicates that Task 1, as a whole, resulted in a reliable difference between FRC and NC samples. It would seem that for Task 1 the FRC Ss tended to spend less time during an average fixation than did the NC.

Track Length (TL). The results for the TL variable are shown in Table 2 and indicate no significant differences between the FRC and NC samples. This seems to suggest that, for the 3 stimuli of Task 1, the amount of linear movement over the pictures was essentially the same for both groups, even though the NC exhibited longer MFD's. It would seem that the NC, although moving their eyes less frequently, tended to produce longer EMs between successive fixations such that a similar linear coverage of the stimuli resulted.

Response Performance. The 3 subtasks of Task 1 were designed to present the S with an increasing subtlety with regard to what was wrong in the picture. This increasing difficulty of the perceptual task was reflected in the effectiveness with which each subtask was solved. The Rain subtask was correctly responded to by 42 of the 44 Ss (18 FRC;

24 NC), whereas 22 Ss (6 FRC; 16 NC) were able to solve the Shadow problem. Only 1 S, a NC girl, was able to detect the error in the Barn stimulus. Chi-square tests of independence showed that only on the Shadow subtask did the groups differ in the adequacy of their responses ($p < .02$).

Task 2: Non-specific Search

Information Search Score. Tests for differences between FRC and NC samples on ISS are summarized in Table 3. These results, while similar in direction to those of Task 1, were less consistent in showing significant differences. The Combined ISS, however, was significant. Three FRC Ss experienced a total of 4 head movements which resulted in the deletion of their data from the study.

Figure 4 is presented to illustrate the characteristics of Task 2. It may be seen there that in cells rated as containing high information (e.g., B2, D3, D4) the NC Ss showed a higher percentage of reflections than the FRC, except in C3 where the doorbell appeared to be of greater interest to the FRC.

The proportion of off-stimulus reflections showed a rather sharp increase, both on the Party subtask (19.7% FRC; 3.5% NC) and for Task 2 as a whole (13.9% FRC; 4.9% NC), as compared to Task 1. However, the FRC-NC ratio for Task 2 remained at the same 3 to 1 level observed in Task 1. The increase in off-stimulus reflections for both groups might be related to the fact that the Task 2 stimuli were relatively smaller in area (5" x 6") than those of Task 1 (7.5" x 7.5"). As a consequence it might be expected that there would be more "overshooting" of EMs

Table 3

Summary of Independent t Tests for Task 2

	FRC			NC					
	$\overline{X}$	sd	n	$\overline{X}$	sd	n	t	df	p[a]
ISS (Story)	94.10	21.42	19	103.27	17.17	24	1.52	41	.07
ISS (Party)	77.03	31.93	20	100.15	16.14	24	2.94†	27	.003
ISS (Washday)	91.10	26.34	17	95.35	21.68	24	.55	39	NS
ISS (Combined)	89.66	16.18	17	99.59	14.00	24	2.05	39	.02
MFD (Story)	.22	.05	19	.23	.07	24	.21	41	NS
MFD (Party)	.22	.07	20	.26	.06	24	1.59	42	NS
MFD (Washday)	.23	.06	17	.23	.06	24	.07	39	NS
MFD (Combined)	.23	.05	17	.24	.05	24	.54	39	NS
TL (Story)	64.27	13.95	19	66.46	15.25	24	.48	41	NS
TL (Party)	70.66	23.57	20	64.77	16.76	24	.94	42	NS
TL (Washday)	67.51	13.76	17	63.92	15.28	24	.75	39	NS
TL (Combined)	67.26	11.54	17	65.05	12.58	24	.56	39	NS

[a]ISS: 1 tailed
MFD & TL: 2 tailed

†Welch t'

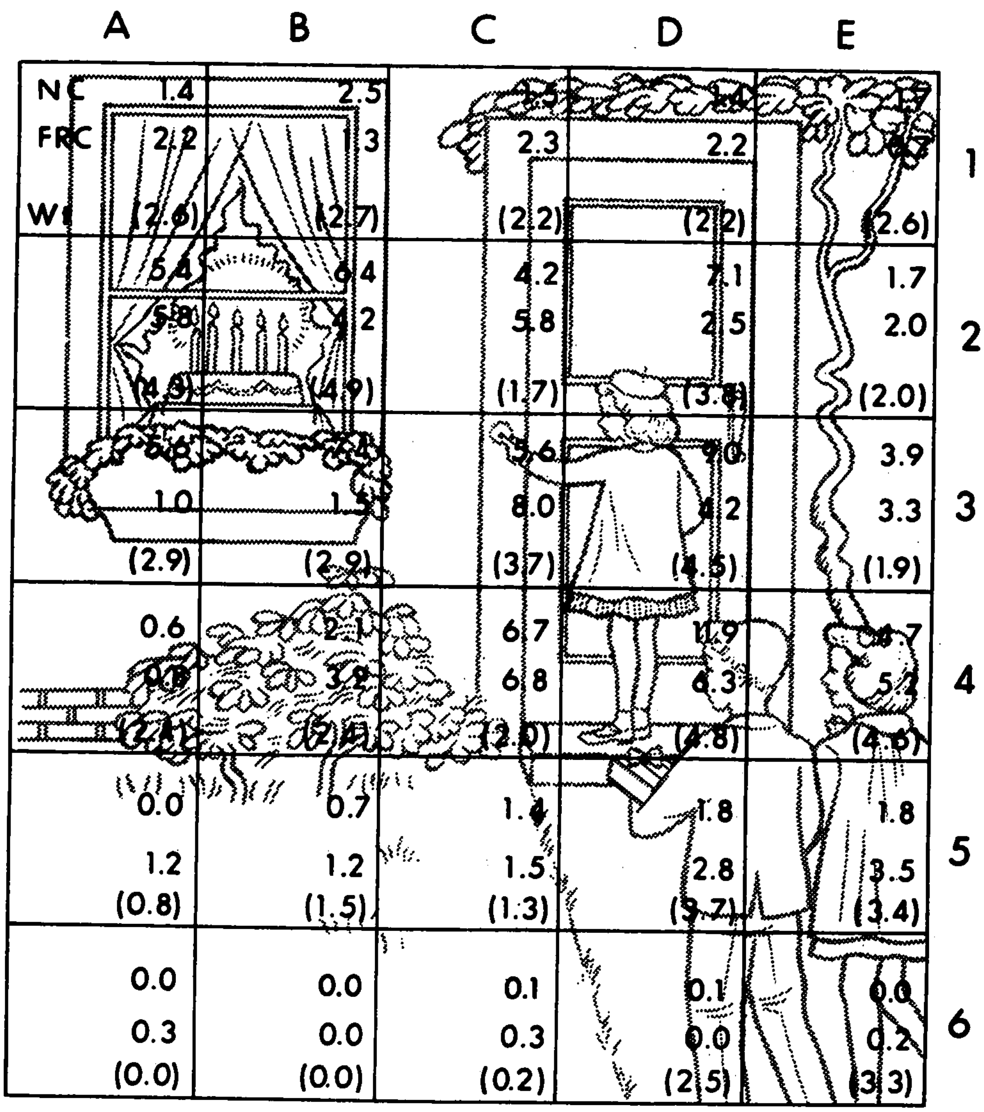

Fig. 4. Information weights, and percent reflections in each cell of the Party subtask for total samples.

beyond the boundaries of the smaller stimuli.

Mean Fixation Duration. Tests of the differences between FRC and NC Ss on MFD, as may be seen in Table 3, were not significantly different. This finding differs somewhat from that of Task 1 although the differences that did occur suggested that the FRC continued to exhibit briefer durations.

Track Length. No significant differences with regard to TL were observed. This finding, which may be seen in Table 3, is essentially the same as that of Task 1 and tends to reinforce the notion that the linear distance covered by EMs over the surface of a stimulus is the same for both groups.

Response Performance. Responses to a set of questions for each subtask were rated by E as to correctness. (The actual questions asked may be seen in Appendix B.) The mean number of correct responses for the FRC and NC on each subtask was, interestingly, identical (Story, 4.0 of a possible 5.0; Party, 4.6 of 5.0; Washday, 3.0 of 3.0).

Correlations Between the Dependent Variables

The correlations between the 3 dependent variables for FRC and NC Ss on each task are reported in Table 4. The most consistent finding is the significant negative correlation between MFD and TL in each instance. This inverse relationship follows from the definitions of the 2 variables. The longer the duration of fixation, the shorter will be the amount of linear movement over the surface of the display, and vice versa.

Table 4

Correlations Between Dependent Variables of Study 1

		FRC		NC	
		ISS	MFD	ISS	MFD
Task 1[a]	MFD	.29		.51*	
	TL	-.16	-.59**	-.39	-.59**
Task 2[b]	MFD	.18		.42*	
	TL	-.06	-.78***	-.17	-.61**

*$p < .05$ **$p < .01$ ***$p < .001$ (2-tailed probabilities)

[a] FRC n=18; NC n=24 [b] FRC n=17; NC n=24

The significant correlations between ISS and MFD for the NC group most likely reflect the NC tendency to spend more time fixating in areas of high information. This relationship does not appear to hold for the FRC sample.

The only substantial relationship between ISS and TL was found for the NC group on Task 1, where the correlation is significant at $p < .07$. This inverse relationship seems to reinforce the suggestion that NC Ss who exhibit a high ISS tend also to have a high MFD. In other words, since MFD and TL are negatively related, a low TL would indicate a high MFD and, therefore, a high ISS.

Discussion

Comparisons of the ISS variable under the conditions of Tasks 1 and 2 have shown reliable differences between the FRC and NC samples. It would appear that Hypothesis 1.1, therefore, has been rather firmly supported.

The lack of a significant ISS difference on the Washday subtask of Task 2 is most probably related to the fact that the content of the picture was completely dominated by the action of the woman chasing the dog. It also contained less incidental information than the other stimuli. For this reason, carefully controlled EM behavior was not required of either group to acquire the essential content of the picture. It was also the only subtask in which no response errors occurred in either group. This finding would seem to support the observation by Zaporozhets and Zinchenko (1966) that on pictures of familiar content, children of different ages showed no differences in EMs.

To elaborate further upon the observed differences, the performances of individual Ss were selected and are presented in Figures 5 and 6. The EMs of these Ss may be traced from start (S) to finish (F) during the first 30 frames of their search. These figures seem to show that the NC concentrated their fixations in cells of high information near the center of the pictures, whereas the FRC tended to fixate in peripheral areas of lesser information. This interpretation seems to be supported by group results on the same stimuli as shown in Figures 3 and 4.

In a general sense it might be suggested that the visual search behavior of the NC group was more "controlled" than that of the FRC. In the terminology of Mackworth and Bruner (1970) this could be interpreted to mean that the NC group tended to employ superior "cerebral programs" in their search for information.

Hypothesis 1.2 was generally supported by the results of Task 1, but not of Task 2. However, on all but one of the subtasks FRC exhibited a numerically briefer MFD, which would suggest a trend in that direction.

When the findings of the present study are compared to the "normal" MFD range of .25 to .40 secs. reported by Ditchburn and Foley-Fisher (1967) and by Gould (1967), it may be seen that both groups exhibited mean values near the lower extreme of that range. This might have been expected inasmuch as the pictorial content of the 6 pictures would have been generally familiar to all Ss, and therefore extended periods of fixation would not be required. The 2 subtasks in which

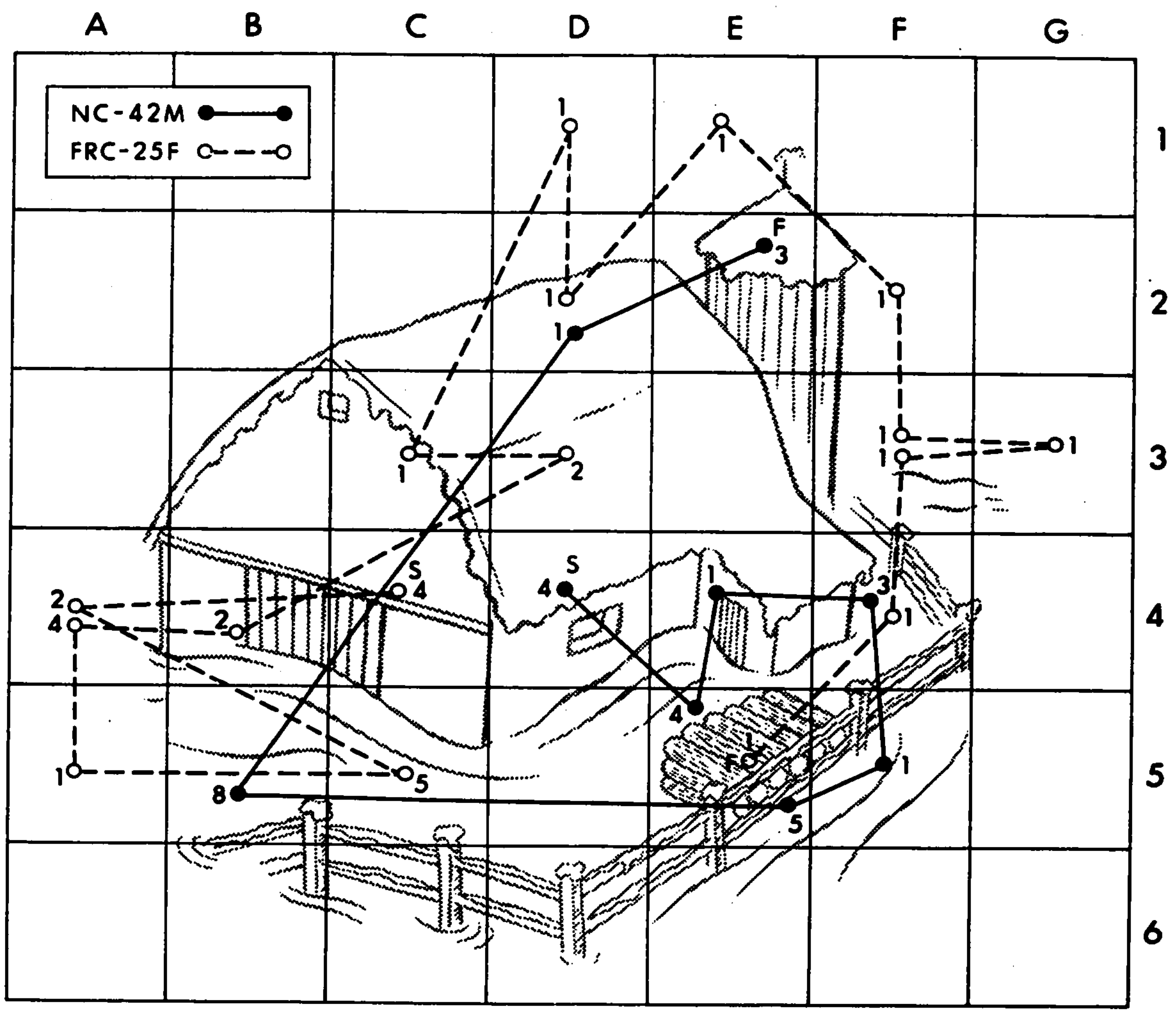

Fig. 5. Eye movements of 2 Ss during their performance of the Barn subtask. (FRC; ISS = 59.4, MFD = .14, TL = 109.9: NC; ISS = 109.3, MFD = .27, TL = 63.0)

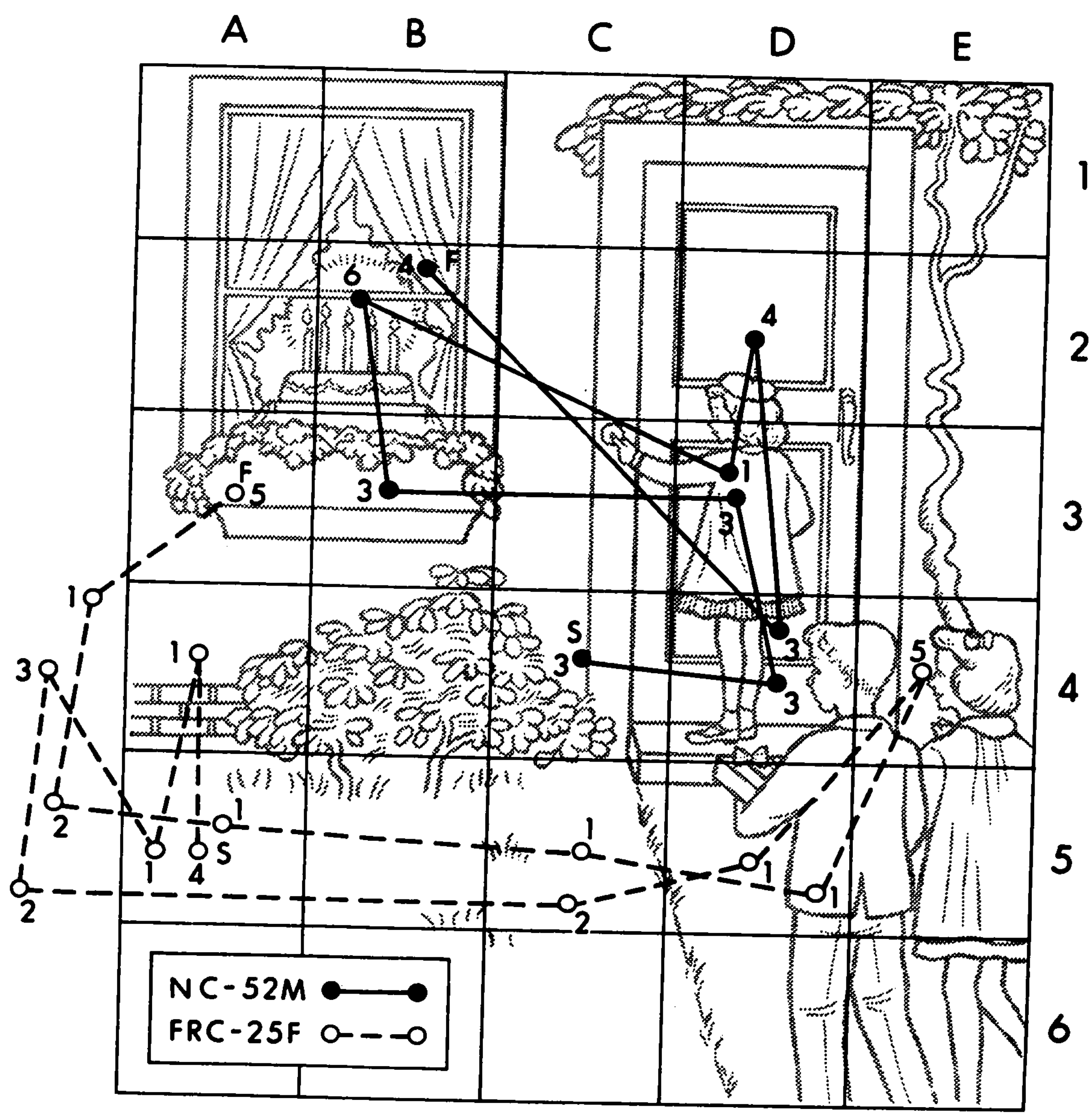

Fig. 6. Eye movements of 2 Ss during their performance of the Party subtask. (FRC; ISS = 56.0, MFD = .14, TL = 79.2: NC; ISS = 125.7, MFD = .38, TL = 49.1)

significant differences were observed were not strikingly different from the others, although the Rain stimulus tended to have a large amount of line detail. In addition, while the pictorial content of the Barn stimulus was a familiar farm scene, the subtlety of the problem may have resulted in a recognition by the NC that added "concentration" was needed to solve the task. It may be that MFD is particularly influenced by characteristics of the stimulus and the difficulty of the search task.

Since no differences on TL were observed, Hypothesis 1.3 cannot be rejected. It would seem that regardless of the task, the FRC and NC samples covered an essentially equal distance over the surface of the display. However, the results of the ISS comparisons suggest that whereas the amount of TL may have been similar, control of EMs, as represented by the points of fixation, was quite different. The NC sample, with approximately the same amount of movement over the stimuli as the FRC, was capable of selecting and fixating on areas of higher information content.

The correlations between the dependent variables tend to support the notion of a reduced FRC search efficiency. The fact that ISS was not significantly related to either MFD or TL for the FRC seems to reinforce the suggestion that they exhibited a less "controlled" search strategy than did the NC. This interpretation is supported by the significant relationship between ISS and MFD in the NC group which implies that the Ss with higher ISS tend to spend more time during an average fixation.

The results of Study 1 seem to suggest that FRC and NC Ss do differ with regard to search strategy. It appears that the FRC tend to search the periphery of a picture, apparently unaware that the essential characteristics of most graphical displays lie near the center. The NC, on the other hand, seem to know that maximum information is most likely to be found in the central region and focus there initially.

While it must be noted that the present study has attempted to describe only the first 3 seconds of search, it is not difficult to argue that search efficiency is closely related to the speed with which the salient features of a display are scanned. If, as it would seem, the FRC have not developed an effective search strategy, each encounter with visual materials would result in comparatively less useful information for them than for the NC. Consequently, the suggestion of a "cumulative attentional deficit" appears to be tenable.

The stimuli used in the study were not sufficiently complex to show the effect of this FRC deficiency in information acquisition, with perhaps the exception of the Shadow stimulus of Task 1. The FRC group gave significantly fewer correct responses to this subtask while exhibiting a significantly lower ISS. If the ISS is a valid index of search efficiency, this is the outcome that would be expected. Future studies should attempt to evaluate characteristics of the stimuli that do distinguish FRC and NC Ss.

CHAPTER 6

Results and Discussion for Study 2

Results

Learning Data

The discrimination learning task generally tended to be too difficult for the FRC sample since only 4 of the 20 Ss reached the criterion of 8 consecutive correct responses. On the other hand, only 3 of the 23 NC Ss failed to solve the discrimination problem. (One of the original 24 NC Ss reported in Study 1 was deleted due to a substantial number of poor EM records.) A test of the difference between the number of learners and nonlearners in the 2 groups was significant (Chi-square = 19.5, df = 1, $p < .001$).

The mean number of trials to criterion was 20.8 (sd = 0.4) for the 4 FRC learners and 14.35 (sd = 5.4) for the 20 NC learners (t' = 5.3, df = 20, $p < .0001$, 1-tailed). Any S who had not reached criterion by the 30th trial was designated a nonlearner. There was, therefore, 4 FRC learners, 16 FRC nonlearners, 20 NC learners and 3 NC nonlearners.

It must be acknowledged that the data provided by only 4 FRC learners and 3 NC nonlearners cannot be considered truly representative. It was felt, however, that with appropriate qualifications these data could provide useful information in an exploratory study, such as the present one. In consideration of the results based on these groups, therefore, the reader is reminded to recognize their tentative nature.

Performance data is graphically presented in Figure 7 under four S groupings. Figure 7a compares the performance of FRC and NC total samples. It may be seen that the FRC tended to respond between 35% and 60% correct quite consistently, whereas performance measures for NC varied from 10% to 80% correct. Except for the greater variability of the NC, however, it is difficult to distinguish between FRC and NC response patterns.

When the performance measures of learners are compared to the nonlearners, as in Figure 7b, the rather extreme variance differences in the percentages of Figure 7a are not evident. This might suggest that the NC nonlearners were the major contributors to the NC variability in Figure 7a. There appear, however, to be no overall differences in the presolution performance of learners when compared to the performance of nonlearners in Figure 7b. The apparent drop in the proportion of correct choices for the learners over trial blocks 9, 10 and 11 resulted from the fact that the 14 slowest learners committed their last errors within those trials. Hence, there was a sharp reduction to zero by the 11th trial block, where the last learner error was committed.

Figure 7c is a backward curve (Hayes, 1953) of the responses of FRC and NC learners. Again, it may be seen that the pre-learning performance of FRC and NC Ss is difficult to distinguish. Quite clearly, however, both groups responded near or slightly below the 50% level to the point where learning occurred.

Figure 7d gives support to the suggestion that the 3 NC nonlearners were extremely variable in their response patterns. This erratic performance, however, may simply reflect the small number of Ss.

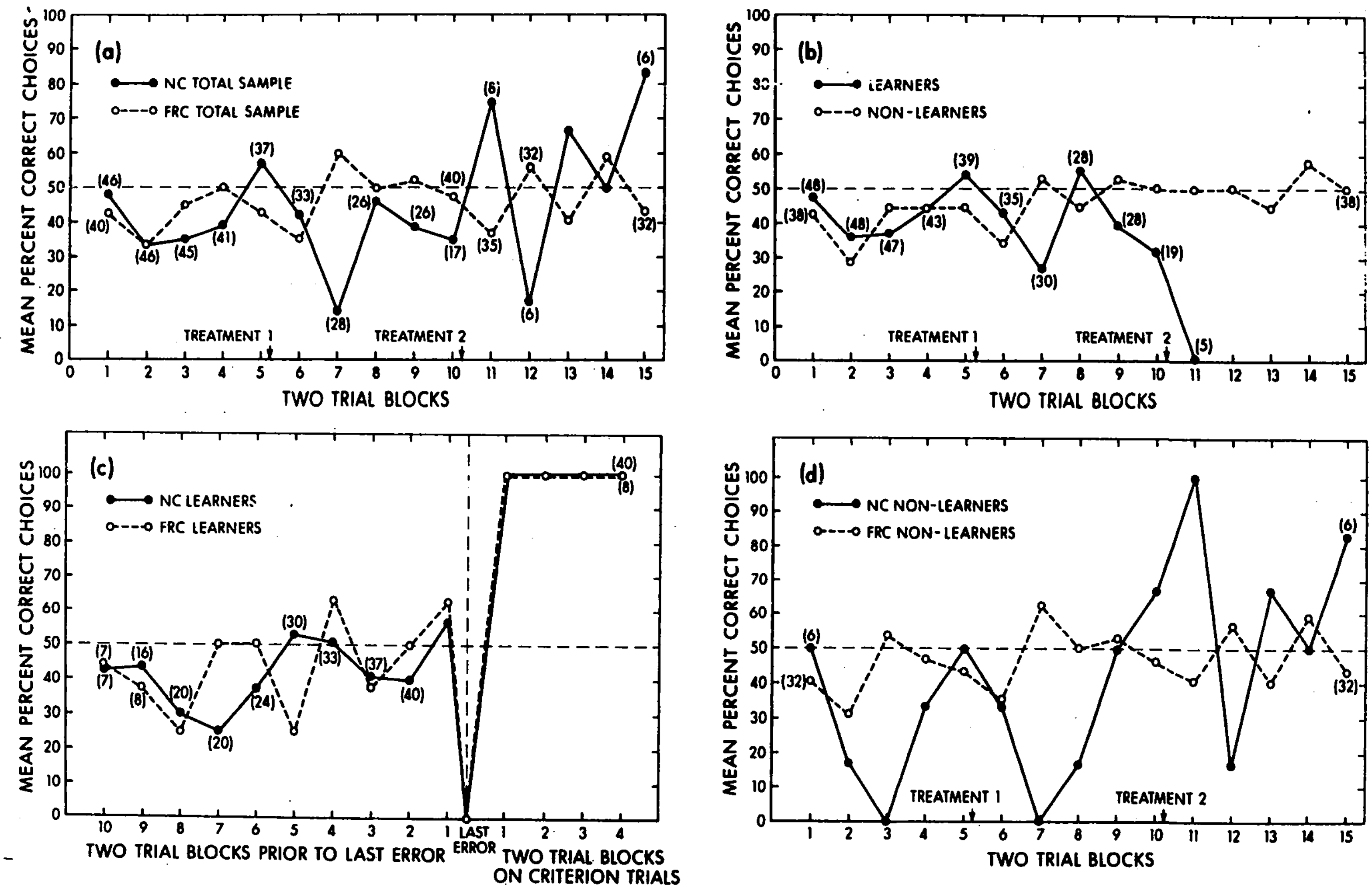

Fig. 7. Discrimination learning curves for mean percent correct choices.

The FRC nonlearners consistently responded at a chance level.

Stationarity. The assumption was made that the discrimination learning task of the present study would result in sudden or single-trial learning similar to that reported by Zeaman and House (1963). Atkinson *et al*. (1965) have used the term "stationarity" to describe the chance-level responses that occur during presolution trials where successive trial outcomes are independent. Stationarity was evaluated in 2 ways; Chi-square tests of independence, and correlated *t* tests based on the number of successes between the first and second halves of each *S*'s presolution trials. Both procedures are described by Atkinson *et al*. (1965, pp. 40-45).

The tests for stationarity indicated that only the NC nonlearners had exhibited a significant change in the proportion of correct responses over trials (Chi-square = 14.6, df = 5, $p < .02$; 3 NC, $t = 6.1$, df = 2, $p < .05$, 2-tailed). Based as it is on only 3 *Ss*, however, this finding must be considered tentative. Figure 7d suggests that even though the responses of the NC nonlearners were variable in the extreme, a trend toward a greater proportion correct is evident. However, in the second to last 2-trial block the NC nonlearners were still responding at a 50% level which would indicate that learning had not to that point occurred.

The most important finding from the tests of stationarity is that the great majority of the *Ss* did not show incremental learning. As a consequence, it seems reasonable to assume that the task of the present study has generally resulted in learning similar to that described by Zeaman and House (1963).

Eye Movement Data

In the sections that follow, EM data for Study 2 is presented both graphically and statistically. Figures 8 through 11 present the mean performance on the 4 dependent variables for each of the S groupings of Figure 7. The forward curves (Figures 8, 9, 11) are formed on the basis of 2-trial blocks with the deletion of each learner's data after his last incorrect response. The number of observations associated with each mean value is indicated in brackets. Where the number of observations remained constant over several points, as with nonlearners, the intervening values are not shown.

The backward curves of Figure 10 are also based upon 2-trial blocks, except for the trial of the last error which is displayed as a single trial to correspond to Figure 7c. In addition there is a reduction in the number of Ss in each 2-trial block to the left of the trial of the last error, dependent upon the trial in which the last error occurred. The backward curves describe EM behavior as the Ss approached the trial in which learning occurred and are continued through the 8 criterion trials in which knowledge of the correct response was assumed.

The statistical analyses parallel the figures as a complement to the graphical information. The analyses have been carried out on the basis of 10-trial blocks for the forward data (Figures 8, 9, 11), and 8-trial blocks for backward data (Figure 10). The 3 blocks are designated from the left as B1, B2 and B3. This designation applies both to forward and backward curves for consistency of description, even though the points of origin of the 2 types of curves are quite different. In other words, B1 refers to the leftmost block of 10 trials for the forward curves, and also to the 9th through 16th trials previous to the trial of the last error for the backward curves. Similarly, B3 identifies trials 21 through 30 for the forward curves, and the 8 criterion trials for the backward curves.

Independent t tests were conducted between FRC and NC for each of blocks B1, B2 and B3. In instances where the assumption of homogeneity of variance was violated, Welch's t' statistic (Winer, 1962, p. 36) has been reported. In addition, correlated t tests within each group were carried out for B1 vs. B2 and B2 vs. B3. In the case of nonlearners it was possible to conduct single classification repeated measures analyses of variance. Only those tests that yielded probabilities of .10 or less have been reported.

It should be noted that any S who did not complete all of the trials of a given block was deleted from that block. As a result, there was substantial reduction in the number of Ss entering certain analyses; particularly those involving NC learners, several of whom had learned within the first 10 trials (B1). For this reason, the statistical analyses do not in most cases reflect the total samples on which mean values for the 2-trial blocks were based. Only the nonlearner comparisons were unaffected by the deletion of Ss. Comparisons of means, however, before and after deletion of learner data indicated only slight deviations in virtually all cases. This limitation of a reduced "n" notwithstanding, it was felt that some quantification of the EM data would be of value in an exploratory study such as the present one.

FRC and NC Total Samples. Comparisons between the FRC and NC samples with regard to Percent Frames on Relevant Cues (PFRC) are presented in Figure 8a. It may be seen that the NC consistently exhibited a greater PFRC than did the FRC. Tests between FRC and NC for each of the 3 blocks indicated significant differences between the groups (B1, 20 FRC, 18 NC, $\underline{t}$ = 1.6, df = 36, p = .06; B2, 20 FRC, 8 NC, t = 2.0, df = 26, p = .03; B3, 16 FRC, 3 NC, $\underline{t}$ = 1.6, df = 17, p = .07; 1-tailed). It should be noted that statistical comparisons involving B3 were based upon nonlearners since all learner data was complete by the 22nd trial.

Of additional interest in Figure 8a is the apparent increase in PFRC for the NC group after Treatments 1 and 2. This would suggest that the introduction of verbal clues regarding the solution of the learning task resulted in the NC quickly focussing on the relevant cues. The FRC apparently did not use the information to the same advantage since only a slight increase is evident. A correlated $\underline{t}$ test of the PFRC difference between B1 and B2 for NC seems to support this supposition (8 NC, $\underline{t}$ = 1.7, df = 7, p = .07; 1-tailed). A similar test between B2 and B3 was not significant.

The rather definite reductions in PFRC, especially in the NC group, immediately prior to Treatments 1 and 2 as well as on the last 2-trial block, seem worthy of note. The reasons for this are not clear since one or more of several factors may have contributed to the reduction. One reason may be related to a sudden lack of interest in the task on the part of $\underline{S}$s who, at those points, might have felt the task was without an obvious purpose. When, however, the instructions of Treatments 1 and 2 were presented, interest may have been re-established with the resulting increase in PFRC.

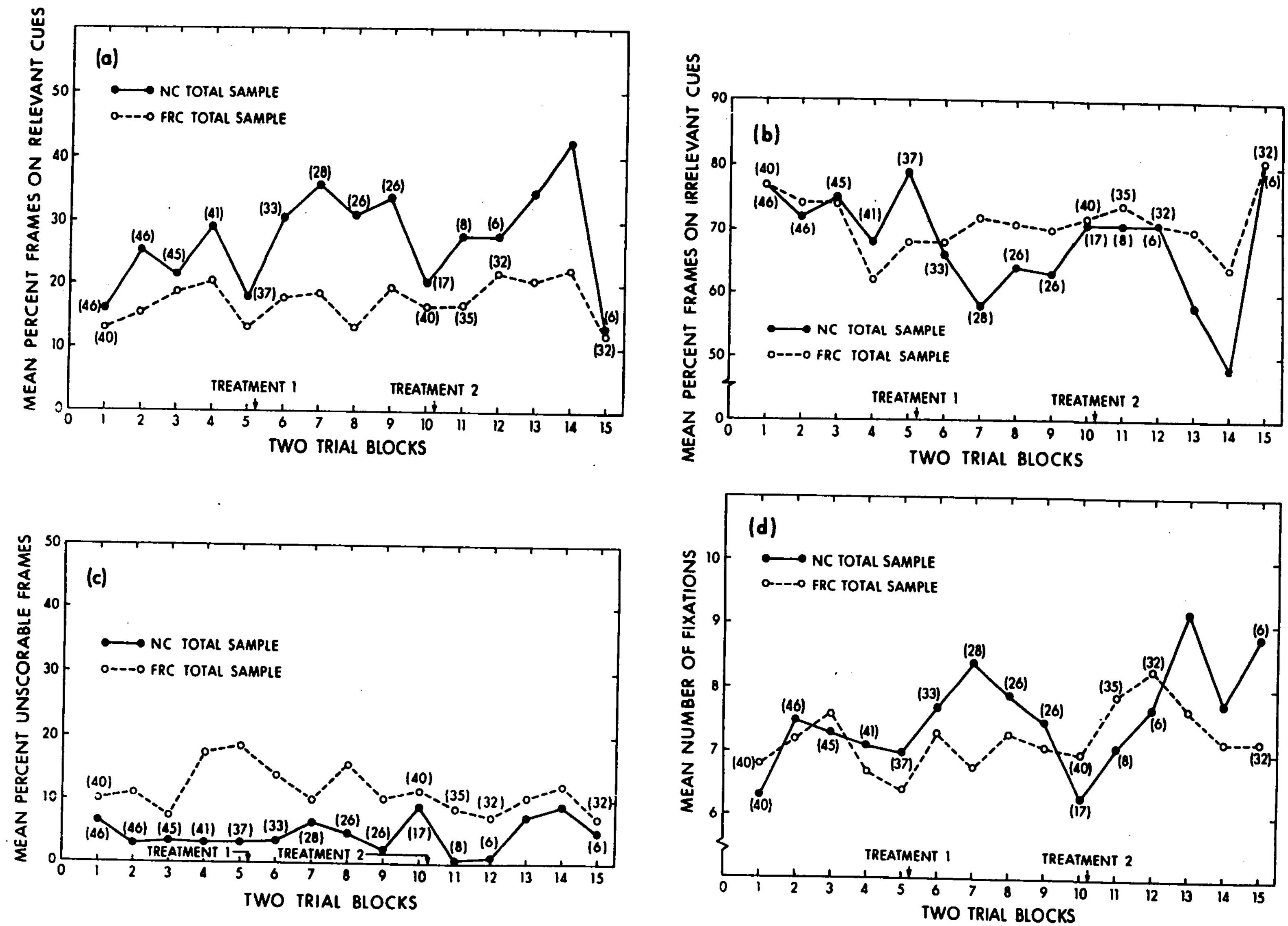

Fig. 8. Forward curves of eye-movement variables for FRC and NC total samples with deletion of postlearning data.

Alternatively, there is a possible order effect inherent in the presentation of the stimuli, which were repeated in the same random sequence for each of the 10-trial blocks. This would apply specifically to the drop in PFRC immediately prior to Treatment 2 and on the last 2-trial block. Some NC Ss, particularly, might have realized that the correct responses to trials 19 and 20 had previously been indicated on trials 9 and 10, and had recognized the correct stimulus without knowing the relevant cue. The same argument could be applied to the drop in PFRC on trials 29 and 30. While this suggestion of an order effect is plausible, it seems unlikely since the memory capacity required to retain the necessary information over a period of 9 or 10 trials would be considerably greater than even an adult might be expected to display.

A third factor related to these reductions in PFRC could have been fatigue. While no S complained of tiredness at any time, it is possible that by the 9th and 10th trials of each 10-trial block, a strain had developed in several Ss that inhibited their search activity. To remain as a viable explanation, however, this effect should have been at least as marked in the FRC as the NC, and this clearly was not the case.

A fourth possibility is that some form of hypothesis testing by Ss on the trials in which the PFRC drop occurred may have taken place. This could have resulted in greater attention, particularly by the NC, to other elements of the display, as is suggested by the comparable increases in PFIC in Figure 8b. There is no way, however, of evaluating this possibility since the Ss were not interrogated with regard to the type of thinking that had led them to the correct solution.

Figure 8b represents the Percent Frames on Irrelevant Cues (PFIC) for FRC and NC. The one finding of note appears to be a substantial drop in PFIC by the NC between B1 and B2. This is the opposite of a similar trend in PFRC (Figure 8a) and gives support to the suggestion of a sudden focussing on relevant cues by the NC after Treatment 1. A test of the difference on PFIC between B1 and B2 was significant (8 NC, t = 1.9, df = 7, p = .05, 1-tailed).

The means for Percent Unscorable Frames (PUF) are described in Figure 8c where it can be seen that the FRC consistently exhibited a greater proportion of unscorable frames than did the NC. In 2 of the 10-trial blocks, FRC were significantly higher than NC on PUF (B1, 20 FRC, 18 NC, t' = 2.5, df = 26, p = .01; B3, 16 FRC, 3 NC, t' = 1.7, df = 13, p = .06; 1-tailed). All other statistical comparisons for Figure 8c were not significant.

The Number of Fixations (NF) for FRC and NC, as may be seen in Figure 8d, tended to vary for both groups, although somewhat more so for the NC. No clear distinction between FRC and NC is evident and this is confirmed by the lack of significant differences between the groups. However, the apparent NC increase in NF from B1 to B2 approaches significance (8 NC, t = 2.0, df = 7, p = .09, 2-tailed). This would seem to provide additional evidence of the NC response to Treatment 1. A similar increase was observed for FRC between B2 and B3 (16 FRC, t = 2.2, df = 15, p = .05, 2-tailed) which would suggest that while the FRC did not respond to Treatment 1, they did to Treatment 2 with an increase EM activity. However, since the 16 Ss involved in this comparison were FRC nonlearners, the increase in activity apparently was not helpful to them in solving the task.

Learners and Nonlearners. The performances of learners (L) and nonlearners (NL) on the 4 dependent variables are shown in Figure 9. It should be noted that 20 of the 24 L's were NC, whereas 16 of the 19 NL's were FRC. A comparison of Figure 9 with Figure 8 reveals several interesting differences.

Figure 9a presents essentially the same PFRC characteristics as Figure 8a, except that the relative points tend to be closer together. This finding supports the suggestion that any visual attention difficulty is more related to the FRC-NC dichotomy than to a L-NL distinction. A *t* test between L's and NL's for B1 approached significance (B1, 19 L, 19 NL, $t = 1.4$, df = 36, $p = .08$, 1-tailed), whereas other comparisons did not.

Figure 9b appears to reflect a tendency on the part of the L's to spend less time on irrelevant cues as the task progressed. A similar although less definite finding was observed in Figure 8b. No PFIC comparisons for Figure 9b, however, were significant.

Figure 9c, when compared to Figure 8c, again suggests that the attention difficulty is more distinct when comparisons are made on an FRC-NC basis. None of the comparisons of PUF for Figure 9c was significant.

The information contained with regard to NF in Figure 9d is similar to that in Figure 8d. An additional finding, however, was a significant increase on NF for NL from B2 to B3 (19 NL, $t = 2.5$, df = 18, $p = .02$, 2-tailed).

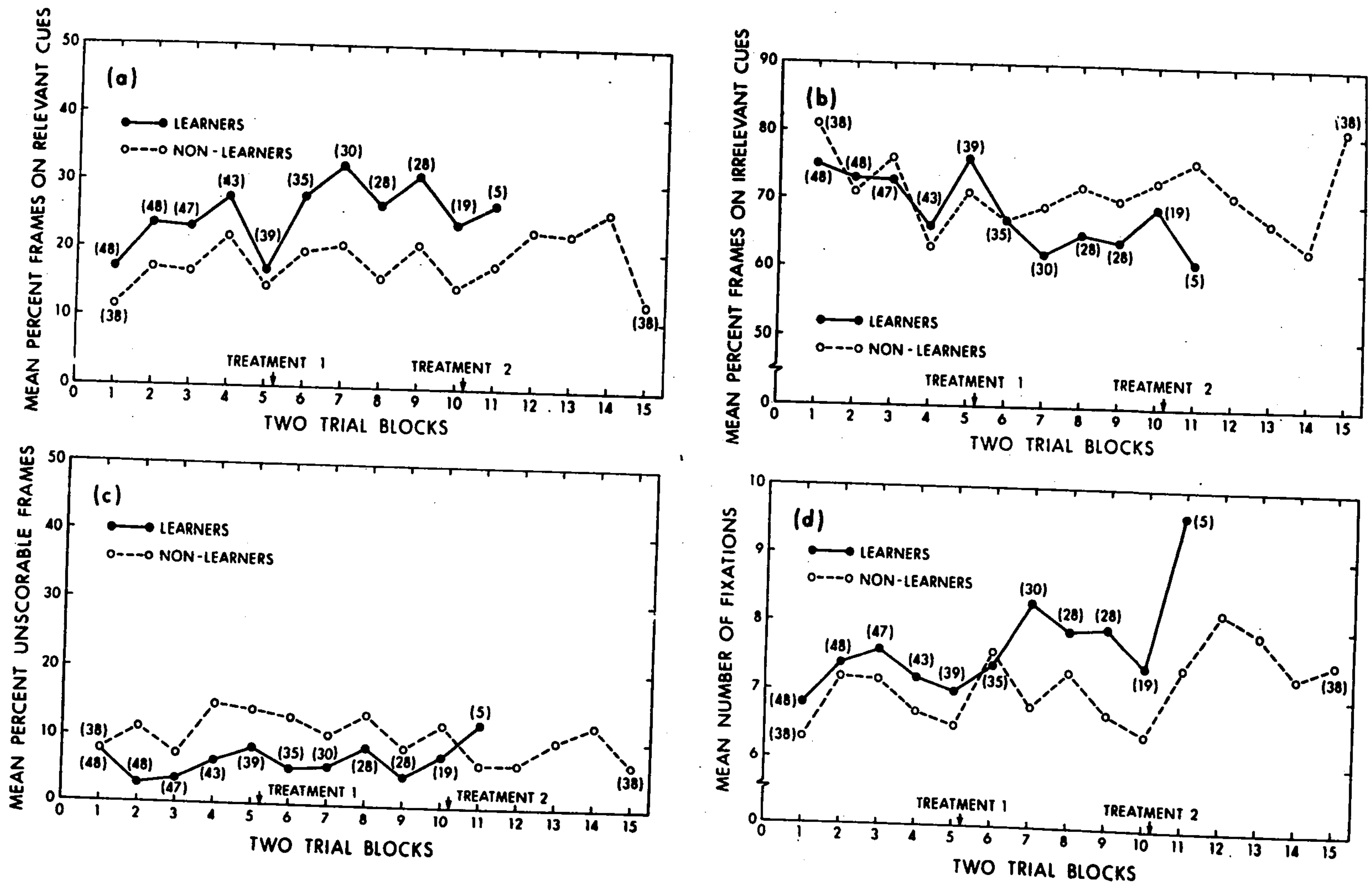

Fig. 9. Forward curves of eye-movement variables for learners and nonlearners with deletion of postlearning data.

FRC and NC Learners. The performance of the learners in both samples, plotted backward and forward from the trial of the last error, is shown in Figure 10. These figures describe the Ss' performance on the dependent variables for a maximum of 21 trials prior to learning, and then continue through the 8 criterion trials following the last error. The statistical tests are based on 8-trial blocks, 2 of which immediately precede learning and the 3rd which includes the 8 criterion trials. It should be noted, again, that since there were only 4 FRC learners, their data must be interpreted with caution.

Figure 10a seems to confirm earlier speculations regarding the FRC visual attention deficiency. It would seem that the FRC learners were only slightly more capable of focussing on the relevant cues, than were the FRC nonlearners (Compare Figure 11a).

Tests on PFRC differences between FRC and NC learners for B2 and B3 were significant (B2, 4 FRC, 17 NC, $t = 1.6$, df = 19, $p = .07$; B3, 4 FRC, 20 NC, $t = 1.9$, df = 22, $p = .04$; 1-tailed). In addition, NC exhibited a significant increase in PFRC from B1 to B2 (10 NC, $t = 3.1$, df = 9, $p = .01$, 2-tailed); the apparent increase between B2 and B3 was not significant. It may be seen in Figure 10a that the FRC also showed in increasing trend in PFRC as they approached the point of learning. This FRC increase seems to indicate, as Zeaman and House (1963) have suggested, that once children begin to attend to the relevant cues they will learn.

Figure 10b does not appear to indicate any overall difference between FRC and NC learners with regard to PFIC, except in B3 where a significant effect was observed (4 FRC, 20 NC, $t = 1.7$, df = 22, $p = .05$,

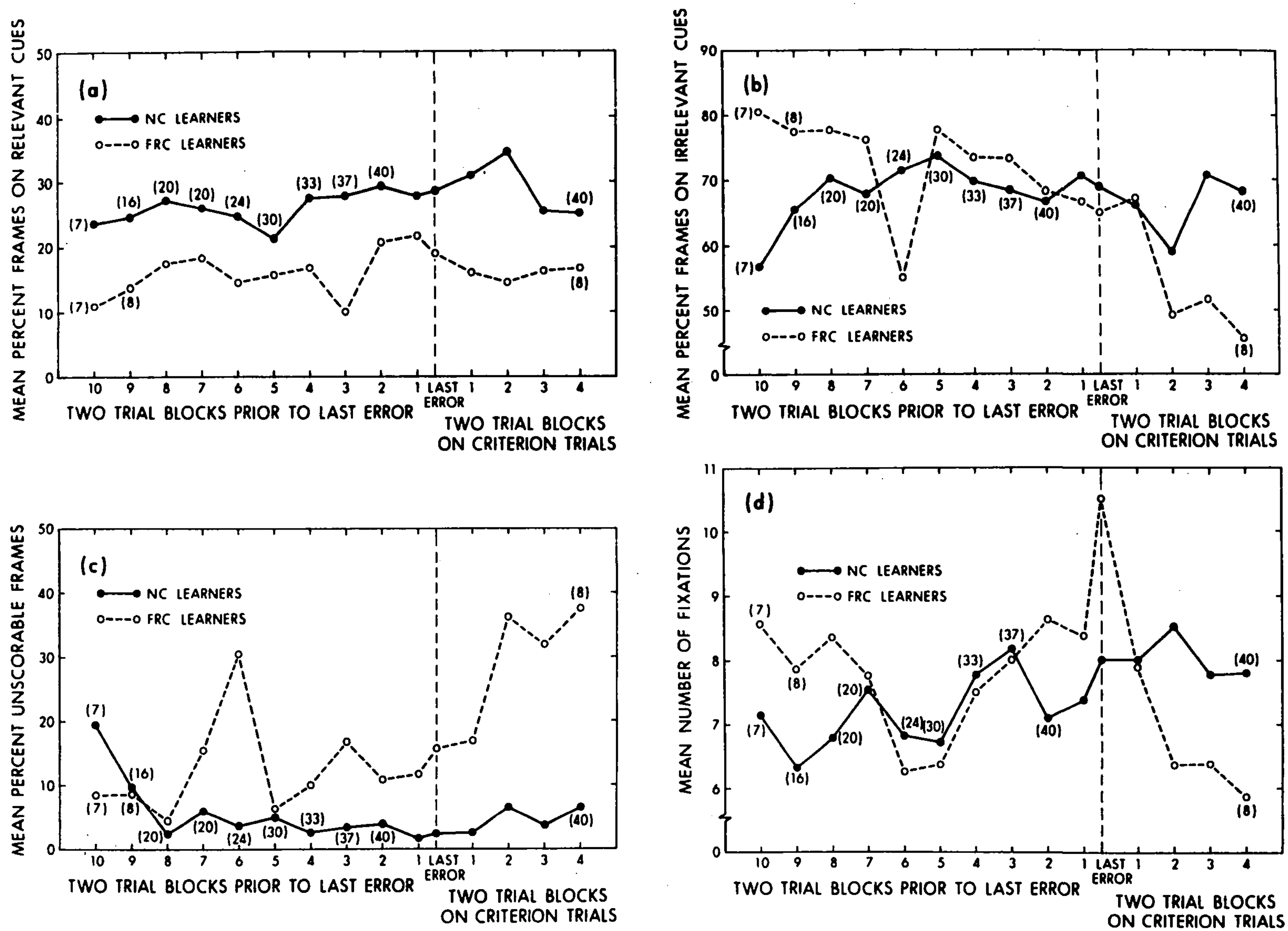

Fig. 10. Backward curves of eye-movement variables for FRC and NC learners.

1-tailed). The rather steady reduction in PFIC by both groups as the last error was approached seems to be the converse of a corresponding increase in PFRC (Figure 10a). This decreasing trend was significant for the NC between B1 and B2 (10 NC, t = 2.5, df = 9, p = .02, 1-tailed) but not, however, for the FRC. The striking drop in PFIC by FRC and a similar trend by NC over the criterion trials presents an interesting matter for speculation. The reason for this reduction in PFIC after learning might be that once the FRC Ss knew the correct response, they scanned just long enough to identify the correct stimulus, pressed the response indicator, and knowing the task had been completed, looked elsewhere than at the stimuli, whereas the NC continued to process information and, perhaps, check out their hypotheses. The increase in PUF for FRC learners in B3 of Figure 10c also tends to support this interpretation.

Figure 10c provides a comparison between FRC and NC learners with regard to PUF. Of particular interest is the finding that each of the 3 between group comparisons revealed that the FRC learners, even though they were able to solve the discrimination problem, continued to exhibit significantly more unscorable frames than the NC (B1, 4 FRC, 10 NC, t = 1.9, df = 12, p = .04; B2, 4 FRC, 17 NC, t = 2.2, df = 19, p = .02; B3, 4 FRC, 20 NC, t' = 2.0, df = 3, p = .07; 1-tailed). This seems to suggest that the FRC learners had difficulty in controlling their EMs similar to the FRC nonlearners, but were able to acquire and process enough information for learning. In general, Figure 10c seems to support the notion that FRC have greater attentional problems than NC.

Figure 10d presents interesting data regarding NF. A general increase in NF may be seen for both groups as they approached the point of learning, (i.e., the last error). This finding is similar to that reported by White and Plum (1962, 1964). Post-learning EM activity appeared to stabilize for the NC, but seemed to fall off sharply for FRC. Unfortunately, the FRC post-learning NF data, in this instance, is contaminated by the sudden increase in PUF as described in Figure 10c. The effect of this PUF increase was to suppress any indication of the number of refixations that may have occurred since none would be observed in a series of unscorable frames. None of the other comparisons for the data of Figure 10d were significant.

FRC and NC Nonlearners. Comparisons between the 16 FRC and 3 NC nonlearners are presented in Figure 11. It may be seen that the performance of the NC nonlearners on each of the dependent variables was, in general, considerably more variable than that of the FRC nonlearners. Undoubtedly, the data from the 3 NC Ss must be considered tentative. There are, however, several comparisons worthy of note.

The only difference on PFRC (Figure 11a) between FRC and NC that approached significance was found in B3 (16 FRC, 3 NC, $t = 1.6$, df = 17, $p = .07$, 1-tailed). The PFRC values for NC in the same figure appear to describe an increasing trend from B1 to B3. A correlated t test between B1 and B2 was significant (3 NC, $t = 4.0$, df = 3, $p = .03$, 1-tailed) and seems to add further support to the notion that NC Ss were better able to use the verbal instructions.

Figure 11b, as did previous figures of PFIC, reflects the NC tendency to focus increasingly on the relevant cues by virtue of the

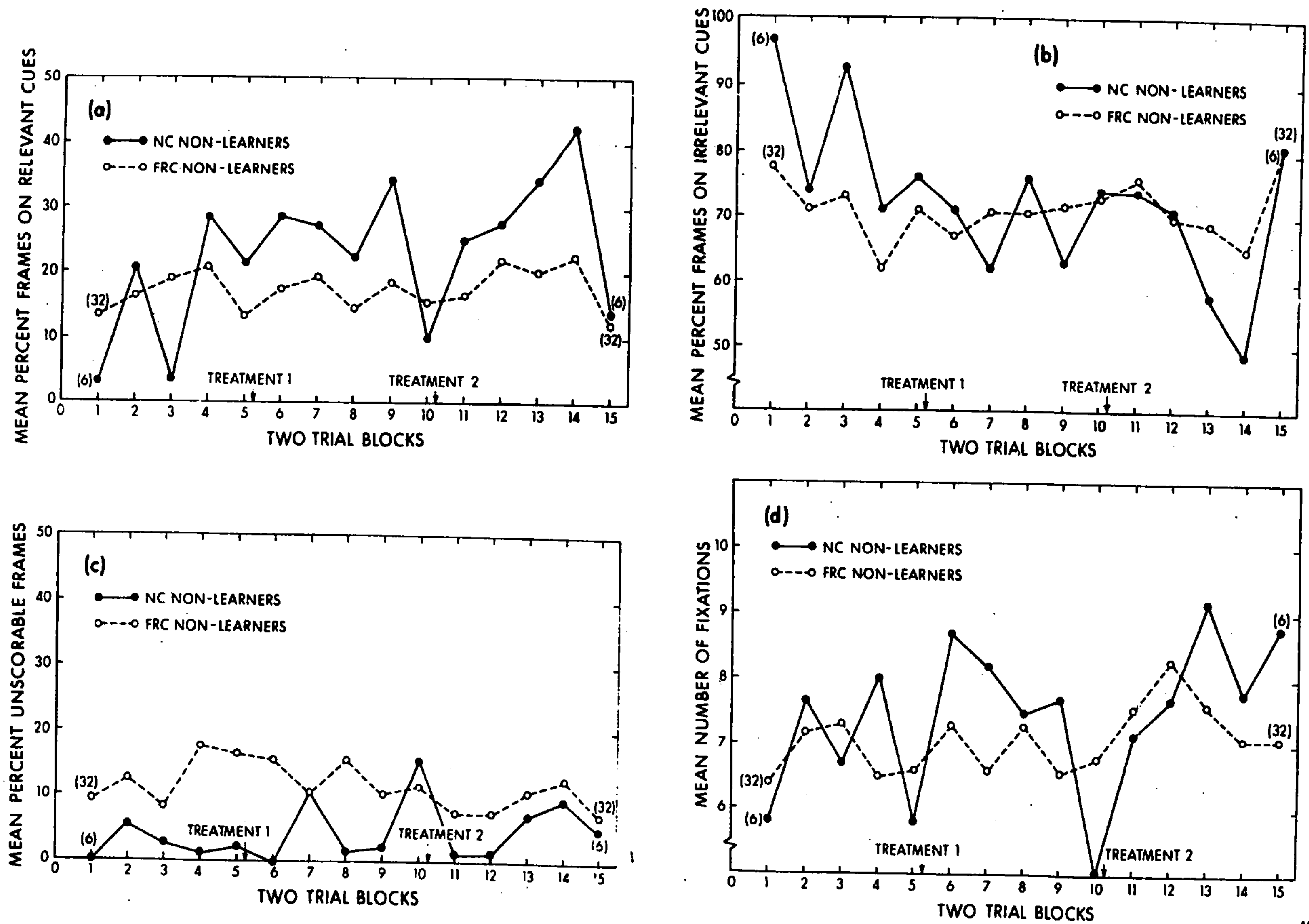

Fig. 11. Forward curves of eye-movement variables for FRC and NC nonlearners.

steadily declining PFIC values. The only significant difference on PFIC was between FRC and NC in B1 (16 FRC, 3 NC, t' = 2.4, df = 7, p = .02, 1-tailed).

Differences were found between FRC and NC on PUF in Figure 11c for B1 (16 FRC, 3 NC, t' = 2.5; df = 17, p = .01, 1-tailed) and B3 (16 FRC, 3 NC, t' = 1.7, df = 13, p = .06, 1-tailed).

Considered jointly, Figures 11a, 11b and 11c seem to indicate that the NC nonlearners, few as they were, tended to respond positively to the instructions of Treatments 1 and 2, whereas the FRC nonlearners showed no similar trend.

The data of Figure 11d appear to give no basis for differentiating between FRC and NC nonlearners with regard to NF. One finding of interest, however, is a significant increase in NF for FRC nonlearners over the 3 blocks, as determined by a repeated measures analysis of variance (16 FRC, F = 3.3, df = 2/30, p = .05). A correlated t test between B1 and B2 was not significant, however, the same test between B2 and B3 did achieve significance (16 FRC, t = 2.2, df = 15, p = .05, 2-tailed).

Correlations Between the Dependent Variables

The correlations between the 4 dependent variables of Study 2 are presented in Table 5. As may be seen, only 3 of the 12 coefficients were significant. An interpretation of the significant relationships seems to focus on the relatively greater PUF exhibited by the FRC. Because PFRC, PFIC and PUF by definition sum to 100%, if one of them is essentially little greater than zero in value, as with the NC on PUF,

Table 5

Correlations Between Dependent Variables of Study 2[a]

	FRC n = 20			NC n = 18		
	PFRC	PFIC	PUF	PFRC	PFIC	PUF
PFIC	-.07			-.85***		
PUF	-.47*	-.79***		-.06	-.36	
NF	.28	-.24	.05	.25	-.41	.43

*$p < .05$ ***$p < .001$ (2-tailed probabilities)

[a]Based on the initial 10 trials.

then the remaining two must carry a high negative relationship since they are interdependent. This would seem to account for the significant negative correlation between PFRC and PFIC for the NC sample.

The FRC, on the other hand, tended to have a considerably higher PUF and lower PFRC than the NC, while PFIC did not appear to differ substantially between either group (See Figure 8). As a result, PUF seems to have assumed an important position in describing the interrelationships of the FRC measures. This finding seems to indicate further evidence toward confirming the suggested visual attention deficiency in the FRC.

Summary of Results

The results of Study 2 have shown substantial differences in learning performance between the FRC and NC samples. The discrimination learning task was too difficult for the majority of the FRC and rather easy for all but 3 of the NC. The 4 FRC that did learn the task required significantly more trials to do so than did the NC learners. However, the task appears to have been successful in presenting a learning situation in which both samples could participate; this was a necessary condition of the experiment.

An added condition, implicit in the statement of Hypothesis 2, required that the type of learning observed in the present study parallel that described by Zeaman and House (1963). Six of the 8 tests associated with Hypothesis 2.1 demonstrated the existence of stationarity, and hence provided strong support toward establishing task similarity. The 2 tests of Hypothesis 2.1d which failed to show stationarity were based on only 3 NC nonlearners, and must be considered tentative. It is possible that these Ss were on the threshold of learning, although there was evidence to the contrary.

Hypothesis 3.1, which predicted that FRC would spend less time fixating on the relevant cues than NC, appears to have received firm support. Figure 8a and the associated statistical tests have indicated that the FRC exhibited significantly lower PFRC than the NC. Further support for Hypothesis 3.1 can be found in the comparisons of FRC and NC learners in Figure 10a, and to a lesser extent in the FRC and NC nonlearner comparisons of Figure 11a.

Hypothesis 3.2, which predicted that FRC would spend more time fixating on the irrelevant cues than NC was not generally supported, although a supporting trend was evident. It would seem that there was little difference between FRC and NC with regard to PFIC.

The significantly greater proportion of unscorable frames observed in the FRC was predicted by Hypothesis 3.3, and seems to add further evidence of the visual control difficulties of retardates.

A joint consideration of the results of testing Hypotheses 3.1, 3.2, and 3.3 leads to the conclusion that the FRC were less able to direct their EMs toward the relevant aspects of the discrimination learning task. This finding seems to provide evidence in support of the Zeaman-House position regarding the "visual-attention" difficulties of retarded children.

Relatively little support was found for Hypothesis 4.1 which predicted that the FRC would exhibit a greater mean number of fixations during the learning task than would the NC. It would seem that the data of the present study do not differentiate between FRC and NC Ss with regard to frequency of fixation.

Hypothesis 5, involving the L-NL grouping, was stated so as to parallel Hypotheses 3 and 4. Comparisons under Hypothesis 5.1a between L and NL Ss on PFRC (Figure 9a) were similar to those of the FRC-NC grouping, but were less distinct. A possible explanation for the reduced differences would seem to be the fact that the L's were dominated by the NC Ss whereas the NL's were essentially FRC. Tests of Hypotheses 5.1b, 5.1c and 5.2 revealed no statistically significant differences. It would appear that the data of the present study are better described in terms of the FRC-NC dichotomy.

Hypotheses 6 and 7 attempted to evaluate the effects on EMs of 2 types of verbal instructions which: (a) directed Ss' attention to the relevant dimension of the discrimination learning task (Treatment 1); and (b) described how the task could be solved (Treatment 2). Hypothesis 6.1a predicted that FRC would not differ with regard to PFRC before and after Treatments 1 and 2. Slight increases over trials for FRC are evident in Figures 8a and 10a. This trend, however, was not found to be statistically significant. Hypothesis 6.1a therefore cannot be rejected. It would appear that the FRC did not generally use the verbal information to direct their EMs toward the relevant cues.

Hypothesis 6.1b, on the other hand, predicted that the NC would apply the verbal information such that an increase in PFRC would occur following Treatments 1 and 2. The evidence to be found in Figures 8a, 10a, and 11a, as well as the significant statistical differences between B1 and B2 in each case, suggests rather firm support for the hypothesis.

The NC were able to respond appropriately to the verbal instructions.

The evaluation of Hypothesis 6.2a, which predicted no FRC differences on PFIC following Treatments 1 and 2, indicates that there is no basis for its rejection. Little difference in PFIC over trials is evident for FRC, except in block B3 of Figure 10b. The sudden reduction there, however, is related to the corresponding increase in PUF as may be seen in Figure 10c, and must therefore be considered artifactual. Hypothesis 6.2b, which predicted a reduction in PFIC for the NC, is supported both graphically, and to a lesser extent, statistically.

No bases were found for the rejection of Hypotheses 6.3a and 6.3b which predicted no differences in unscorable frames following Treatments 1 and 2, for FRC and NC respectively. However, a gradual decrease over trials in PUF for FRC may be seen in Figure 8d, which seems to suggest that the FRC did persist in their attempts to solve the task.

Hypotheses 7.1a and 7.1b predicted no differences in NF following Treatments 1 and 2, for FRC and NC respectively. There is some evidence to warrant the rejection of Hypothesis 7.1a. Figures 8d and 11d seem to indicate a gradual tendency in the FRC toward an increased NF over trials that is rather pronounced immediately following the presentation of Treatments 1 and 2. This suggestion seems to receive support from the significant F-test associated with Figure 11d. It would seem that the FRC did recognize that the verbal clues were potentially useful, even though they were generally unable to benefit from them.

The NF performance of NC Ss, as described by Figures 8d and 11d, seems to suggest that Treatments 1 and 2 were influential in increasing the amount of their EM activity. Comparisons between blocks B1 and B2 for NC approached significance and suggested that Hypothesis 7.1b may not be tenable. This finding, however, must be considered tentative.

It seems evident that the NC, in general, were able to apply the information of Treatments 1 and 2 to a greater advantage than were the FRC.

Two further points, both associated with Figure 10, seem worthy of note. The first is directed toward the FRC learner increases in PFRC (10a) and NF (10d) immediately prior to the trial of the last error. Zeaman and House (1963) have indicated that once "attention" is focussed on the positive cue of the relevant dimension, learning will occur. It would appear that the FRC data of Figure 10a provide support for this premise. Additional support seems to lie in the FRC increase in NF which might indicate that the FRC Ss had suddenly formed a "hypothesis" regarding the solution of the task and immediately proceeded to confirm it by considering the range of possibilities. A similar, though less noticeable, change in NF can be seen for the NC. While it must be recognized that the data provided by 4 FRC learners is hardly adequate to confirm this aspect of the Zeaman-House theory, the evidence would seem to be supportive.

The second point is related to the sudden increase in PUF by the FRC, and to a lesser extent the NC, after learning has presumably taken place (Figure 10c). The suggestion has already been made that this trend is possibly associated with the Ss' awareness of the correct response and the knowledge that once the response was made the trial had been completed. It would seem, as Schroeder (1970), and White and Plum

(1962, 1964) have suggested, that some optimum time, probably less than a second, was required for S to select the correct response once learning had occurred. It could, therefore, be inferred that the 3-second time base used in the present study was sufficient to describe the essential characteristics of visual search under the conditions of the discrimination learning task used here.

The intercorrelations among the dependent variables in Table 5 seem to add support to the suggestion of an FRC difficulty in EM control. The greater proportion of unscorable frames exhibited by the FRC appeared to be the dominant relationship expressed. For the FRC, PFRC and PFIC were significantly related to PUF, but not to each other. The single significant correlation for the NC was between PFRC and PFIC. The NF variable was not significantly related to any of the other 3 dependent variables.

Discussion

The hypotheses of Study 2 seem to have received general support. The most significant finding appears to be that the retarded Ss, when compared to normals, were deficient in their control of EMs. The FRC were observed to have difficulty in focussing on those stimulus elements which were relevant to the solution of the learning task by tending, instead, to spend the greater proportion of their time viewing irrelevant aspects of the field of view, both within and beyond the display area.

Even after specific verbal instructions regarding the solution of the task were presented, the FRC did not seem to effectively increase the proportion of time spent viewing the relevant cues of the task. The NC, on the other hand, showed that they had responded to the instructions by immediately focussing on the relevant cues after the instructions had been given.

Of the 4 dependent variables used in Study 2, PFRC and PUF appear to have been the most sensitive to differences between FRC and NC Ss. The differences observed on both variables were quite consistently in the predicted direction. The PFIC and NF variables revealed few significant differences, but did tend to reflect the expected differences.

It seems, therefore, that the application of "looking behavior" as an operational definition of visual attention could have some merit. In view of this it might be reasonable to suggest that the criticism of Mostofsky (1968) and Wischner (1967), regarding the lack of such a definition in the Zeaman-House theory, has to some degree been met in the present study.

To the extent that looking behavior as defined here, and visual attention in the Zeaman-House theory are similar, the present findings seem to support the assumption of a retardate attentional deficiency that is an explicit feature of the Zeaman-House formulation. In other words, the analysis of EM behavior during discrimination learning seems to indicate that retardates do not effectively search out the essential aspects of the stimuli.

There was some evidence, though based on only 4 FRC learners, that once Ss began to focus on the relevant stimuli, learning did take place. This, too, is an explicit feature of the Zeaman-House theory, and follows from Wyckoff's (1952, 1954) earlier position.

According to Kendler and Kendler (1962, 1970) children in the age range of the Ss of the present study (8-12 years) would normally be functioning at the "verbal mediation stage" and, therefore, could be expected to apply verbal mediators to a discrimination learning task. On the two occasions in which verbal mediators were supplied (Treatments 1 and 2), the retarded Ss showed little indication of having used them, whereas the normal Ss gave strong evidence of having done so. It would appear that the retarded Ss were most likely functioning at the lower level "verbal deficiency stage." This interpretation seems to be supported by the finding of Milgram and Furth (1964) of a verbal deficiency in younger CA and lower MA Ss, and by Scott's (1964) suggestion that retardates do not use verbal mediators even when they are available.

The results of the present study appear to have given objective support to the Zeaman and House (1963) contention that retardate discrimination learning is influenced by a visual-attention deficiency. There seems little reason, therefore, to challenge the notion expressed by Mackintosh (1965), Shepp and Turrisi (1966), and Wolff (1967) that the Zeaman-House model is the most parsimonious description of retardate discrimination learning, to date.

CHAPTER 7

Summary and Conclusions

Summary

The major objective of Study 1 was to determine whether functionally retarded (FRC) and normal (NC) children could be differentiated on the basis of eye-movement (EM) measures taken during visual search tasks. Three dependent variables, information search scores (ISS), mean fixation duration (MFD), and track length (TL) were used to evaluate the hypotheses of the study. Of the 3 variables, ISS emerged as the most sensitive means of distinguishing the EM activity of FRC and NC Ss. This finding has been interpreted to suggest that the FRC were less able to search out the areas of high information content in pictorial displays than were the NC. The implication seemed to be that the FRC were handicapped in their attempts to derive information efficiently by the lack of a generally effective search strategy. It appeared that the FRC may have engaged in a somewhat random search by focussing on aspects of the stimuli that were rated to have a relatively low information component. The NC, on the other hand, seemed to focus more on the "central" areas of high information, the result perhaps of having learned that the essential characteristics of most visual displays are centrally located.

The MFD variable reflected significant differences between the samples under the conditions of a specified search task, but not when the purpose of the search was unspecified. Where differences on MFD did occur, the FRC exhibited a briefer period of fixation than did the NC. This seemed to suggest that the FRC, having less control over their EMs moved impulsively over the display in the hope that the solution to the task would be readily apparent. The NC, it appeared, fixated until an adequate intake of available information had occurred before proceeding to the next stimulus element. It seemed that the time devoted to the average fixation was related to the nature of the task, and to characteristics of the stimulus such as complexity, novelty, and detail. In general, the results suggested that MFD was able to distinguish between FRC and NC under certain stimulus conditions.

The amount of linear movement over the stimuli, as measured by the TL variable, failed to show any significant differences between FRC and NC. It seemed that both samples recognized the need for at least a minimum coverage of the stimuli in terms of distances between fixations.

Study 1, then, seems to have shown that certain measures of EM activity are capable of distinguishing the visual-perceptual activity of retarded and normal children. The essential difference between FRC and NC appeared not to be in how much of a stimulus was scanned, but upon which parts of the stimulus fixations occurred. In other words, it seemed that it was the quality rather than the quantity of visual search that differentiated FRC and NC Ss.

Study 2 was based on the premise that EMs could be used in describing differences between FRC and NC Ss during the course of discrimination learning. The major hypotheses of Study 2 were formulated in terms of the Zeaman and House (1963) theory. Four measures of EM activity, percent frames on relevant cues (PFRC), percent frames on irrelevant cues (PFIC), percent unscorable frames (PUF), and number of fixations (NF) were used to define "looking behavior" which, it was assumed, could be related to the "visual attention" construct of the Zeaman-House theory.

The major objective of Study 2 was to determine the extent to which EM measures reflected those differences in looking behavior that were predicted by the Zeaman-House position. Of the dependent variables, PFRC and PUF proved to be the most sensitive to retardate-normal differences. In virtually all comparisons the FRC Ss exhibited lower PFRC values than did the NC. This finding was interpreted as an indication of objective support for the Zeaman-House contention of a retardate visual-attention deficiency. There was some additional evidence, based however on the data of only 4 FRC learners, that once those Ss began to look at the relevant dimension, they did learn the discrimination, as Zeaman and House would have predicted.

The PFIC and PUF variables described what might be considered the negative components of EM activity during discrimination learning. In effect, a fixation that was not on a relevant cue was either on an irrelevant cue, or it was unscorable. Few substantial FRC-NC differences were observed on PFIC, whereas FRC consistently exhibited higher PUF values. The NF variable tended not to distinguish between FRC and NC Ss, suggesting that the amount of EM activity did not differ between the groups.

In summary, it appeared that the FRC did show considerably greater difficulty than the NC in selecting out and focussing upon those aspects of the discrimination learning task that were essential to its solution.

The second objective of Study 2 was directed toward an evaluation of the effects of verbal information on EMs. It was expected that the FRC would be less responsive to verbal directions than would the NC. The results seem to have supported this expectation. The NC showed substantial increases in PFRC immediately following the statements of how the discrimination could be solved, whereas the FRC exhibited only slight increases. It appeared that the FRC were, indeed, less able to benefit from the verbal information.

The results of both studies seemed to present the consistent finding of a retardate deficiency in looking behavior. The retardates were observed to engage in a somewhat random search behavior in which most points of fixation were either on irrelevant stimulus elements, or beyond the boundaries of the display area. Even when told where to look in order to obtain maximum information, the retardate was less able to bring the designated elements under scrutiny than was the normal child.

Conclusions

Theoretical Implications

A theory which fails to provide an operational definition for its major construct probably lacks sufficient explanatory power to be generally applicable. This criticism has been levelled at the manner in which Zeaman and House (1963) have used the term "visual attention", by Mostofsky (1968) and others. Part of the difficulty seems to lie with the tendency of Zeaman and House to equate Wyckoff's (1952, 1954) "observing response" with their own construct. As Reese and Lipsitt (1970) have pointed out, however, the terms are not equivalent. Kendler and Kendler (1970) have suggested that "visual attention" appears to include filtering and encoding, as well as observing, properties.

The present study has attempted to provide objective evidence of the function of the "observing response" component by defining it in terms of EM behaviors. To the extent that the results of the study are valid, it appears that the analysis of EMs has shown that retarded children are deficient in visual attention. This statement is supportable whether or not the construct of attention includes more than observing behavior, since unless the child can control his EMs sufficiently to focus on those components essential for learning, he logically cannot learn. It would seem, therefore, that at the visual receptor level, at least, the assumption of a visual attention deficiency in children of low IQ, as Zeaman and House suggest, is tenable.

The nature of the mediation that takes place during learning presents a much more difficult theoretical problem. An attempt was made in the present study to determine whether verbal instructions would result in changes in EM behavior. The results indicated that the normal children were able to apply the instructions more effectively than the retardates. Kendler and Kendler (1962, 1970) have suggested that children operating at a level of verbal fluency will use verbal mediators during learning, but those without such fluency will tend to apply perceptual mediators. The results found here tend to support this supposition.

The question also arises as to the bases for these observed differences between normal and retarded children. Luria (1969) has suggested that retardates are lacking in what he calls "voluntary attention", which is based upon "mediated structures." He indicates that children with unstable mediated activity can be so distracted by stimulus change as to inhibit learning. Gal'perin (1969), advocating a somewhat similar position, refers to "intellectual operations" which permit the learner to select a specific approach to solving a problem. Presumably, if the learner has not developed an adequate repertoire of these "operations", as would seem to be the case with retardates, learning is difficult, if not impossible. The lack of an adequate inhibitory mechanism in retardates, on the other hand, is offered by Berlyne (1960), Hagen (1967), and Heal and Johnson (1970) as an explanation for ineffective visual-perceptual activity. In this context, the retardate is hindered in his learning efforts by the inefficient acquisition of information.

These theoretical positions seem to be comparable in predicting that retardates will exhibit visual-perceptual behavior that is less effective than that of normals. The findings of the present study appear to be in agreement with that prediction.

Limitations

It would appear that most studies in mental retardation are hampered by inadequacies of design and the present one may not be exempted from this criticism. One of the major difficulties is associated with the definition of mental retardation. The present study has designated "functionally retarded children" as a subgroup of the educable mentally retarded, having no known organic defect or emotional upset. The latter qualification is not too difficult to establish, but the former can only be tentatively assumed since negative findings of organicity do not insure that such defect does not exist. Hence, the FRC sample used here could possibly contain Ss with brain damage.

Some authorities, according to Baumeister (1967), insist that studies similar to the present one should provide both CA and MA matched normal samples for comparison. The MA match was not included here for two reasons. First, it was felt that the younger MA matches would have considerable difficulty in adapting to the EM recorder and their performance would, therefore, be confounded with a measurement difficulty component. Hence, their data would not be useful in comparisons with older Ss. Secondly, Baumeister (1967), Goulet (1968), and Spitz (1969) have questioned the general usefulness of MA matches by suggesting that the MA is probably not a valid concept. Some readers, however, might feel that the lack of an MA matched comparison sample is a limiting factor in the present study.

Several other possible limitations of the study deserve mention. First, the recording procedure was rather intensive and continued for approximately 30 minutes. While no S complained of fatigue, it is possible that some Ss were tiring near the end of the session and this may have affected their performance. Second, although the discrimination learning task appeared to result in single-trial learning as expected, the use of 2-dimensional stimuli might have resulted in some differences from the 3-dimensional stimuli commonly used by Zeaman and House. Third, because the 10 stimuli of Study 2 were repeated in the same random sequence on 3 occasions, it is possible that an "order effect" may have operated. There was, however, little evidence to suggest that this had occurred. The decision to repeat the order was based on convenience in presentation which, in retrospect, was a questionable justification. Fourth, the instructions for Treatment 2 of Study 2 were stated in a negative form; that is, the Ss were told how to identify the incorrect stimulus. This was done to amplify the effects of possible differences in verbal ability, but may have led to the failure of some FRC to recognize that the instructions were associated with the solution of the learning task. In that case the treatment might not have been completely valid for the FRC Ss.

Perhaps the most severe limitation was imposed by the fact that there were only 4 FRC learners and 3 NC nonlearners in Study 2. As a result, all comparisons that involved these groups had to be expressed in tentative terms. A similar limitation resulted from the differential deletion of those Ss who had reached criterion in Study 2. While such deletion was unavoidable, its influence on the results was difficult to determine.

A final comment with regard to the effect on statistical inference of conducting a large number of comparisons on the same samples, as in the present study. The number of observed "significant" differences that are chance occurrences is difficult to assess. To allow for some flexibility in interpretation a probability level for significance was purposely not stated, thereby allowing the reader to impose his own. In addition, the reader could interpret the statistical results in light of the graphical presentation of the data. While some may argue against this approach, it can have merit when applied to an exploratory study in which underlying relationships, however tentative, might lead to research of a more definitive nature.

Implications for Further Research

A major reason for undertaking an exploratory study is to uncover conceptual and methodological problems in the field of interest. The limitations of the study, stated above, have pointed to a number of areas that require further evaluation.

The retardate sample, for instance, was representative only of a rather narrowly defined subgroup of retarded children, and covered a fairly restricted age range. Studies, therefore, should be carried out on Ss of differing retardate categories and ages. In this regard, the wide-angle EM recorder described by Mackworth (1968) would permit the study of children much younger than those used here. Further, the differential effects of pictorial complexity and verbal instructions on the EM activity of retarded Ss require extensive study. In this regard, the ISS variable appears to hold promise as a particularly sensitive index of EM behavior.

The fact that there were only 4 retardates who learned the discrimination task diminished the value of findings based on them. Consequently, studies in which a larger proportion of the retardate sample was able to reach criterion would allow a better description of the learning process. In addition, no attempt was made to evaluate discrimination learning under conditions of transfer. Since transfer paradigms play an important role in the study of discrimination learning, it should be of interest to evaluate EM behavior during transfer learning.

The present study evaluated only the first 3 seconds of visual search, and while there was evidence to suggest that this time base provided useful data, EMs studied over a longer duration could uncover additional information relative to retardate-normal differences, especially with regard to the effects of habituation during visual search tasks.

Mackworth and Bruner (1970) have inferred that EM activity is controlled by "cerebral programs" which are based on stored internal experience. Similarly, Mackintosh (1965) has noted the need for a better understanding of the mediational process during learning. The study of EM behavior seems capable of providing objective evidence of learning processes which, in turn, could lead to a learning theory more encompassing than that of Zeaman and House.

Implications for Education

The present study has reaffirmed that visual-attention as well as verbal deficiencies exist in retarded children. These deficiencies combine to produce learning difficulties that are often insurmountable. Efforts, therefore, should be directed toward improving the perceptual and verbal characteristics of retarded children as early in life as possible. This would entail the identification of retardates long before their entry into formal education. Valid instruments for identification should be developed and applied as early as the second or third year of the child's development. Those children found to be potential retardates, for whatever reason, then could be given special programs to insure that on their entry into school, they were prepared to function at levels that were optimal for them.

It has been shown (e.g., Cunningham, 1965) that visual attention responses in retardates can be improved by successive approximations to the desired outcomes. An approach such as this, however, requires individualized instructional techniques which are extremely time consuming and costly. For this reason, the development and application of special programs for the retarded has been handicapped. The expanding technology of computers into the field of education, however, may provide an economically feasible means whereby both the diagnosis and remediation of retardate learning difficulties can be facilitated. Such devices as television displays, audio input units, and image projectors, all under the control of a computer, could be used to present the child with specially designed learning experiences.

It may well be that David Zeaman's optimism regarding the ultimate improvement in the learning of retarded children will be borne out.

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A P P E N D I C E S

APPENDIX A

Information Rating Procedure

Colleague:

Attached is a series of six stimulus pictures that have been used in my study of eye movements. Each picture has been divided into cells of equal area.

Would you be kind enough to rate the relative "information content" of each cell within each picture, (i.e., rate each picture independently of the others), on a six point (0-5) scale? Simply enter the value you select into the corresponding cell, preferably with a red pencil.

As a general guideline, you might like to select the lowest and highest cells and assign them a "1" and a "5", respectively, with the remaining cells ranging relative to them. The same value or weight may, of course, be used for more than one cell. Please use only whole numbers.

A cell carrying no information would be set at "0".

Please rate the pictures in the order they are presented.

Thank you very much.

APPENDIX B

Questions for Task 2 of Study 1

Story

1 How many children did you see?

2 How many girls were there in the picture?

3 What was happening on the stove?

4 What kind of chair was the lady sitting on?

5 What was the lady doing?

Party

1 How many boys were there in the picture?

2 How many girls were there in the picture?

3 What could you see in the window?

4 Was the boy carrying anything?

5 What was he carrying?

Washday

1 What kind of day was it?

2 What was the dog doing?

3 What was the woman doing?