Eye movements and perceptual error: A developmental study

EVANS MANDES,¹ *George Mason College of the University of Virginia, Fairfax, Va. 22030*

This study is concerned with the direction of eye movements during the occurrence of perceptual error. The hypothesis is that there is a positive relationship between eye-movement directionality and location of a stimulus in a particular field, and that this relationship holds for children and adults. One test of this hypothesis is that perceptual errors are associated partially with errors in eye movements themselves. Postexposural eye movements were studied in a sample of 24 7-year-old children and 36 adults. The stimuli comprised families of geometric figures; members of a family differed from each other only on one side (distinguishing feature). These figures were presented tachistoscopically in four orientations, the distinguishing feature appearing randomly at the top, bottom, left, and right of the figure. Multiple-choice arrays were presented in four orientations. The results are consistent with the proposal that errors in the perception of the distinguishing feature are associated with initial eye movements to the opposite field of the distinguishing feature.

The role of eye movements in visual perception has been carefully documented during the past century (Scott, 1962). Several different types of eye movements have been delineated, such as scanning and pursuit movements, visual nystagmus, and saccadic movements. However, the eye movements associated with the perception of tachistoscopically presented material have received considerably less attention than perhaps they deserve. These movements, referred to as postexposural eye movements, are typically small in the size of their excursion and occur from 100-300 msec after the exposure of the stimulus. The hypothesis most frequently associated with the function of these movements is that they serve to facilitate the retention of the iconic memory of the stimulus which, under tachistoscopic exposure, fades rapidly with time.

Two positions concerning the function of postexposural eye movements have been developed. The first, pointed out by Bryden (1961) and offered as an alternative interpretation of his own data, is that these eye movements may be a result of recognition (recognition hypothesis) rather than serving to facilitate

it, i.e., the S sees the stimulus and then moves his eyes. The second, referred to as the facilitation hypothesis (Mandes, 1966; Abelson, 1963), maintains that the S moves his eyes and then sees the stimulus; in other words, the eye movement here serves to preserve the iconic image as it fades in memory.

The present study has attempted to provide limited developmental data for the facilitation hypothesis. The basic argument is simply to analyze the eye-movement patterns associated with the error responses in perception. The recognition hypothesis would predict that eye movements occurring to stimuli which are perceived in error should not necessarily be correlated with the directional properties of the stimuli, i.e., eye-movement direction and stimuli misperceived in a particular field are not necessarily related. The facilitation hypothesis, however, maintains that perceptual errors are related to the misdirection of eye movements so that an analysis of error perception for a directional stimulus should show a distribution of eye movements occurring in the opposite direction of the stimulus.

A subsidiary position espoused by Abelson (1963) maintains that the facilitative effects of eye movements are associated with familiarity of the stimulus. As Ss become exposed to similar figures, the usefulness of the postexposural eye movements is diminished. This position is in accord with Hebb's theory (1949), which maintains that when familiarity with lines and angles develops, perception becomes a more immediate process and eye movements become less advantageous. This second point is also investigated in this study by providing developmental data comparing eye movements and error perception for children and adults. These data are expected to provide a useful comparison with respect to facilitation and familiarity, particularly in view of the fact that postexposural eye movements have not been studied in children.

SUBJECTS

Thirty-two college undergraduates, 16 male and 16 female, were selected for the first part of the experiment. The second phase of the experiment used 24 children, 12 boys and 12 girls, with a mean age of 7-6 and an age range of 7-1 to 7-11.

STIMULI

Figure 1 depicts the distinguishing-features forms used in this study. These stimuli have been used elsewhere (Mandes & Ghent, 1963). They

were constructed in such a way that members of a given family were identical on three sides and differed only in the construction of the fourth side. As Fig. 1 shows, each figure is characterized by a family feature at one end, straight lines on two sides, and a distinguishing feature at the other end. In order to identify a figure correctly within a given family, the distinguishing feature must be perceived. The nine figures shown were presented tachistoscopically in each of four orientations such that the distinguishing feature appeared at the top, bottom, left, and right of the figure. Eighteen items were presented in the vertical position and eighteen in the horizontal position, or 36 items in all, with Ss balanced as to the initial dimension and with items randomized within a given position.

The distinguishing-features forms were 4¼ in. in length and 1-1/8 in. in width with a stroke width of 1/8 in. The lines were drawn in black, using a low-reflectance Chart-Pak matte, with each stimulus mounted on a 6-in.-square white posterboard. The stimuli were centered either vertically or horizontally with respect to the fixation point and were displayed within a 7-in. square. The stimuli subtended a visual angle of 10 or 5 deg on each side of the fixation.

APPARATUS

Two pieces of equipment were used in

Fig. 1. Distinguishing features forms used in this experiment grouped according to family. Each figure is oriented with the family characteristic pointed at the top and the distinguishing feature at the bottom.

this study: (1) a Gerbrands mirror tachistoscope and (2) an electrooculograph (EOG). The EOG was a Grass Model 5A polygraph with Model 5A1 preamplifier. Electrodes were manufactured by Telemetrics Products, Inc., and were of the nonpolarizable variety. Eye-movement recordings were taken only on the left eye, since it was assumed that for gross eye movements (greater than 1 deg), eye movements are conjugate. The electrodes were placed temporally and nasally to measure horizontal eye movements and above and below the eye for vertical displacement. A commercial electrode jelly, manufactured by Telemetrics Products, was used to decrease skin resistance. The machine was calibrated for each S to yield a deflection of 5 mm for each 7 deg of eye movement. In analyzing the results, an eye movement was considered to have occurred whenever a deflection, bearing characteristic fast or slow drift, of 2 mm or greater occurred within 100-300 msec after exposure (Crovitz & Daves, 1962; Bryden, 1961). The reliability of judgments as measured by product-moment correlation was +.86. The judgments were made by two independent judges for the first 16 adult Ss only. In order to record the onset and the offset of the stimulus from the same pen that recorded eye movement, an electrical field technique was employed. By exposing the electrical field of the microswitches controlling the tachistoscopic timer and by placing them near the magnetic field of the pen recorder, E was able to record onset and offset deflections directly each time the timer was placed in operation. A small antenna placed near the timing device was used to attenuate 60-cycle interference. Head movements were controlled by using a combination chin rest and bite board.

PROCEDURE

Each S was given a pretraining trial with figures similar to those used in the experiment. Eight practice stimuli were used. The orientation of the practice stimuli was presented randomly. After the practice period, the stimuli were presented tachistoscopically at a constant exposure duration of 40 msec for the adults and a variable speed between 50-100 msec for the children. Neutral density filters (0.50) were placed over the eyepieces in order to increase the difficulty to an average error level of 25%.

The Ss made their responses by selecting the figure seen from an array of multiple-choice items, which contained only the items of a given family. In all instances, the Ss were unaware of what figure was presented in all cases. That is, they made their selection after tachistoscopic exposure of the stimulus.

Table 1
Error Perception by Eye Movements for Stimuli (Adults = A; Children = C)

Orientation of Distinguishing Features Perceived in Error		Eye Movement Direction											
		Top				Nonrecordable Eye Movements				Total		z-Scores	
		Top		Bottom		Nonrecordable Eye Movements		Total		z-Scores			
		A	C	A	C	A	C	A	C	A	C		
Top	12 (7,5)	12 (9,3)	23 (19,4)	15 (11,4)	18	8	53	35	2.03*	0.76			
Bottom	25 (14,11)	14 (8,6)	13 (6,7)	7 (3,4)	9	14	47	35	2.11*	1.73			
Left	Left		Right		11	12	34	39	1.25	2.00*			
	9 (7,2)	9 (5,4)	14 (10,4)	18 (14,4)									
Right	12 (6,6)	5 (3,2)	5 (4,1)	11 (7,4)	6	6	23	22	1.95*	-1.75			

* $p < .05$

RESULTS

The results of both experiments with adults and children are depicted in Table 1. For each of the four conditions of distinguishing-features forms presentation, a binomial test between the two eye-movement contingencies, i.e., top vs bottom or left vs right, was performed to determine the degree of significance. An example of the interpretation of the data of the first row is as follows: When the distinguishing feature appeared at the top, 53 perceptual errors were made by the adults and 35 by the children. For the adults, 12 initial eye movements were directed postexposureally at the top where the distinguishing feature was and 23 were directed initially at the bottom, with 18 eye movements that failed to reach the criterion of an eye movement imposed by this study. A binomial test was performed only on the 12-23 comparison, yielding a significant $z = 2.03$. In a general way, the data support the hypothesis that error perception is associated with eye movements to the opposite field which presumably contributes, in part, to the nonveridicality of the behavioral perceptual response. To test the possibility that eye-movement function varies with developmental stage, the data were converted to percentage responses. This analysis failed to confirm any relationship and suggested instead that eye movements are equally advantageous for both 7-year-olds and adults under these experimental conditions. This relationship held for all dimensions of the stimulus except the right condition, which will be discussed later.

To test for the possible effects of familiarity on the eye-movement scores, a subanalysis was performed for each condition of eye-movement direction. This analysis is depicted by the scores in the parentheses in Table 1. These scores represent errors committed for the first half and the second half of the total

sequence of 36 stimuli scored. The idea is, of course, that Ss become more familiar through exposure with the stimuli toward the end of the sequence than at the beginning, and that eye movements would serve a more facilitative effect at the beginning than at the end. The findings here indicate that, in general, significantly more recordable eye movements occurred for the first half of the sequence than for the second half ($z = 3.19$, $p < .01$) and that this relationship held equally for the children and the adults.

DISCUSSION

It appears, then, that postexposural eye movements do play a role in the recognition of tachistoscopically presented material. The mechanism of postexposural facilitation as interpreted in this study may operate in the following manner: A tachistoscopically exposed stimulus excites a portion of the visual brain with the strength of excitation fading as a function of time. The postexposural eye movement serves to facilitate the perception of a specific trace by (1) localizing the distinguishing feature in space and (2) initiating a scanning movement towards the opposite portion of the stimulus. The combined action of (1) and (2) serves to preserve the memory trace of the stimulus and to keep it from falling below response threshold. When the S fails to localize the stimulus element, then this failure operates deleteriously upon perception so that the eye movement contributes minimally to the preservation of the iconic memory. However, as Sperling (1960, 1963, 1967) has shown, there is a persistence of short-term visual memory of several hundred milliseconds beyond total stimulus duration time during which information beyond that contributed by eye movements themselves can be extracted. In other words, as these data clearly imply, postexposural eye movements are a correlate of the memory process, both in children and in adults,

without being all of that process.

From the developmental point of view, eye movements observed in this study operate equally for both children and adults, although they appear to be correlated more strongly with veridical perception in adults. Indeed, the only ambiguity in these data is for the children, and that concerns the movement of the eyes in the direction of the right field and their failure to perceive the distinguishing feature in the right field. Although this tendency is not significant, there is some evidence in the literature (Dyer & Harcum, 1961) to suggest that second-grade children tend to fixate toward the right portion of the visual field. These authors have interpreted their findings as suggesting that, for this developmental period, recency effects (the last element perceived in a series of elements) are stronger than primacy effects, which tend to favor the left portion of a series of elements exposed horizontally. Failure to perceive the elements on the right even when initial eye movements are directed there, as revealed in this study with children, may reflect the continued confusion of this direction and scanning tendencies learned during reading which direct eye movements from left to right.

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NOTES

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Response latency as a function of list length in paired-associate learning¹

JOHN CERASO, LEONARD BADER, and MARSHALL SILVERSTEIN, *Institute for Cognitive Studies, Rutgers, The State University, Newark, N.J. 07102*

This study investigated the degree to which a scanning mechanism might occur in paired-associate recall. A further question was whether or not scanning might occur in the early phases of learning but then drop out with overlearning. The experiment involved observing the latency of responses at recall when length of list (8 or 16 pairs) and degree of practice were the independent variables. An attempt was made to control for the confounding variable of differential learning that occurs when lists of different lengths are involved. The corrected data presented evidence for scanning at the early phase of learning (i.e., faster recall in the shorter list) and evidence that scanning dropped out with overlearning.

Two possible kinds of recall processes can be logically distinguished in paired-associate recall. One is the recognition or identification of the stimulus term, the other is the retrieval of the response term. Either of these types of recall could occur via a sequential memory search. In recognition, the stimulus term presented to S could be compared to the stored representatives of the stimulus terms of the list, one by one, until a match is found. Again, once the stimulus term has been identified, there could be a sequential search of the response alternatives until the appropriate one is found.

Sternberg (1966) has presented evidence for a sequential process in a recognition task, and so one might expect a similar finding in paired associates. Failure to find such evidence would argue against sequential processing for both recognition and retrieval. In the present experiment, as in the Sternberg experiment, the independent variable is length of list, the assumption being that sequential processes are revealed by longer response latencies in longer lists.

A second thought that determined the design of the present experiment was that search processes might characterize the early stages of learning but might be

supplanted by other mechanisms as practice continues. Comments by Ss during PA learning often suggest deliberate learning strategies (the use of mnemonics, etc.) during the early portions of learning, giving way to more automatic recall with overlearning. Perhaps search processes are associated only with the earlier, more deliberate phase of learning.

The present experiment, then, provided for the observation of response latencies during recall for lists varying in length and varying in degree of practice.

METHOD

A list of 16 nonsense-syllable four-letter monosyllabic noun pairs was constructed and was used as the long, or 16-item, list. The stimuli were taken from the Archer (1960) list and were from 28 to 38 in association value. The responses were from the Thorndike-Lorge word count (1944) with G frequencies from 2 to 25.

These 16 pairs were split into two subsets of eight pairs each. The mean associative value of the nonsense syllables was the same in both subsets, as was the mean frequency value of the words. Only one of these subsets was used as the list for the short or 8L group. After the experiment was completed, we looked at the number of items recalled from each of these subsets. In the 16-pair list, there were a total of 262 items recalled in all conditions. Of these, 132 were from the pairs used in the short list and 130 were from the pairs not used. It would seem, then, that, as items, the long and short list pairs were quite comparable.

Slides of the material were prepared and were projected on a wall about 6 ft in front of S by a Kodak Carousel slide projector. During the recall trials, presentation of the stimulus started a clock, and the S's response activated a throat microphone which stopped the clock so that O could record the latency of the response.

PROCEDURE

The pairs were learned by the anticipation method, with the slides shown at a 3-sec presentation rate. There were two presentation orders for the lists, with a 6-sec intertrial interval. At the conclusion of the last learning trial, a recall trial was given where S was presented with each stimulus item and where S's response and