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EYE FIXATIONS DURING A PSEUDO CONCEPT FORMATION TASK

BY

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ABSTRACT

Eye fixations of 14 boys (mean age 10.75 years) and 14 adult males (mean age 20.42 years) were recorded during two pseudo concept formation problems in which feedback (reward or nonreward) was controlled by the experimenter. It was postulated that, if subjects were using hypothesis testing strategies in which new hypotheses were selected on trials following nonreward but not on trials following reward, they would make more fixations, and these fixations would be of a longer total duration, following nonrewarded trials than following rewarded trials.

The stimulus used in the experiment consisted of a circle divided into three equal sections. Each section contained one of three cues; colour (red or blue), size (large or small circle), and line orientation (horizontal or vertical). Each subject was given two 15 trial training problems in which two simple hypotheses, red and vertical line, provided the correct solution for the first and second problem, respectively. Training problems were followed by two 9 trial pseudo problems for which there was no solution; rather feedback was sequenced so that in each pseudo problem four trials followed negative feedback on the immediately preceding trial and four trials followed positive feedback. Eye fixations were recorded using an infra red corneal reflection technique.

Results confirmed the two predictions - subjects made more fixations and fixated for a longer period of time on the display following nonrewarded trials as compared with the number and duration of fixations following rewarded trials. Data were consistent with the notion that eye movements reflect underlying cognitive processes as described in hypothesis sampling theory.

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CHAPTER I

INTRODUCTION

There are three types of eye movements of great importance in our perception of the visual world around us: convergence movements, which keep both eyes pointing at whatever is the centre of our attention; saccadic movements that shift both eyes to a new centre of interest; and pursuit movements that follow an object moving in space or maintain fixation on an object as we move in space (Haber and Hershenson, 1973, p. 22). In addition there are other movements which compensate for movements of the head and trunk; miniature movements encountered during fixation of a stationary object; involuntary rolling or torsional movements of the eye about the line of gaze, and nystagmus which is a general term applied to a large class of eye movements of an oscillatory or unstable nature (Young, 1963). Of these seven, only saccadic eye movements or saccades are the concern of this study. Saccadic, or fast eye movements, are the little jumps by means of which we voluntarily move our eye conjugately from one fixation point to another. While our eyes are actually moving we see little or nothing (Llewellyn-Thomas and Stasiak, 1969) and effective visual perception is only possible during visual fixations. The duration of these fixations varies with different tasks but average about 300 msec when one is reading (Llewellyn-Thomas and Stasiak, 1969) and lower (between 170 and 200 msec) when conducting a visual search (Luria and Strauss, 1975). Thus eye movement behaviour is characterized by a series of saccades interspersed with fixations.

Saccadic eye movements have been a fruitful source of empirical data for testing psychological theories relating to such diverse problems as approach-avoidance conflict (Webb, Matheny and Larson, 1963), paired-associate learning (McCormack, Fingas, Haycock and Moore, 1968), problem solving (Kaplan and Schoenfeld, 1966; Nakano, 1971), cognitive development (Fleming, 1969; Boersma, O'Bryan and Ryan, 1970; Olson, 1970; O'Bryan and Boersma, 1971), and discrimination learning (for example, Schroeder, 1969a, b; 1970).

Saccadic Eye Movements in Perceptual Tasks

Several studies have reported developmental differences in the child's ability to select and process information in perceptual tasks. Mackworth and Bruner (1970) have characterized children's saccades during inspection and recognition of pictures as erratic and piecemeal when compared to those of adults. Their children tended to concentrate upon less informative details of the pictures and showed less consistency in their visual fixation patterns during a second showing of the same pictures than adults. These authors noted that their younger children (six year olds) had difficulty combining "steps" (short eye movements concentrating upon central areas of the stimulus field they were looking at) with "leaps" (longer eye movements that search peripheral in addition to central areas of the stimulus field) in an effective search strategy that could both search out fine features by close inspection and at the same time scan peripheral features of the stimulus field. To some extent this ability to combine peripheral and central scanning is the issue of a study by Vurpillot (1968) who found differences in the scanning strategies of three year old in comparison to nine year old children. She used six pairs of stimuli consisting of drawings of houses; three identical pairs, and three pairs differing in terms of number of windows (one, three or five) in the drawings. When presented with a pair of drawings the children had to decide whether they were the same or different. She found that children under six years typically scanned only a limited portion of each pair and made their judgements on this insufficient information, but beyond age six the children had developed scanning strategies which optimized their ability to make the discrimination.

Vurpillot's study inspired Olson (1970) to investigate visual search patterns of four and six year old children. In this study, 13 subjects were selected to view pictures of houses. They were told that they were going to see a picture of a house, that they were to pretend it was "their house", and they should try to remember what it looked like. They were then presented with pictures of houses which differed in one feature from "their house"; for example, one house was missing the door, another a window, in another there were three windows rather than the two found in "their house", and the last one had door and windows which had different shapes from "their house". The children had to decide whether the house picture projected was the same as or different from "my house". For the five older subjects 65% of the judgements were correct whereas for the eight younger subjects only 19% of their judgements were correct. Further analysis revealed that, especially for the younger children, houses which resembled the original model in all but one feature were judged to be the same as it. In a second exposure to the set of pictures, the older children's performance jumped to 85% correct, and the younger subjects to 33% correct. Again, younger children tended not to notice the single altered feature when the search was on the basis of memory. In the original viewing of the model, four of the five older children focussed upon all four of the features that were critical whereas only one of the eight younger children examined the model sufficiently to hit on these features. The pattern of search also differed between the two groups, older children conducted longer searches than younger subjects, as if they were aware of some discrepancy but did not know what it was. Olson concluded that the less effective visual search patterns exhibited by the younger children were the result of a failure of these subjects to know what to look for and to utilize information appropriately once they thought they did know. This conclusion corresponds to that of Vurpillot (1968) who found that children under age six never took into account the whole of a stimulus, but limited their scanning to a small area of each house and made judgements after collecting a mere sample of the information available.

Nodine and Lang (1970) reached a similar conclusion in their comparison of eye movement patterns of non-readers (kindergarteners) and readers (third graders) performing a visual differentiating task involving matched and unmatched pairs of four-letter pseudo words. In a later study, Nodine and Steuerle (1973) attempted to determine which features of stimulus objects were utilized by different age levels for making discriminatory choices. Eye movements of kindergarten, first and third grade subjects were examined during differentiation of matched and unmatched letter pairs. Both first and third grade subjects required fewer fixations, less fixation time and fewer cross-comparisons per pair than did kindergarteners. In addition to less quantity, visual fixation patterns of first and third graders were more attuned qualitatively to informative features of letters than kindergarteners. That is, older subjects showed considerably tighter scanning patterns and had fewer random fixations. From this study and a later one (Nodine and Simmons, 1974) the authors concluded that older subjects were able to call upon memory for identification and interpretation of visual inputs while younger subjects relied upon a purely perceptual strategy to extract and process information. A recent study by Whiteside (1974) also confirms that younger subjects (four year olds) scan the entire stimulus display, not necessarily focussing upon appropriate parts of it, while college students not only confine their saccades to a smaller area but also focus upon appropriate parts of the stimuli. These studies indicate that, in children from age four through to age nine, there are large differences in eye movement patterns for a variety of perceptual tasks.

Saccadic Eye Movements during Discrimination Learning

In developmental research, the role of eye movements in discrimination learning was first investigated by White and Plum (1964). In this study, the authors recorded eye movements of nursery school children as they attempted a series of eight discrimination problems. Half of the children were given a "hard" problem (a set of eight pairs of figures, each pair differing in only one configural detail) and half an "easy" problem (a set of eight pairs of pictures of birds). In each problem the children had to learn which one of the pair was correct. Results of the two experiments suggested that saccades increase in number as the child approaches the criterion performance level and then the mean number of saccades per trial decreases. These results, the authors suggest, indicate a relationship between amount of stimulus scanning and efficiency of discrimination learning.

Schroeder (1969, a, b), using a discrete trail discrimination task, found that undergraduate student subjects ordered their fixation frequencies of stimulus components in consistent patterns, looking most often at a stimulus which had previously been associated with reward and less at other stimuli. In his experiments, four stimuli were simultaneously projected on each trial, one stimulus in each corner of a screen, and fixations to each of these stimuli were recorded. Task variables investigated included number of reinforced (S+) and nonreinforced (S-) stimuli in the display and practise effects. Schroeder found that subjects fixated one positive stimulus to the exclusion of other stimuli, regardless of whether there were one or two S+ stimuli, and frequency of fixations of all stimuli decreased over a 20 trial block. He also found that the majority of his students (21 of 25) fixated more on a form cue in preference to a line orientation cue.

In a follow-up study, Schroeder (1970) reversed these configurational preferences and increased total fixation frequency but his subjects still showed a decreasing number of fixations over trials, scanning the screen fully only on the first few trials and then gradually decreasing their fixations of the stimuli until final responses were made without removing their gaze from the centre of the stimulus display. Schroeder suggested that motivation for exploratory perceptual behaviour arises from lack of information. Lack of information leads to uncertainty and conflict, which results in exploratory responses that intensify stimulation from the environment. Thus subjects fixated upon all four stimuli early in experimental sessions but soon fixated only upon the stimulus they had been reinforced for choosing. Successive reinforcements reduced the uncertainty regarding which stimulus was going to be reinforced. With reduction in uncertainty came loss of interest in the stimulus display. This tendency to look at the reinforced stimulus more often than nonreinforced stimuli has also been noted by Oscar-Berman and Bakoplus-Banos (1971) who found that both six year old children and adults looked at the positive stimulus more often than at the negative one in a two-choice pattern discrimination task.

In attempting to relate eye movement behaviour during discrimination learning to cognitive processes, White and Plum (1964) suggest that, as children solve a set of similar problems, they develop a mental picture of the problem, or a set, which enables them to solve the problem more quickly and reduces the need to scan the stimuli. They found that their subjects decreased stimulus scanning as they worked through a series of eight problems.

Nakano (1971) asked whether or not higher mental processes could be reflected in eye movements. In his study, sixth grade children were shown two sets of pictorial stimuli in either a non-problem solving (C1) or problem solving (C2) situation. In C1, subjects were told just to look at the pictures for 10 sec while in C2 they were asked to pick out the odd object among the five objects displayed. In comparing the first 2.5 sec with the last 2.5 sec of the 10 sec each subject was allowed to view the stimuli, Nakano found that in C1 the number of fixations gradually decreased over time. In C2 the number of fixations was greater than C1 during the first 2.5 sec but decreased again to the same number as C1 during the last 2.5 sec of viewing following problem solution. Nakano concluded that the increase and decrease in number of saccades was related to the difficulty of the problem and to each subject's ability to solve it. In a second experiment, the same tasks were given to undergraduates. Nakano found that they took longer to view the stimuli and generally made more fixations than the younger children. These studies provide some evidence for a link between saccades and cognitive processes.

Hypothesis Theories of Discrimination Learning

During the past decade, hypothesis theory has emerged as a leading theory of concept formation and discrimination learning in humans (for example: Levine, 1963, 1966). According to this theory, at the outset of a discrimination learning problem the subject selects a hypothesis from the pool of possible solutions to the problem. He then responds according to his hypothesis. For example, a subject may hypothesize that the red cue is correct in a stimulus array that has three binary dimensions - colour, (red vs blue) size (large vs small) and shape (circle vs square) and he would always pick the red cue. Other assumptions of the theory concern the effects of feedback. If the subject is informed that his response is correct, he retains his hypothesis and responds in accordance with it on the next trial, whereas, if he is informed that his response is incorrect, he abandons his hypothesis and is generally assumed to adopt a new one. The subject adopts and abandons hypotheses until he selects one that always results in positive feedback.

Gholson, Levine and Phillips (1972) identified several systems by which adults and children solve discrimination learning tasks. These systems fall into two general classes; Strategies, which, in principle, allow the subject to discover the solution to the problem, and Stereotypes, which produce the persistent repetition of a hypothesis despite its disconfirmation. Subjects using Stereotypes typically manifest one of three systems in their cue choices; a cue may be chosen on the basis of some feature the subject "likes" such as colour (stimulus preference), on the basis of its position relative to other cues (position preference), or the choice may alternate from one section of the stimulus array to another (position alternation). Strategies may also be divided into three classes; (a) focussing, in which the subject eliminates from his pool of hypotheses all those which could no longer be logically tenable, given the feedback received on all previous trials; (b) dimension checking, in which the subject proceeds one dimension at a time, systematically checking all possible hypotheses and discarding those proven incorrect until the solution is found; (For example, a subject may hypothesize that the colour red is correct, then if red is part of the stimulus array on trial one the subject would presumably say the stimulus is correct. If, on the next trial, blue is projected the subject would say that the stimulus is incorrect. If he was informed that the stimulus was correct on trial two, he would infer that the colour dimension was irrelevant and would select a new dimension) (c) hypothesis checking, in which the subject chooses one hypothesis (e.g.red) and if it is disconfirmed proceeds to a new hypothesis (e.g. blue) and continues selecting a new hypothesis until he arrives at one which always receives positive feedback. Gholson et al., (1972) found that the frequency of use of the different types of problem solving systems varied with the age of the subject. Kindergarteners almost always used Stereotypes, while subjects from grades two upwards virtually always used Strategies, with grade two subjects manifesting mainly hypothesis and dimension checking systems while college students almost always used a focussing system. This finding supported those of other researchers (for example, Eimas, 1969; Ingalls and Dickerson, 1969) who had found that subjects from grades two through college used hypothesis systems when solving discrimination problems.

Problem

Little attention has been given to exploring the relationship between eye fixations and the cognitive activities described by hypothesis theories of discrimination learning. If it is assumed that eye fixations are related to information processing as described by hypothesis theory it might be expected that when the subject is sampling a new hypothesis following negative feedback he scans all the cues to recall which hypotheses are present in the pool of solutions. On the other hand, following positive feedback, the subject needs only to identify which value of his working hypothesis is present on the trial. This analysis would predict that, before their response on trial n, subjects would fixate the stimulus display for a longer time and the number of fixations would be greater if they had received negative feedback following their response on trial n-1 than if they had received positive feedback on trial n-1.

Some evidence in support of this prediction has been obtained by Whiteley and Holden (Note 1) who found that children from grades two and five had longer observing times following negative feedback than following positive feedback in a pseudo concept formation task. In this study, subjects looked into one of two boxes, each of which contained a stimulus card which varied along three dimensions: form (circle, square), colour (red, blue) and size (large, small).. In order to view the stimulus card the subject pressed his forehead against a panel directly above a viewing aperture.

This response turned on a light inside the box allowing the subject to view the stimulus card and simultaneously activated a clock for the duration of the response.

The purpose of the present study was to investigate the effects of positive and negative feedback on eye movement behaviour. The data obtained by Whiteley and Holden (Note 1) suggests that type of feedback controls looking behaviour and the use of an eye view monitor to measure fixations on the stimulus cues gave a more accurate measure of observing behaviour than was obtained in the earlier study. As in the Whiteley and Holden study each subject was given two nine-trial problems in which feedback was controlled by the experimenter and not by the subject's choice responses. The feedback was sequenced such that four trials followed negative feedback on the preceding trial and four trials followed positive feedback. Ten year old boys and adult males provided the two age levels in the present study.

Two predictions were tested. Firstly, the number of fixations on the stimulus array following negative feedback was expected to be greater than following positive feedback for both age levels. Secondly, it was predicted that the total fixation time to the stimulus display following negative feedback would be greater than following positive feedback for both age levels. It was necessary to analyze the mean duration of fixations (total fixation time/ number of fixations) in order to investigate whether or not the duration data merely reflected more fixations following negative feedback as compared with longer average fixations following negative feedback. A further analysis of the number of times each area of the display was fixated by each subject was carried out to explore possible differences in scanning activity between the two groups. Owing to the relatively advanced age of the children used in the study, it was not expected that there would be age differences in eye fixations between the groups.

CHAPTER II

METHOD

Subjects

Subjects were 14 boys, mean age 10.75 years (sd 1.2 months, range 9.08 to 12.50 years) and 14 adult males, mean age 20.42 years (sd 2.92 months, range 17.75 to 26.75 years). The boys were volunteers from a local public school who were recruited by a letter (Appendix A) sent to their parents through the school. The adults were undergraduates enrolled in an introductory psychology course who participated as part of a course requirement. Approximately 50 subjects were lost owing to various procedural and technical difficulties. Males were chosen as subjects in order to eliminate a technical difficulty encountered when adult females were tested on the apparatus.

Apparatus and Stimuli

The stimulus display consisted of a circular picture divided into three sections. Each section was assigned a different binary dimension: the bottom section contained a colour cue - red versus blue; the top left section a size cue - large versus small circle and the top right section a line cue - horizontal versus vertical line. Combining the six cues with one another resulted in eight stimulus displays shown in Figure 1. Separating each stimulus picture during data collection was a centering slide, which was simply a stimulus picture missing its three cues. Each set of stimulus and centering pictures was loaded into a Kodak Carousel slide tray and projected onto a screen located approximately five metres in front of a Kodak model 850H slide projector. The diameter of the projected stimulus picture was 30 cm.

The subject's response panel was made out of an aluminum chassis 28 x 23 x 5 cm. Two subject response buttons were located on the top face of the panel so that the left button could be operated by the left hand and the right button by the right hand. The left button was marked "correct" and the right button was marked "incorrect" in letters approximately 1 cm high. Located in the side facing the subject was a Sonalert model number 110 alarm. The response panel was wired so that a response on either button would produce a "beep" from the alarm or silence (feedback was determined by the experimenter). The subject was able to depress only one button at a time and could make just one response per stimulus picture. This response advanced the slide projector to the centering slide used during the intertrial interval.

Both the subject's response panel and the slide projector were wired into the experimenter's control panel.

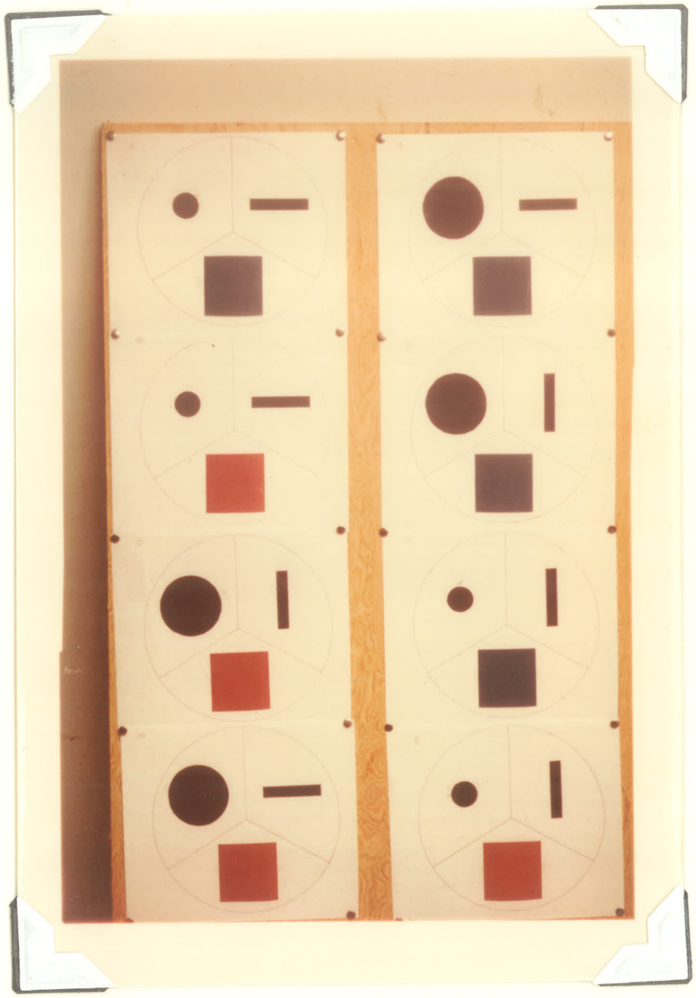

Figure 1. Stimulus Pictures used in Experiment.

This allowed the experimenter to: (a) determine the type of feedback given after each trial; (b) manually change slides to start each experimental session; and (c) control the length of the intertrial interval by means of a Hunter timer which was also wired into the panel.

Eye movement data were recorded using a Whittaker model 1984 HM eye view monitor interfaced with a Kennedy 1100 nine channel digital tape recorder. This monitor utilizes infra red light reflected from a subject's pupil to follow changes in eye position.

Procedure

The subject was brought into the eye movement and pupillometric laboratory. He was asked to stand in front of a board upon which were mounted the eight stimulus pictures (Figure 1). Part one of the instructions were then read out:

> Hi! Will you just stand here, please, and look at these pictures (experimenter points to board). Now, I am going to give you four problems; in each problem you will see a series of pictures like these. Each problem has a "correct" solution and your job is to find the correct solution to each problem. For example, if this blue square is "correct"; then the red square will be "incorrect". If the small circle is "correct", then the large circle will be "incorrect". If this horizontal bar is "correct"; then the vertical bar will be "incorrect". And vice versa - if red is "correct", then blue will be "incorrect"; if large is "correct", then small will be "incorrect"; if vertical is "correct", then horizontal will be "incorrect". Okay? (Experimenter pointed to each

> shape as he spoke.) So, to recap.; you will have four problems; each problem will have a series of pictures like these and your job will be to try and find the correct solution to each problem and so solve the problem. Now would you go and sit over there (experimenter points to eye view monitor chair). To start, just take a guess - tell me if you think the picture is correct or incorrect and I will tell you if you are right or wrong.

Training Problems. After the subject was seated the first of two, 15 trial, training problems was given. To start a training problem the first of a series of 15 slides was projected onto the screen. The order of presentation of slides was obtained by assigning the numerals one through four to the stimulus pictures on the left side of Figure 1, top to bottom, and the numerals five through eight to the pictures on the right side of Figure 1, top to bottom, and randomly selecting one number at a time without replacement. The order of selection determined the order of presentation of the first eight slides while slide number nine was a repetition of the first slide projected. The remaining six slides were picked following a similar procedure. The order of presentation of slides was constant for all subjects (Problem One-8, 2, 5, 6, 4, 7, 3, 1, 8, 1, 5, 2, 6, 3, 4; Problem Two-1, 3, 5, 6, 7, 8, 2, 4, 1, 8, 2, 7, 4, 6, 5). Unlike the pseudo-problems used in data collection, these two problems had a solution (in problem one "red square", in problem two "vertical line"). Stimulus slides were projected onto a screen situated five metres in front of the subject. The subject was asked to try to solve the problem and to make a verbal response (either "correct" or "incorrect") after viewing each picture. Feedback was given verbally by the experimenter following each response (either "right" or "wrong"). After nine trials the subject was asked the correct solution to the problem, if he did not know it he was told the solution and was asked to give the correct response for the remaining six trials. The same procedure was used for the second training problem.

Pseudo-Problems. Following the two training problems, the subject was handed the subject response panel and its operation was explained to him:

> Okay - that is the first two problems. We are now going to do two more but this time your chin will be resting upon this bar here (experimenter points to chin rest of eye view monitor). I am going to change the slides, just putting them in a different order, but before I do, I want to show you this box (experimenter picks up subject response panel). This machine requires that you keep your head as still as you possibly can, which means that you cannot talk. So, instead of you telling me "correct" or "incorrect" I want you to use these two buttons (experimenter indicates buttons on panel). If you think the picture on the screen is correct, I want you to press this button here (experimenter points to left hand button). If you are right, you will hear a "beep" here (experimenter points to Sonalert buzzer) and you will win a dime. If you think the picture on the screen is incorrect, I want you to press this button here (experimenter points to the right hand button). Again, if you are right, you will hear a beep and will win a dime. Both times, if you are wrong you will hear nothing, and will win nothing. Now, let us go over that

> again (experimenter repeats instructions for response panel). I am going to change these slides, while I am doing this you make sure you know which button is which (experimenter hands response panel to subject).

While the subject was familiarizing himself with the panel, the experimenter changed the order of slides in readiness for the two pseudo-problems used during data collection. Part three of the instructions was then read:

> Okay, there are two more things and we can begin. I am now going to line your eyes up with these dots (experimenter indicates dots on centering slide projected on the screen). You will be putting your head on the bar and I want you to keep it as still as you can and please do not talk. That is the first thing. The second thing is that in between each problem picture (experimenter points to panel of stimulus pictures (Figure 1))you will see a slide like this one (experimenter points to centering slide). When you see this slide (centering) you are just to look at the centre of it and press no buttons - you only press buttons when you see your problem pictures. Do you understand?
>
> Do you have any questions?

The eye view monitor was swung in front of the subject and adjusted so that his chin was resting comfortably upon the chin rest. In addition to the above instructions, the following questions were asked of child subjects:

> What do you do when you see the blank picture?
>
> What do you do when you see the problem picture?
>
> If you think it is a "correct" picture, which button do you press?
>
> If you think it is an "incorrect" picture, which button do you press?
>
> What happens if you are right?

What happens if you are wrong?

What do you do with your head when it is resting on the bar?

The first of two, nine-trial, pseudo-problems was then presented. Unlike the training problems, these problems were not solvable by the subject. Rather, feedback following every response was controlled by the experimenter such that, in both blocks of trials, 2-5 and 6-9, two trials followed positive feedback and two trials followed negative feedback. Schedules of trials with these characteristics were devised by Ogilvie, Surridge and Amsel (1969) and these schedules (see Table 1) were used in this experiment.

TABLE 1

SEQUENCES OF R AND NR TRIALS

	Trials	Sequences							
	1	R	R	N	R	N	N	R	N
Trial Block 1	2	R	N	R	R	N	R	N	N
	3	N	N	R	N	R	R	N	R
	4	N	R	N	N	R	N	R	R
	5	R	N	N	N	N	R	R	R
	6	N	N	N	R	R	R	R	N
Trial Block 2	7	N	R	R	R	R	N	N	N
	8	R	R	R	N	N	N	N	R
	9	R	R	R	R	R	R	R	R

Each of the eight stimulus pictures was arbitrarily assigned the numerals one through eight. Using these numerals, a computer generated 120 sets of random numbers nine digits long. One of these sets was assigned to each of the two experimental problems for each subject and slides were projected in the order indicated by the set assigned.

Assignment of sequences of reward and nonreward to each problem followed a similar procedure: each of the sequences devised by Ogilvie, Surridge and Amsel (1969) (Table 1) were arbitrarily assigned numerals one through eight. A random sequence utilizing these digits was computer generated and each problem was assigned a number from this list. This number determined which schedule of rewarded and nonrewarded trials was assigned to each experimental problem. A sample assignment of pictures and type of feedback appears in Table 2.

The subjects' eyes were calibrated with the eye view monitor and data collection began with the experimenter switching on the tape recorder and manually changing the slide projector until the first stimulus picture was projected. The subject inspected the picture for as long as he liked and made his choice by depressing one of the buttons on his response panel. This response changed the slide to a blank centering picture and gave feedback (a

TABLE 2

SAMPLE RUN OF STIMULI USED DURING DATA COLLECTION

	Trial Number	Stimulus Picture Number	Description of Cues			Type of Feedback Given
			Bottom	Left	Right	
PROBLEM ONE	1	2	red	small circle	horizontal bar	R
	2	5	blue	large circle	horizontal bar	R
	3	6	blue	large circle	vertical bar	N
	4	7	blue	small circle	vertical bar	N
	5	4	red	large circle	horizontal bar	R
	6	2	red	small circle	horizontal bar	N
	7	6	blue	large circle	vertical bar	N
	8	7	blue	small circle	vertical bar	R
	9	3	red	large circle	vertical bar	R
PROBLEM TWO	1	3	red	large circle	vertical bar	N
	2	8	red	small circle	vertical bar	N
	3	4	red	large circle	horizontal bar	R
	4	1	blue	small circle	horizontal bar	R
	5	4	red	large cirlce	horizontal bar	R
	6	6	blue	large circle	vertical bar	N
	7	5	blue	large circle	horizontal bar	N
	8	1	blue	small circle	horizontal bar	R
	9	7	blue	small circle	vertical bar	R

short beep) if the trial was a rewarded one. If the trial was rewarded a dime was dropped into a box within hearing range of the subject. Then followed a 10 sec intertrial interval in which the subject was instructed to look at the centre of the centering picture. Following this interval, the next stimulus picture was projected. This procedure was followed until nine trials had been completed, then a blank appeared on the screen. At this time, the subject was told that the first problem was over and that a new problem with a new solution was about to start. He was asked to "try and solve this problem, too". In both training and experimental problems, the subject was allowed as much time as he needed to make a response. Minor adjustments of the eye view monitor, to ensure that the subject stayed within range of the machine, were made by the experimenter throughout data collection. Also, occasionally, a subjects' head was physically reoriented to ensure he stayed within range. Data collection terminated with the subject making his response to the final slide of experimental problem two. The experimental session lasted approximately 20 minutes.

CHAPTER III

RESULTS

Eye-Fixation Data

Output from the eye view monitor was recorded on a nine track digital tape recorder at the rate of 60 measurements per second. Data were taken from each subject for at least five minutes; therefore each subject generated at least 18 thousand lines of computer printout. This information was broken down as follows:

Each subject generated a "file" on the tape. A "scrap file" was artifically introduced between each subject file in order to separate them. A computer programme was written which identified each file and deleted scrap ones (Programme one in Appendix B).

A subject file consisted of several thousand lines of data. A programme (Programme two in Appendix B) was written which divided these data into lines generated by the subject viewing individual slides being projected at any given time. The programme printed out slide numbers and number of lines associated with each slide number. Each centering slide was projected for 10 sec, so the printout for these slides was a constant 600 (± 5) lines. By identifying the sequences of centering slides it was a relatively easy task to identify slides of problem pictures.

Printout from programme two was transferred onto computer cards. The numeral "0" prefixed scrap data (from centering slides etc.) the number "1" usable data. A programme (programme 3 in Appendix B) was written which separated and discarded "0" output and divided "1" output into fixations. Using a stationary artificial pupil, data were obtained by "fixating" this pupil upon the five location points of the centering slide. That is, the practise pupil was treated as if it were a human eye and the eye view monitor was set up exactly as if it were focussing upon a human pupil. Once the necessary adjustments had been made two cross hairs appeared upon the television monitor which indicated eye position. These cross hairs were adjusted until the practise pupil was "looking" at the centre of the centering slide. Data were then taken for 10 sec. This procedure was followed until all five points of the centering slide had been "fixated" for 10 sec. It was found that the mean variation in output using this pupil was 6.6 units on the horizontal axis and 6.4 units on the vertical axis. Therefore, one criterion for a fixation was that output had to be constant on both axes ± 3.5 units. According to previous studies (Gould and Schaffer, 1967; Yarbus, 1967; Gould and Dill, 1969; Mackworth and Bruner, 1970; and Luria and Strauss, 1975) eye fixation durations averaged .35 sec, with the lowest fixation duration being .17 sec (Luria and

Strauss, 1975). A time of .20 sec was decided upon as the minimum duration criterion for a fixation; hence, before a subjects' eye movement was scored as a fixation, the output from the fixation programme had to have a sequence of at least 12 lines which did not vary more than ± 3.5 from one another on both horizontal and vertical axes. This programme printed out horizontal and vertical indices of data satisfying these requirements and the number of lines of printout associated with each fixation.

Number of Fixations. The number of fixations was computed by counting the number of fixations made by each subject, according to the above criteria for a fixation. The number of fixations made on trial one of each problem was ignored since this trial did not follow a reward or nonreward. Thus, eight trials in each problem were available for analysis. The schedules of rewarded and nonrewarded trials used resulted in four trials following reward and four trials following nonreward in each problem. The mean number of fixations was obtained for each type of trial (following reward and following nonreward) for each problem. This mean number of fixations was entered into an analysis of variance with age (adults versus children) as the between groups factor and type of trial (rewarded versus nonrewarded) and problem (one versus two) as the within groups factors. Table 3 gives a summary of this analysis. As can be seen,

TABLE 3

ANALYSIS OF VARIANCE OF MEAN NUMBER OF FIXATIONS

SOURCE	SS	df	MS	F
Age	1.627	1	1.627	.28
Error	151.383	26	5.822	
Problem	.524	1	.524	.24
Error	56.648	26	2.178	
Feedback	18.761	1	18.761	11.33*
Error	43.047	26	1.655	
Age x Problem	.319	1	.319	.15
Age x Feedback	4.119	1	4.119	2.49
Problem x Feedback	.000	1	.000	.00
Age x Problem x Feedback	.080	1	.080	.09
Error	24.493	26	.903	

* $p < .001$

there were no significant differences in the number of fixations made by the two groups. Also, there were no significant differences in fixations made on problem one in comparison to problem two. The type of feedback received on the previous trial was, however, highly significant, $\underline{F}$ (1, 26) = 11.33, $\underline{p} < .001$. Both adults and children made more fixations following nonreward than following reward. An average of 3.19 fixations occurred following reward compared to an average of 4.01 fixations following non-reward.

Total Duration of Fixations. Programme 3 printed out not only horizontal and vertical indices of each fixation but also the number of lines of printout associated with that fixation. The eye view monitor scans the pupil 60 times per second, so each line of printout represented one sixtieth of a second of fixation time. In order to calculate fixation time for each subject, each problem was blocked into the four rewarded and four nonrewarded trials of interest. Then the number of lines of printout for each of these four blocks (two in each problem) was summed and divided by four. This gave the mean total time of fixation of each subject following rewarded and nonrewarded trials for each problem. These data were entered into an analysis of variance with age (adults versus children) as the between subjects factor and type of trial (rewarded versus nonrewarded) and problem (one versus two) as the within subjects factors. Table 4 summarizes these results. There were no significant differences in duration of fixations between problems or between age groups. Feedback was important in determining how long the subjects fixated upon the stimuli ($\underline{F}$ (1, 26) = 19.55, $\underline{p} < .001$) with longer fixation times being recorded following nonreward than following reward for both groups - mean times were 1.56 sec following reward and 2.00 sec following nonreward.

Mean Duration of Fixations. The mean duration of fixations was calculated by dividing the mean total fixation times by the mean number of fixations made by each subject following either rewarded or nonrewarded trials in both problems. This gave four mean times for each subject - following reward in both problems and following nonreward in both problems. The children's individual times were added together to give a mean duration of fixations in each of the four categories for the children as a whole. Adults' times were similarly calculated. These mean durations were entered into an analysis of variance with age (adults versus children) as the between subjects factor and type of trial (rewarded versus nonrewarded) and problem (one versus two) as the within subjects factors (Table 5). It can be seen that there was a significant interaction between age and type of feedback given. Actual times are reported in

TABLE 4

ANALYSIS OF VARIANCE OF DURATION OF FIXATIONS

SOURCE	SS	df	MS	F
Age	3.472	1	3.472	3.23
Error	27.161	26	1.045	
Problem	.046	1	.046	.11
Error	11.191	26	.430	
Feedback	5.377	1	5.377	19.55*
Error	7.151	26	.275	
Age x Problem	.000	1	.000	0.0
Age x Feedback	.549	1	.549	1.99
Problem x Feedback	.000	1	.000	.00
Age x Problem x Feedback	.450	1	.450	2.56
Error	4.578	26	.176	

* $p < .001$

TABLE 5

ANALYSIS OF VARIANCE OF MEAN DURATION OF FIXATIONS

SOURCE	SS	df	MS	F
Age	.421	1	.421	2.26
Error	4.840	26	.186	
Problem	.088	1	.088	2.99
Error	.768	26	.029	
Feedback	.003	1	.003	.22
Error	.343	26	.013	
Age x Problem	.031	1	.031	1.05
Age x Feedback	.085	1	.085	6.43*
Problem x Feedback	.042	1	.042	2.73
Age x Problem x Feedback	.054	1	.054	3.49
Error	.404	26	.015	

* $p < .05$

Table 6. A simple effects of differences test (Kirk, 1968) was performed upon these data. As shown in Table 7, there was a significant difference between groups at level one (rewarded) but none at level two (nonrewarded). A within groups comparison was then made using these same data. Table 8 shows that there were significant differences in adult performance following rewarded when compared with nonrewarded trials (.63 sec following reward compared to .57 sec following nonreward) but there were no such differences in children's behaviour. Intercorrelations amongst total number of fixations, total duration of fixations and average duration of fixations for adults and children can be found in Tables 18, 19 and 20 in Appendix D.

Subsidiary Analyses

Location of Fixations. One of the criteria for starting an experimental session was that the cross hairs indicating eye position of the subject on the eye movement television monitor were relatively stable around the centre point of the centring slide. In addition, each subject was asked to keep looking at the centre of the centring slide prior to the start of the experiment. It was assumed that the printout associated with this time would accurately represent the centre of the stimulus slide. The means of the last ten lines of these data were computed for both

TABLE 6

MEAN DURATION OF FIXATIONS IN SECONDS FOLLOWING REWARDED AND NONREWARDED TRIALS

	Rewarded	Nonrewarded
ADULTS	.632	.569
CHILDREN	.457	.502

TABLE 7

BETWEEN GROUPS DIFFERENCES FOLLOWING REWARDED AND NONREWARDED TRIALS

Source	SS	df	MS	F
Rewarded	.443	1	.443	4.43*
Nonrewarded	.061	1	.061	.61
Error	5.200	52	.100	

* $p < .05$

TABLE 8

COMPARISON OF WITHIN GROUPS DIFFERENCES FOLLOWING REWARDED AND NONREWARDED TRIALS

Source	SS	df	MS	F
Adults	.060	1	.060	4.62*
Error	.338	26	.013	
Children	.030	1	.030	2.30
Error	.338	26	.013	

* $p < .05$

horizontal and vertical axes and these means were taken as horizontal and vertical indices of the centering slide for that particular subject. It was found that the distance, in digital output units, left to right across the centering slide was approximately 18 units and, from top to bottom, approximately 36 units. Using these indices it was possible to construct a matrix of horizontal and vertical lines the intersection of which corresponded to horizontal and vertical indices for any fixation upon the stimulus pictures. By superimposing the matrix upon a picture of the stimulus slides it was possible to plot the location of each subject's fixations. The means for the centre of the stimulus pictures for an individual subject were used as the centre of the matrix and the location of each fixation relative to this centre was plotted. Because of inexperience with eye movement location technique, "noise" within the system, and the difficulty of trying to precisely locate fixations upon what turned out to be a very small target area it was decided to identify each fixation only within one of the three sections of the stimulus pictures. A further category "not on matrix", was added when it became apparent that subject's eye fixations were being recorded by the apparatus even though they were not aimed directly towards the stimulus display (Figure 2 illustrates this procedure).

The number of fixations recorded in each of the

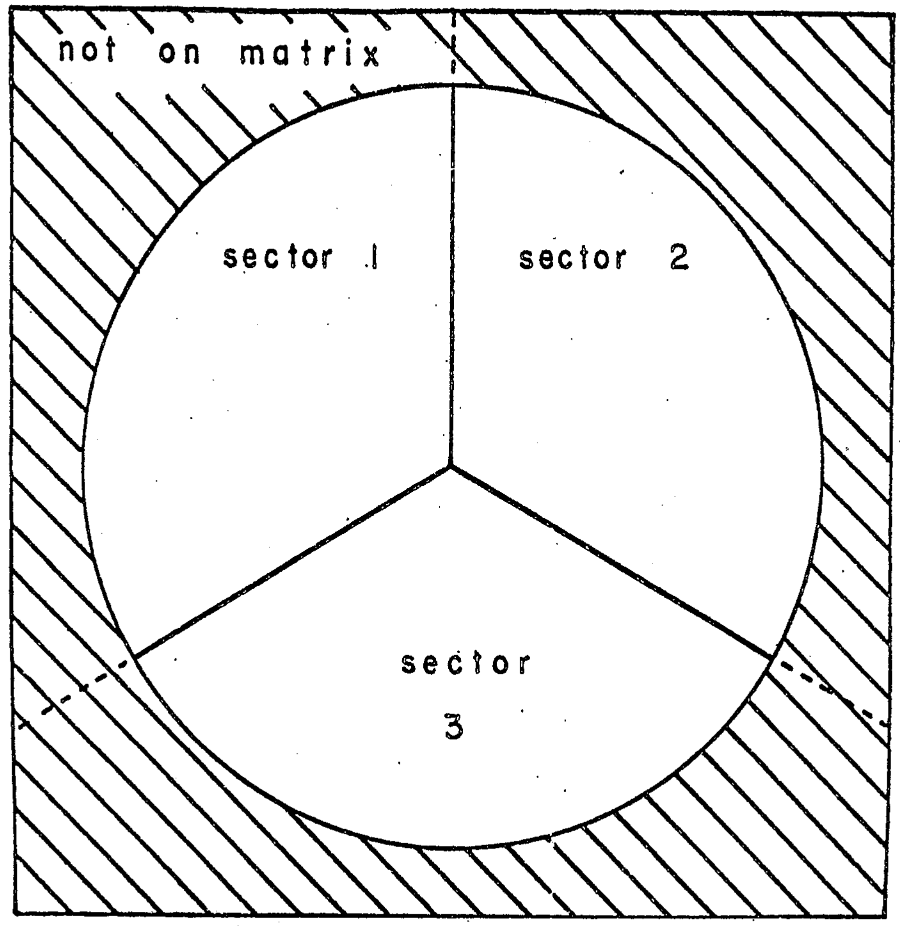

Figure 2. Location of Sectors used in Data Collection

four sectors was treated to an analysis of variance, with age (adults versus children) as the between subjects variable and sector (one, two, three or not on matrix) and problem (one versus two) as within subjects variables. As Table 9 reveals, there were significant differences in the number of fixations made to the different sectors, an age by sector interaction and an age by sector by problem interaction. The means involved in the three way interaction are shown in Table 10. Post hoc pair-wise comparisons of these means were made using Tukey's Honestly Significant Difference (HSD) procedure (Kirk, 1968). Comparisons between adults and children within each sector for each problem indicated that children looked fewer times at sector one than adults in problem two - none of the other comparisons was significant (HSD value = 8.58). Comparisons of the number of fixations between problem one and problem two for each sector indicated that there were no significant differences between problems for children or adults (HSD value = 8.54). Comparisons of sectors within each problem indicated no significant differences between sectors for children. Adults made more fixations in sector two (line orientation) than off matrix in problem one. In problem two, adults made more fixations to sector one (size) than to sector three (colour) and off matrix (HSD value = 8.54).

TABLE 9

NUMBER OF FIXATIONS PER SECTOR COMPARING PSEUDO PROBLEM ONE WITH PSEUDO PROBLEM TWO

SOURCE	SS	df	MS	F
Age	27.859	1	27.859	.60
Error	1197.253	26	46.048	
Problem	4.290	1	4.290	.28
Error	397.220	26	15.278	
Sector	1348.320	3	449.440	6.44**
Error	5440.691	78	69.752	
Age x Problem	.111	1	.111	.01
Age x Sector	584.828	3	194.943	2.79*
Problem x Sector	99.406	3	33.135	1.23
Age x Problem x Sector	354.867	3	118.289	4.39*
Error	2101.591	78	26.943	

* $p < .05$

** $p < .001$

TABLE 10

MEAN NUMBER OF FIXATIONS PER SECTOR FOR EACH PSEUDO PROBLEM

	Sector	Cue	Adults	Children
PROBLEM ONE	1	size	8.714	8.571
	2	line orientation	10.500	8.928
	3	colour	7.071	3.071
	4	not on matrix	1.214	4.286
PROBLEM TWO	1	size	14.071	5.143
	2	line orientation	7.786	9.214
	3	colour	4.714	3.928
	4	not on matrix	2.214	7.500

Training Problems

Each subject was given two training problems in order to familiarize him with the task presented during eye-monitoring. Figure 3 shows the performance of each group on the two training problems. As can be seen from the figure, there was a marked improvement in performance from problem one to problem two by each age group. Using a criterion of problem solution of correct performance on trials 6 to 9, two adults and two children solved the first problem and 12 adults and 10 children solved the second problem. The age group differences are not statistically significant.

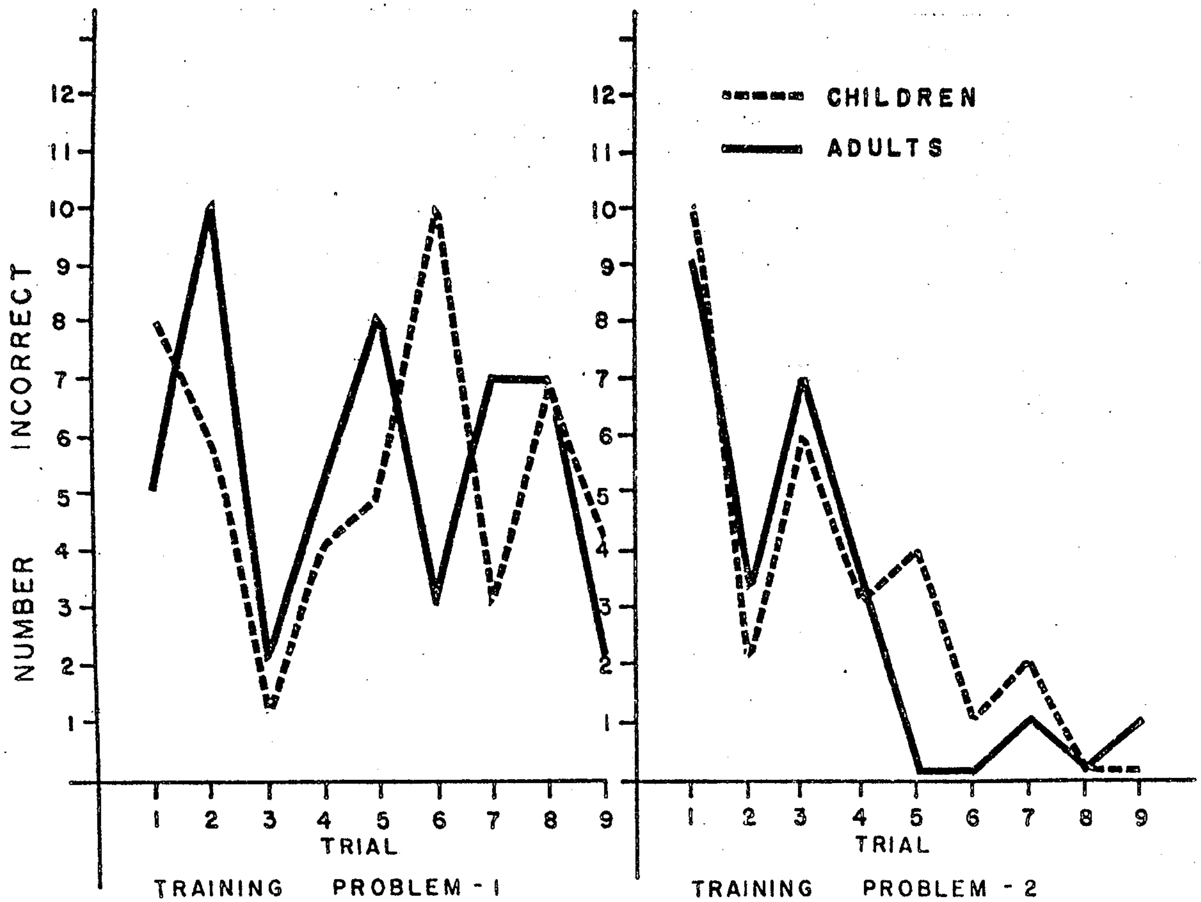

Figure 3. Performance of Groups on Training Problems

CHAPTER IV

DISCUSSION

The fact that the two age groups performed equally well on the pretaining problems indicates that the problems were about equally difficult for the two groups. This finding is not unexpected. In Piagetian terms (Ginsberg and Opper, 1969, p. 164) the children would be considered to be in the later stages of the concrete operational period and, consequently, could be expected to have a similar capacity to solve this type of problem as adults. Results obtained from other researchers (for example: Eimas, 1969; Ingalls and Dickerson, 1969; Gholson, Levine and Phillips, 1972) also support this finding. They found that subjects beyond age six virtually always used hypothesis systems in order to solve simple concept formation problems similar to those used in this study. That most subjects were able to solve training problem two suggests that, at the beginning of the experimental problems, these subjects were familiar with the type of solution required. There was no evidence that the number and duration of eye fixations changed from the first to the second pseudo problem, so it may be assumed that subjects' exposure to the first insoluble pseudo problem did not influence their attention to the second pseudo problem.

It was expected that, if subjects were using hypothesis sampling strategies to solve the problems, the number of fixations to the stimulus array following nonrewarded trials would be greater than the number of fixations following rewarded trials. The total duration of these fixations following nonrewarded trials was also expected to be greater than following rewarded trials. Prediction one was confirmed - there were significant differences in the number of fixations made by the subjects, with both children and adults making more fixations following nonrewarded trials as compared with rewarded trials. Similarly, prediction two was supported by the data, as both groups had significantly longer total fixation times following nonrewarded than following rewarded trials. Analysis of the average duration of fixations indicated that children's average durations were unaffected by feedback and that adult's average fixation times were longer following reward than following nonreward. This result indicates that the reward versus nonreward difference for total duration of fixations resulted from the larger number of fixations that occurred following nonrewarded as compared with rewarded trials.

Two possible explanations of subjects' eye movement behaviour present themselves. Subjects could have been looking at the cues following nonreward in order to aid in retrieving the possible hypotheses from memory and then sampling a new hypothesis without further attention to the stimuli before deciding to choose a new one and make a response. Presumably, following reward, the subject would simply identify the cue consistent with his hypothesis and make the appropriate response. In this situation, one would expect a greater number of fixations following nonreward than following reward but not longer average fixation times. On the other hand, following nonreward subjects could have been fixating upon a cue while deciding whether to use it as the next hypothesis. If this were the case one would expect longer average fixation times following nonreward than following reward because, following nonreward, the subject is not only identifying the cue but also trying to decide if he will sample it, while following reward he would presumably just identify the cue. The present data were consistent with the first alternative since number of fixations increased following nonreward whereas average duration of fixation did not.

The finding that adults had longer average duration of fixations following reward compared with nonreward suggests that they were applying different strategies to the task in comparison to the children. One explanation might be that adults were using more sophisticated strategies than the children, which utilized positive feedback. Both Eimas (1969) and Ingalls and Dickerson(1969) found that their college student subjects had more efficient strategies than children from grades two through ten. In addition, Levine (1966) found that his college student subjects rejected more incorrect hypotheses from their pools of hypotheses, and hence learned more effectively, following reward than following nonreward. Adults in the present study may have spent the time following reward in eliminating hypotheses no longer tenable because of this feedback. This cognitive activity might have resulted in adults having longer average fixations following reward if the decision about retaining a cue in the sample of hypotheses was made while fixating the cue.

Adults more reliably differentiated between the sectors of the stimulus picture and the off matrix sector than did the children. For adults, the number of fixations to sectors one and two in pseudo problem one and sector one in pseudo problem two were significantly different from those made to the off matrix sector whereas the children did not fixate reliably more often on any stimulus sector when compared with the off matrix sector. There was a significant difference between the groups in the number of fixations made to sector one in pseudo problem two, with adults concentrating over half of their total fixations for this pseudo problem on the sector that held the cue (size) previously unused in the training problems. The children made the largest number of fixations in both pseudo problems on the cue (line orientation) that had been used in the last training problem. This evidence suggests that adults were more likely than children to switch to a new cue as a result of failure to solve the first pseudo problem.

An extension of this study would be to investigate the problem solving systems adopted by the subjects. Gholson et al., (1972) found that subjects generally used one of two types of system, either Strategies or Stereotypes, in solving simple discrimination tasks similar to those used in this study. A Strategy is a system that allows a subject to systematically reject incorrect hypotheses, leading him ultimately to problem solution. On the other hand, a Stereotype system has the subject responding according to a set pattern (for example - the subject always picks the colour cue, or always picks the cue on the left) regardless of feedback received, and the solution to the problem may not be found. Typically, the type of system used depends upon the age of the subjects tested, with kindergarteners (in the Gholson et al., study) virtually always using Stereotypes and children from grade two upwards almost always using Strategies. It would be expected that the older the subject the more he would fixate upon the cue consistent with the hypothesis he is holding. For example, if he was using a Strategy, one would expect him to ignore cues of rejected hypotheses and focus upon cues still available as possible solutions to the problem. On the other hand, with children using Stereotypes, one would expect the eye fixation pattern to reflect the Stereotype being used. For example, a child consistently picking, say the colour red, would be expected to concentrate his fixations upon this cue, to the exclusion of other cues.

If, as the present study suggests, eye movements can reflect cognitive processes similar to those described by hypothesis sampling theory, then a further study using the blank trial technique developed by Levine (1966) testing children of differing age levels might throw some light upon systems being used by different age groups. This technique permits the experimenter to monitor the specific hypothesis the subject is using at any point in a discrimination learning task. Basically, Levine showed that if no feedback is given following the subject's choice response for a few consecutive trials (blank trials) the subject will respond according to a single hypothesis during those trials. One may construct a sequence of blank trials such that each hypothesis yields a unique response pattern. With such a sequence, the hypothesis a subject is using may be inferred. The subjects would be expected to fixate upon the cue consistent with the hypothesis they are holding. In this case, the fixation patterns would be expected to concentrate upon the "hypothesis" cue throughout the blank trial sequence. That is, the subject would fixate one cue until he received feedback regarding his choice of that cue.

A limitation of the eye view monitor is that it records eye movements only when the eye is actively engaged in searching the stimulus field within the correlates previously calibrated by the experimenter at the start of data collection. Fixations which fell outside of these correlations were either not recorded or had to be disregarded by the experimenter. A future experiment should have a stimulus picture sufficiently large that all eye movements made by a subject fall into the calibrated area. A larger target could be projected with a different kind of projector lens, and a zoom lens on the video camera recording the stimulus array would allow greater definition of the stimulus picture used.

Electronic interference (noise) within the system also presented problems in that it interferred with the transfer of data from the video camera to the tape used for data storage. For example, noise sometimes activated the slide counter without a slide change actually occurring. This made interpretation of output more difficult because programme 2 relied upon the slide count to identify data.

The system requires that a subject keep his head still for the duration of data collection. It was a strain for adults to remain still for longer than seven or eight minutes and almost an impossibility for children to do so. A head restraint, such as a bite bar, is necessary in further research with the eye monitor.

Finally, techniques for analyzing eye movement behaviour were being developed during the course of the experiment and had not reached the level of sophistication necessary to more precisely locate points of fixation or to record the track length of the eye as it examined the stimulus array. Development of computer programmes which refine analyzing techniques must continue at least until digital output is more clearly interpretable. Experimentation with analogue output might result in the integration of the two systems, with an increase in data interpretability. In addition, inclusion of a video system to visually record eye movements might serve as a backup to both systems.

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APPENDIX A

Letter of Permission sent to Parents of Possible Subjects

THE UNIVERSITY OF MANITOBA

DEPARTMENT OF PSYCHOLOGY

WINNIPEG, CANADA
R3T 2N2

October 20, 1975

Dear Parent:

Your superintendent and principal have granted permission for a psychological study to be carried out in cooperation with Dalhousie school.

Only children whose parents grant permission will participate.

In this study, children's eye-movements will be measured as they attempt to solve simple problems that involve learning to choose one of four geometric forms. Eye-movements are recorded by measuring the location of the pupil of the child's eye relative to a picture of the problem using television cameras. Since this research involves using equipment installed in a laboratory in the Duff Roblin Building at the University of Manitoba, it will be necessary to bring the child from home. The children will be transported by car to and from the laboratory. Mr. Roger Holden, a graduate student in psychology will be conducting the research. Since it may be necessary to test the children outside school hours, Mr. Holden will telephone parents who consent to allow their children to participate and arrange a convenient appointment time.

Each testing period will last about sixty minutes, not including transportation time. During the test session each child will receive a number of nickels; this incentive is an important part of the study and not a payment for participating although this money will be given to the child at the end of the test session and will amount to about one dollar.

The purpose of the study is to obtain information about the learning processes of children of different ages. Since we are not attempting to assess the individual abilities of the children, the performance record of individual children will be confidential.

Please indicate below whether or not you give permission for your child to participate in the study by signing on the appropriate line.

If you grant permission, please give your home telephone number so that we can arrange an appointment time.

Ask your child to return the letter to his teacher.

Thank you for your cooperation.

Sincerely,

John H. Whiteley, Ph.D.
Associate Professor
Ph: 489-7417

Name of Child ______________________________

Permission Granted (Parent's signature) ______________________________

Home telephone number ______________________________

Permission Refused (Parent's signature) ______________________________

APPENDIX B

Computer Programmes Used in Data Analysis

Use of Fixation Programmes. The first step in data analysis was to run programme 1 which transfers the data to a new tape in a format readable by a Fortran programme. The second step was to run programme 2, which requires as input the file created by programme 1. Programme 2 runs through the file and counts the number of records taken during successive slide presentations. The final step was to run programme 3, in conjunction with a set of cards and the file created in step one. The cards were manually punched by the experimenter from the output of programme 2. Each subject file contained data recorded during the series of problem slides used in data collection interspersed with centering slides which contained no analyzable information. Data cards were punched which allowed the computer to disregard output from centering slides and to pick out analyzable data from each subject file. Programme 3 ran through these records and checked for fixations. The computer languages used were: Programme 1 - P/L 1, Programme 2 - Fortran, Programme 3 - Fortran.

TABLE 11

PROGRAMME 1

```
IANITOBA COMPUTER CENTER ***          DATE= 6/09/76   TIME=11:31 AM

 PPMOVE: PROCEDURE OPTIONS(MAIN);
     DECLARE PD INPUT RECORD ENVIRONMENT (U(3584));
     DECLARE PPDISK OUTPUT RECORD ENVIRONMENT (VS(13022,13018));
     DECLARE 1 PPFILE,  2 SAMPLE(512),
               3 P1    BIT(1),
               3 P2    BIT(1),
               3 P3    BIT(4),
               3 P4    BIT(10),
               3 P5    BIT(8),
               3 P6    BIT(8),
               3 P7    BIT(8),
               3 P8    BIT(4),
               3 P9    BIT(4),
               3 P10   BIT(4),
               3 P11   BIT(4);
     DECLARE 1 OUTFILE,  2 TAMPLE(723),
               3 T1    FIXED BIN(15,0),
               3 T2    FIXED BIN(15,0),
               3 T3    FIXED BIN(15,0),
               3 T4    FIXED BIN(15,0),
               3 T5    FIXED BIN(15,0),
               3 T6    FIXED BIN(15,0),
               3 T7    FIXED BIN(15,0),
               3 T8    FIXED BIN(15,0),
               3 T9    FIXED BIN(15,0);
     OPEN FILE(PD) INPUT, FILE(PPDISK) OUTPUT;
     ON ENDFILE(PD) BEGIN;
                    DO J=N TO 724;
                    T1(J)=9999;
                    T2(J)=9999;
                    T3(J)=9999;
                    T4(J)=9999;
                    T5(J)=9999;
                    T6(J)=9999;
                    T7(J)=9999;
                    T8(J)=9999;
                    T9(J)=9999;
                    END;
                    WRITE FILE(PPDISK) FROM (OUTFILE);
```

TABLE 12

PROGRAMME 2

```
OF MANITOBA COMPUTER CENTER ***          DATE= 6/09/76  TI

          INTEGER*2 DATA(9,724)
          READ(3,END=99) ((DATA(I,J),I=1,9),J=2,724)
          DATA(3,1)=DATA(3,2)
          N=1
          NS=1
     10   NM=NS
          NS=NS+1
          IF(NS.LT.725) GO TO 30
          DATA(3,1) = DATA(3,724)
          READ(3,END=99) ((DATA(I,J),I=1,9),J=2,724)
          NM=1
          NS=2
     30   IF(DATA(3,NS).NE.DATA(3,NM)) GO TO 80
          N=N+1
          GO TO 10
     80   NT=NM-1
          IF(NT.EQ.0) NT=1
          WRITE(6,86) DATA(3,NM),N,DATA(9,NT)
     86   FORMAT(' ',3I12)
          N=1
          GO TO 10
     99   STOP
          END
```

Explanation of Printout from Programme 2 (see Table 13)

Slide count - each slide change during data collection was automatically recorded on the data tape.

Number of records - the eye view monitor records at a rate of 60 measurements per sec. This output indicates the number of records associated with each slide change.

Subject number - this was manually introduced onto the data tape by the experimenter.

TABLE 13

EXAMPLE OF PRINTOUT FROM PROGRAMME 2

slide count	number of records	subject number
14	372	4
15	120	4
0	638	4
1	477	4
0	36 — 1	4
1	612	4
2	34 — 2	4
3	612	4
4	217 — 3	4
5	612	4
6	194 — 4	4
7	612	4
8	173 — 5	4
9	612	4
10	187 — 6	4
11	612	4
12	212 — 7	4
13	607	4
14	179 — 8	4
15	612	984
0	184 — 9	4
1	612	1584
2	621	4
3	170 — 1	4
4	613	1287
5	126 — 2	4
6	611	4
7	192 — 3	4
8	608	4
9	234 — 4	4
10	612	4
11	206 — 5	4
12	612	4
13	92 — 6	4
14	611	4
15	173 — 7	4
0	606	4
1	190 — 8	4
2	612	4
3	184 — 9.	4
4	421	4
0	2	361

TABLE 14

PROGRAMME 3

```
* MANITOBA COMPUTER CENTER ***          DATE= 6/09/76  TIME=11:17 AM


        IMPLICIT INTEGER(H)
        INTEGER*2 D(9,723)
        INTEGER VA(12),HA(12),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10,V11,V12
        EQUIVALENCE (VA(1),V1),(VA(2),V2),(VA(3),V3),(VA(4),V4),
       *  (VA(5),V5),(VA(6),V6),(VA(7),V7),(VA(8),V8),(VA(9),V9),
       *  (VA(10),V10),(VA(11),V11),(VA(12),V12)
        EQUIVALENCE (HA(1),H1),(HA(2),H2),(HA(3),H3),(HA(4),H4),
       *  (HA(5),H5),(HA(6),H6),(HA(7),H7),(HA(8),H8),(HA(9),H9),
       *  (HA(10),H10),(HA(11),H11),(HA(12),H12)
        READ(3,END=999) D
        NR=723
 10     READ(5,15) ID,ISN,IN
 15     FORMAT(I1,I3,I6)
        IF(ID.EQ.9) GO TO 999
        IF(ID.EQ.1) GO TO 50
 25     IF(IN.GT.NR) GO TO 40
        NR=NR-IN
        GO TO 10
 40     IN=IN-NR
        READ(3,END=999) D
        NR=723
        GO TO 25
 50     CONTINUE
        WRITE(6,51)
 51     FORMAT('    ----------------------------------------------------')
        NA=724-NR
        NTC=0
        INIT=0
        I=1
        DO 100 LOOP=1,IN
        IF(NA.LT.724) GO TO 53
        READ(3,END=99) D
        NA=1
 53     NTC=NTC+D(8,NA)
        IF(D(5,NA).EQ.0) GO TO 99
        IF(INIT.GT.0) GO TO 65
        VA(I)=D(6,NA)
        HA(I)=D(7,NA)
        I=I+1
        IF(I.LT.13) GO TO 99
        INIT=1
        NT=0
        NMAXV=0
        NMINV=0
        NMAXH=0
        NMINH=0
        GO TO 67
 65     V1=V2
        V2=V3
        V3=V4
        V4=V5
        V5=V6
        V6=V7
        V7=V8
        V8=V9
        V9=V10
```

Explanation of Printout from Programme 3 (see Table 15)

Subject number - same as for programme 2.

Vertical and horizontal axes - these are indices of eye position on the vertical and horizontal planes relative to some predetermined point.

Number of records - same as for programme 2.

Feedback - record of the type of feedback given on any one trial. Manually introduced by the experimenter onto data tape.

TABLE 15

EXAMPLE OF PRINTOUT FROM PROGRAMME 3

subject number	vertical axis	horizontal axis	number of records	feedback 0=nonreward 1=reward
110	127	103	37	0
110	127	105	32	0
110	132	109	27	0
110	130	100	30	0
110	128	112	27	0
				0
110	128	108	18	1
110	127	111	12	1
110	125	113	21	1
110	124	117	12	1
				1
110	125	107	43	1
110	129	113	15	1
				1
110	121	115	14	1
110	122	109	59	1
110	128	107	15	1
110	127	103	17	1
110	125	99	20	1
110	125	104	22	1
110	125	103	13	1
				1
110	128	100	12	0
110	128	103	13	0
110	125	98	25	0
110	127	109	12	0
110	128	106	28	0
110	126	104	21	0
				0

APPENDIX C

Data Used in Analyses

TABLE 16

RAW DATA OF ADULTS

Subject No	Age	FIXATIONS Problem One R	FIXATIONS Problem One NR	FIXATIONS Problem Two R	FIXATIONS Problem Two NR	TOTAL TIME Problem One R	TOTAL TIME Problem One NR	TOTAL TIME Problem Two R	TOTAL TIME Problem Two NR	TRAINING PROBLEMS No Correct 1	TRAINING PROBLEMS No Correct 2
3	18.50	2.50	8.50	2.00	2.00	2.03	4.55	1.33	1.41	5	5
4	18.50	1.00	2.50	3.00	3.00	.73	1.32	2.03	2.22	3	8
5	18.25	2.50	1.50	2.00	3.00	1.33	.66	.94	1.17	4	7
6	26.75	1.00	1.50	2.00	3.25	1.94	1.62	2.05	3.70	5	6
7	20.25	1.25	2.50	1.75	2.75	.87	1.54	.79	1.51	6	7
8	19.25	3.33	5.33	3.50	3.75	2.23	3.01	1.89	2.99	7	6
11	20.25	4.25	4.25	4.00	3.75	1.56	1.85	1.47	1.37	6	8
13	17.75	2.25	7.33	5.25	11.50	1.53	3.48	2.17	4.40	8	7
14	26.75	3.00	3.50	3.75	4.00	1.04	1.24	1.20	1.49	6	7
15	20.08	7.00	6.25	3.75	4.25	2.63	2.18	1.09	1.24	6	8
16	19.00	1.67	2.00	2.50	3.75	2.54	2.34	2.04	2.58	7	8
18	18.17	7.50	5.75	4.25	6.50	2.65	2.05	2.24	3.18	6	8
19	19.67	3.75	5.00	2.25	5.25	2.03	2 78	1.74	2.61	5	7
20	22.75	2.75	4.00	3.50	4.25	1.46	2.24	1.21	2.22	5	7

ADULTS

a) R = Following reward
NR = Following nonreward

TABLE 17

RAW DATA OF CHILDREN

	Subject No	Age	FIXATIONS				TOTAL TIME				TRAINING PROBLEMS	
			Problem One		Problem Two		Problem One		Problem Two		No Correct 1	No Correct 2
			R	NR	R	NR	R	NR	R	NR		
CHILDREN	21	12.33	2.50	4.00	3.33	2.50	.80	1.06	1.28	1.17	6	6
	22	11.17	3.67	3.75	4.75	4.25	1.43	1.69	1.73	1.62	4	8
	24	11.33	3.25	5.50	4.25	7.25	1.82	2.52	1.65	2.93	3	8
	25		2.75	2.67	3.50	1.67	1.17	2.08	2.20	1.47		
	32	9.08	4.00	3.50	2.25	4.33	1.25	2.01	.78	1.36	5	9
	33	11.00	2.25	4.00	3.00	4.25	1.52	2.31	.99	1.69	3	5
	40	11.92	3.25	2.25	3.25	4.00	1.84	1.38	1.41	1.47	7	7
	39	11.08	3.25	4.75	3.25	4.25	1.70	2.49	1.80	1.62	2	7
	47	9.17	2.75	3.00	2.75	2.25	.99	1.37	1.06	.76	5	7
	49	9.42	3.25	4.50	3.00	3.50	1.44	2.44	1.43	2.03	8	6
	51	11.25	4.00	3.75	3.00	3.75	1.75	2.51	1.78	2.21	4	7
	52	9.75	3.00	2.00	2.33	1.75	1.13	.64	.72	.44	3	6
	54	12.42	2.33	3.00	2.75	1.75	1.81	1.96	2.06	1.96		
	56	9.17	3.25	3.75	6.33	7.50	1.17	1.28	2.11	2.70	9	6

a) R = Following reward
NR = Following nonreward

APPENDIX D

Correlations of the Dependent Variables Total Number of Fixations(a), Total Duration of Fixations(b) and Average Duration of Fixations(c) for Adults, Children and the Group as a Whole.

TABLE 18

CORRELATIONS OF THE DEPENDENT VARIABLES TOTAL NUMBER OF FIXATIONS(a), TOTAL DURATION OF FIXATIONS(b) AND AVERAGE DURATION OF FIXATIONS(c) FOR ADULTS

		VARIABLE a	b	c
VARIABLE	a	1.000	.539*	-.578*
	b		1.000	.326
	c			1.000

* $p < .05$

TABLE 19

CORRELATIONS OF THE DEPENDENT VARIABLES TOTAL NUMBER OF FIXATIONS(a), TOTAL DURATION OF FIXATIONS(b) AND AVERAGE DURATION OF FIXATIONS(c) FOR CHILDREN

		VARIABLE a	b	c
VARIABLE	a	1.000	.580*	-.318
	b		1.000	.568*
	c			1.000

* $p < .05$

TABLE 20

CORRELATIONS OF THE DEPENDENT VARIABLES TOTAL NUMBER OF FIXATIONS(a), TOTAL DURATION OF FIXATIONS(b) AND AVERAGE DURATION OF FIXATIONS(c) FOR THE GROUP AS A WHOLE

		VARIABLE a	VARIABLE b	VARIABLE c
VARIABLE	a	1.000	.549**	-.411*
	b		1.000	.507*
	c			1.000

* $p < .05$

** $p < .001$