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EYE FIXATIONS DURING A PSEUDO CONCEPT FORMATION TASK

BY

ROGER W. HOLDEN

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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