LATERAL BIASES IN SCANNING TWO-DIMENSIONAL REPRESENTATIONS OF THREE-DIMENSIONAL SCENES

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FRANK HOLLY
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presented by

Frank Holly

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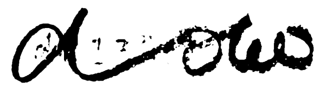

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ABSTRACT

LATERAL BIASES IN SCANNING TWO-DIMENSIONAL REPRESENTATIONS OF THREE-DIMENSIONAL SCENES

By

Frank Holly

Previous work had indicated that there may be a preference for looking at the right half of symmetrical targets with minimal depth cues. Pilot work supported this conclusion and extended it to symmetrical targets representing three-dimensional scenes.

The present study attempted to relate this lateral bias in looking behavior to some of the lateral effects found by Bartley and co-workers using asymmetrical pictures of three-dimensional scenes. Among other things, these studies had found that items in the left foreground appear nearer than items in the right foreground and that this effect is stronger when a large background item is on the right side rather than the left.

In attempting to relate these two sets of findings, observers were presented with symmetrical and asymmetrical scenes and their eye fixations recorded. For each

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asymmetrical target there was another one which was its mirror-image. It was found that: (1) there was no difference in fixation time between right and left halves, (2) the first fixation, however, tends to be to the left of later fixations, (3) location of the foreground item does not affect fixation time on this item, and (4) there are no sex or order effects.

The results were related to other studies which had indicated that the first fixation is the best indicator of attensity whereas total fixation time is an indicator of the difficulty of cognition of a given part of the target. The lack of sex differences in this and other eye movement studies using adult subjects was contrasted to studies of children in which sex differences were found. There were, however, sizeable individual differences in the present study and these were discussed in terms of another study which found certain differences in looking behavior to be related to I.Q. The Noton and Stark theory that pictures are remembered and recognized in terms of eye movement patterns was also discussed.

LATERAL BIASES IN SCANNING TWO-DIMENSIONAL REPRESENTATIONS OF THREE-DIMENSIONAL SCENES

By

Frank Holly

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INTRODUCTION

A number of articles have been written concerning the left-right question in art and how a mirror image of a painting differs from the original (Schlosser, 1930; Wolfflin, 1941; Oppé, 1944; Gaffron, 1950; and others). One of the most complete treatments of the subject is that given by Gaffrom (1950). Janssen's <u>Reading Woman</u> (Figures 1 and 2) is one of the examples used in her article to show some of the perceptual changes resulting from such a reversal. In part, she noted that: (1) In the original, while seeming to stand further away, we seem to look directly against the side wall and against the front of the large chest. In the mirror image, on the other hand, we seem to look in a different direction, namely along the side wall. (2) In the mirror image the slippers seem more important; we perceive them at first glance and they seem to stand nearer to us. It now seems easy to look into the inside of the foremost slipper while we seem to be looking at its outside in the original. (3) In the mirror image the distance to the back wall seems greater; the picture space appears deeper.

Figure 1.--PIETER JANSSEN, Reading Woman. Munich, Alte Pinakothek.

Figure 2.--Mirror Image of Figure 1.

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Gaffron explained all such left-right effects by her theory that (1) there is a glance curve which begins in the left foreground, penetrates toward the depth, and then turns over toward the right (Figure 3), and (2) people when viewing a picture tend to locate their imaginary standpoint at the beginning of this glance curve, i.e., on the left side of the picture.

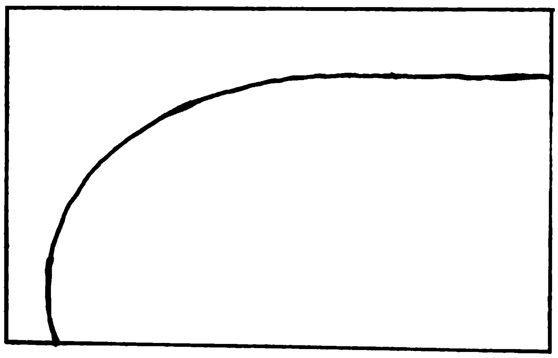

Figure 3.--The Glance Curve As Envisioned by Gaffron and Other Art Commentators. (From Gaffron, "Right and Left in Pictures," Art Quarterly, 1950).

The glance curve causes a greater salience for those objects lying along its path and determines some of the rules of composition. The left foreground and right background are good places for the important objects in the picture while the left background and right foreground are relatively dull. It also explains the greater depth

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in the mirror image of the Reading Woman than in the original; in the original the curve is first detained by the drapery on the chair in the left foreground of the picture and then meets the back of the woman. In the mirror image it is virtually uninterrupted, following the lines of the floor up to the back wall, thus giving the impression of greater depth.

Gaffron does not propose a glance curve in the most literal sense; eye movement recordings of persons viewing pictures do not show the eye traversing such a path. Rather, it is a phenomenon based upon the central processes of vision whereby all objects located within the range of this path are recognized spontaneously while we must look separately for those located outside it, i.e., in the right foreground or upper left background.

The location of the viewer's imaginary standpoint on the left results in a different set of effects. This causes the left side of a picture to seem like "our side." "We feel that items located here are closer to us and have greater importance to us. A person standing in the left foreground with his back turned toward us arouses a decided feeling of identification with ourselves, whereas a person looking out of the picture from the left foreground seems directly opposed to us." It also causes right-to-left movement portrayed in the picture to have

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the character of approach while movement from left to right seems to be withdrawing from us. The right side, on the other hand, seems further away and items on that side are subjectively less important. One can look for effects of this nature in two more of her examples (Figures 4 through 7).

The various commentators on this right-left question have not necessarily agreed on all points. Wolfflin (1941), writing earlier than Gaffron, believed that the right side was generally of greater importance. He also believed in the physical reality of the glance curve. Oppé (1944), in turn, disagreed with Wolfflin's assessment of some of the works of Raphael. Associated with most tapestries and etchings is an earlier, mirror-image, cartoon from which the etching or tapestry was made. A favorite argument among those interested in this right-left question is whether the cartoon or the mirror-image tapestry (etching) reflects the composition actually intended by the artist. In Raphael's Death of Ananias (Figures 8 and 9) Wolfflin finds in the abnormal position of Ananias an argument in favor of his theory that the composition was intended to read as in the tapestry, and from left to right. He supposes that Raphael deliberately emphasized the catastrophe by throwing the figure of Ananias against the natural direction of the composition.

Figure 4.--RAPHAEL, The Change to Peter (cartoon). London, Victoria and Albert Museum.

Figure 5.--Mirror Image of Figure 4.

Figure 6.--REMBRANDT, The Return of the Prodigal Son. Leningrad, The Hermitage.

Figure 7.--Mirror Image of Figure 6.

Figure 8.--RAPHAEL, Death of Ananias (cartoon). London, Victoria and Albert Museum.

Figure 9.--RAPHAEL, Death of Ananias (tapestry). Rome, Vatican.

Oppé, like most other art historians, considers instead the cartoon to be a model of composition which flows logically and dramatically in waves from a center and in which the action proceeds mainly from left to right. The crowd on the left have their backs to the spectator and look upwards to the Apostles, the staircase in the dark corner and the people on it ascend, while on the right, under an open space, quiet upright personages frame the group of the prostrate Ananias and of the man who points excitedly towards the Apostles in the center from whom the catastrophe proceeds. In his view, the tapestry shocks with an immediate effect of confusion and the figure of Ananias is all but overlooked.

A study by Adair and Bartley (1958) represented the first attempt to apply psychophysics to this problem of sideward differences (<u>sideward</u> is used as the perceptual correlate of the physical term <u>lateral</u>). They used five scenes with varying degrees of lateral asymmetry as determined by five judges. The judges were used because of the complexity of the scenes and the consequent complexity of determining asymmetry metrically.

There were two orientations, normal and mirror-image reversed, of each scene and two sizes, 4 x 4 and 8 x 8 inches, yielding a total of four prints of each scene. During each trial, there was one small print and one large print visible to the observer. The small prints were placed at a fixed distance, just to the right of the track, and the large prints were placed on a carriage on the track. The two large versions of each scene appeared in combination with each of the two small versions of the same scene and the task of the O's was to adjust the metric distance of the large print so that the scene in it appeared to be at the same distance as the corresponding scene in the small print.

It was found that the pictures which had the prominent items on the left were placed at a greater distance than those which had these objects on the right. In addition, the distance setting of the prints was influenced by the asymmetry factor in the manner expected; the greater the asymmetry in a scene, the more accentuated were the left-right differences.

The next pair of studies relate to Gaffron's statement that "A person standing in the left foreground with his back turned toward us arouses a decided feeling of identification with ourselves whereas a person looking out of the picture from the left foreground seems directly opposed to us." Bartley and Thompson (1959) used prints whose asymmetry was established on a more objective basis. All scenes consisted of a human figure standing on the center stripe of a roadway extending from the foreground to the horizon. There were also some trees and a few other objects in the scenes. The human figure was placed in five different positions: two placements on the left, two on the right, and one in the center. In agreement with the previous study, it was found that the human figure when on the extreme left appeared nearer than when on the extreme right. The same difference was found between the less extreme positions but to a lesser extent. Thompson and Bartley (1959) used two pictures which contained a human figure standing in the center. The only difference between the two pictures was that in one the subject was facing the camera while in the other he had his back to it. They found that the man with his back to the camera seemed nearer.

Four other studies in this same tradition were performed by Swartz and Hewitt (1970), Swartz and Swartz (1971), Nelson and MacDonald (1971), and Holly (1971). In the Swartz and Hewitt study (1970) subjects from grades 1 through university level were presented with original vs. mirror-image views of each of a series of twenty pictures. They were asked for their preference of each pair and the grand mean number of original views selected was significantly greater than chance expectation. Preference for the original varied significantly over pictures with the following properties of lateral organization emerging most distinctly as influential in the response: (a) pattern of lighting, (b) profile orientation, (c) handedness characteristics, (d) quadrant distribution of important objects, and (e) ease of entering the picture space. Choice was also a function of the positional arrangement of the two views. With respect to individual differences, when preference behavior was averaged over paintings, educational level was a more important dimension than either sex or handedness. When preference was considered for paintings singly, the influence of sex and handedness was considerable.

Swartz and Swartz (1971) performed a predictive study in which they selected twelve paintings on the basis of the five factors of lateral organization found by Swartz and Hewitt to be of importance. Adult subjects were shown the original and a mirror-image reversal of each of these pictures and asked to select the one they preferred from each pair. The pictures had been selected so that in six of them the preponderance of lateral factors predicted a preference for the original while a preference for the reversals was expected in the other six. In two instances there was a preference for the predicted picture (one original and one reversal) while in the other ten cases no significant difference was shown. In a replication with fourth graders, one picture (one of those which showed a significant difference in the first part of the study) showed a significant preference for the predicted version.

In the Nelson and MacDonald (1971) study, subjects were shown fifteen displays consisting of a picture and its mirror-image. The pictures had been selected so that they contained important items in both the left and right foregrounds. The experimenter assigned a title to each display such that in one picture it referred specifically to the item in the left foreground while in the other it referred to the item in the right foreground. When subjects were asked to assign the title to the most appropriate version of each display they showed a significant tendency to make the title refer to the item in the left foreground rather than the right foreground.

In the study by Holly (1971), an attempt was made to force the observers' imagined standpoint to the center and thereby reduce the saliency of the left side. It was thought that either of two means would accomplish this result. In one version of the photographs (Figure 10) there was a straight highway which ran from center foreground to center background and whose center stripe was in the exact center of the picture (Set III). The result was a well-defined center point and supposedly a compelling sense of viewing the scene from the center.

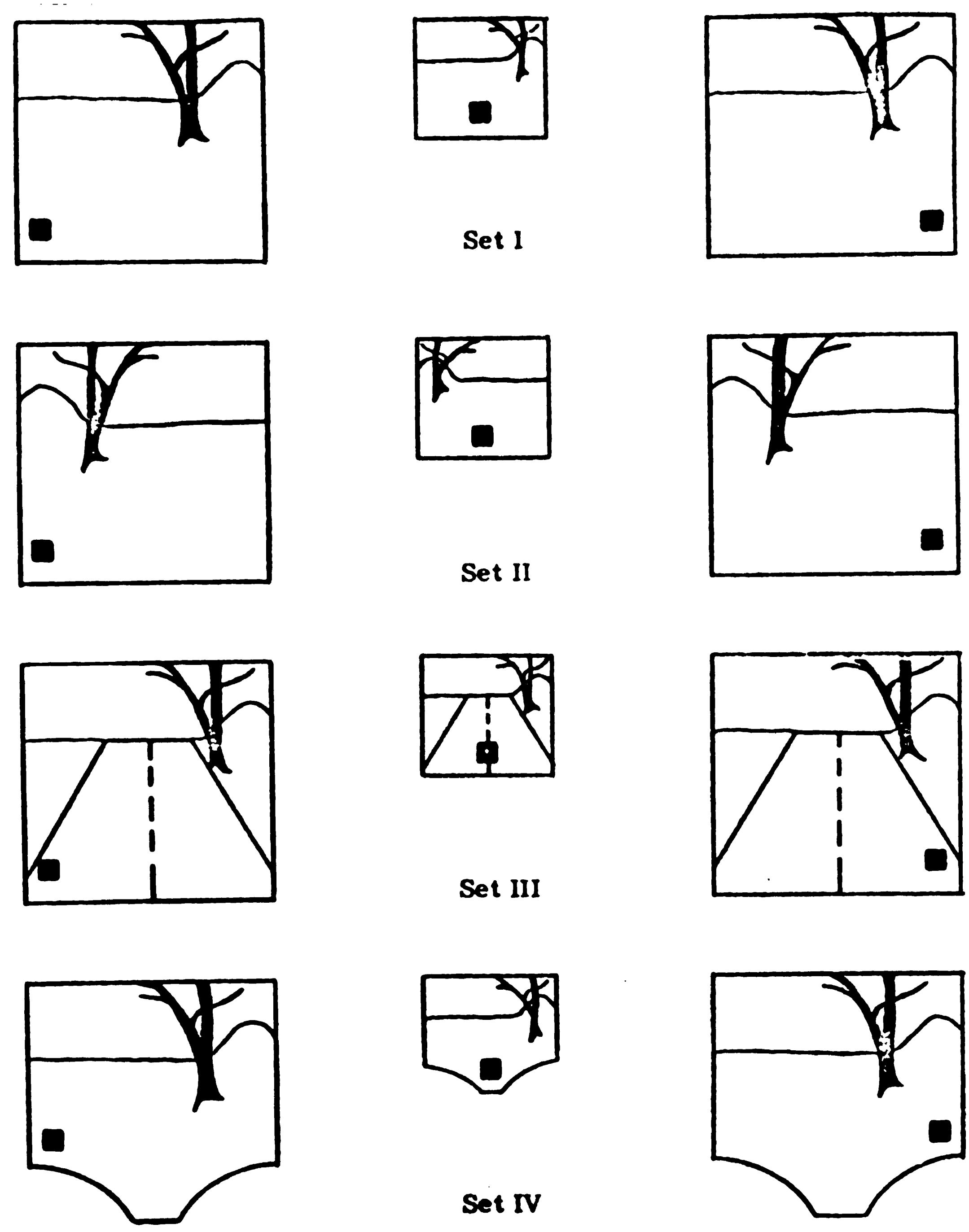


Figure 10.--Targets Used in M.A. Thesis by Holly.

In the other version, the photograph was cropped in such a manner as to bring the foreground to a point in the center, again hoping to force the observers' standpoint to the center (Set IV). The apparent distance of the critical item (black rectangle) in these pictures was compared to that in the regular pictures (Sets I and II). The results revealed no significant change, indicating that even when the location of the objective vantage point is well defined the effects do not disappear.

Traditionally, those interested in eye movements have been either the old-time peripheralists of early behaviorism or the Hebbians with their emphasis on redintegrative processes. Recently, however, a new breed of computer-interfaced psychologists have become intrigued by saccadic eye movements perhaps because of their analogy to the sudden, non-continuous shifts in computer processing. Typical of this latter group are Noton and Stark, whose work has recently gained some prominence. They have taken note of the regularities in scanning evidenced when a given person views and re-views a given picture and have used this to build a serial model in which eye movements serve as the links between the discrete snapshots etched in the memory trace.

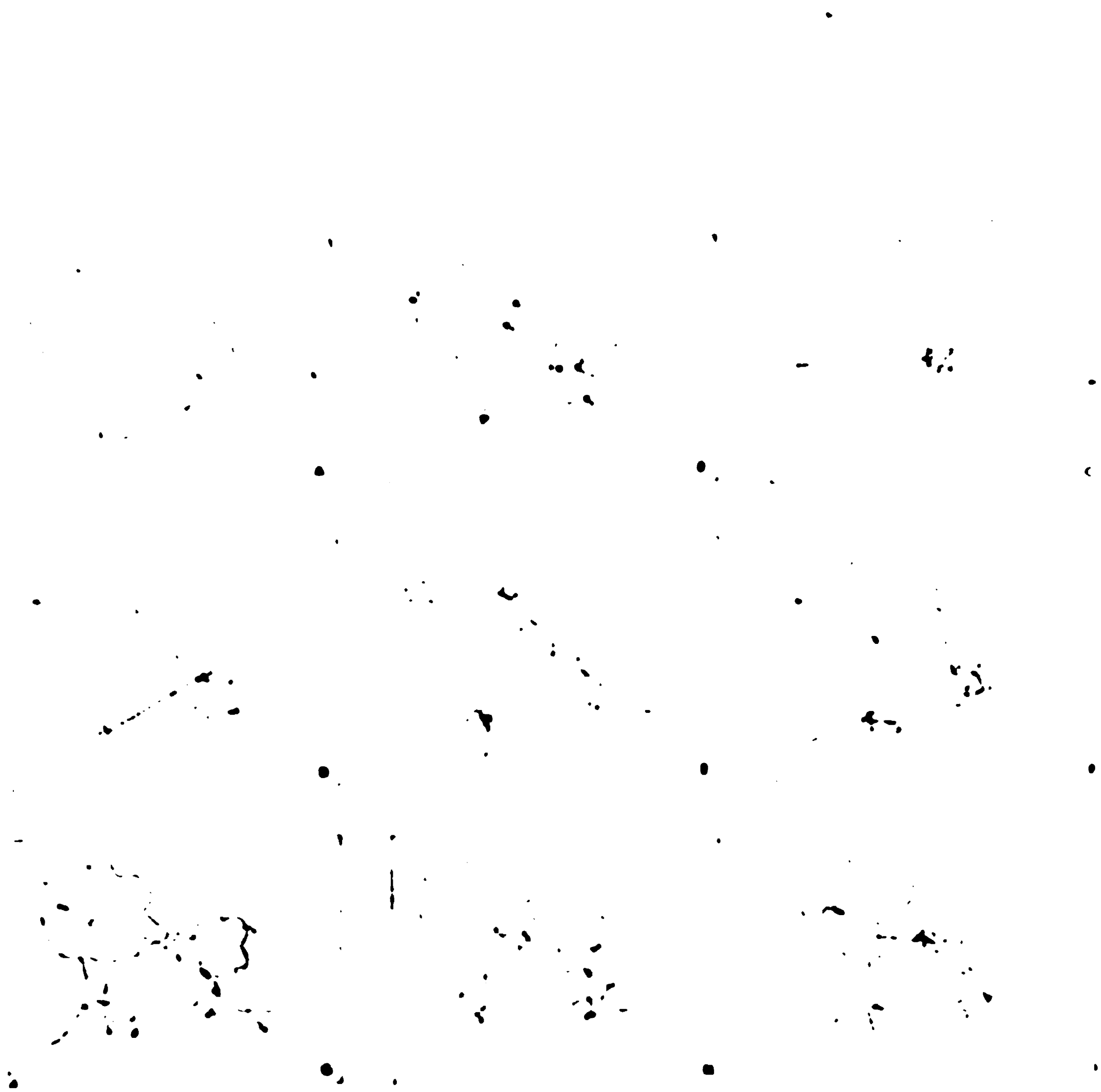
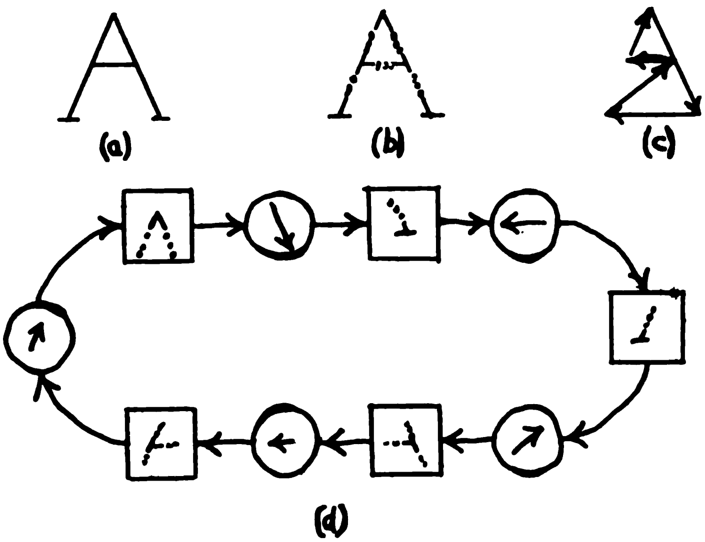


Figure 11.--One of the Targets Used by Noton and Stark with the Scanpath of One Subject Superimposed.

In one of their studies (Noton and Stark, 1971) the targets were pictures of a car, a man's profile, and a scene with two trees (Figure 11). During the initial viewing phase, subjects spent 25% of the time following a fixed scanpath which tended to recur intermittently with the rest of the time taken up by movements to various irregular or unpredictable points. In the recognition phase, subjects tended to begin with the scanpath and, in fact, spent 65% of their time, on the average, following the scanpath during this phase. The authors offer a model of pattern recognition in which the memory trace of a pattern is a sort of S-R chain in which the Ss are the various features of the pattern and the Rs are the eye movements or attentional shifts linking one feature to another. The addition of attentional shifts to eye movements as the Rs of the model is in deference to the fact that pattern recognition obviously can occur with no eye movements. Graphically, they show this in the following way:



Sensory Memory Trace
Motor Memory Trace

Figure 12.--Internal Representation of a Pattern: (a) pattern, (b) features, (c) scanpath, (d) feature ring. (From Noton and Stark, Vision Research, 1971.)

There are reliable differences between subjects as well as between pictures in the scanpaths. The authors cite the between subjects differences as evidence that the scanpath is a bona fide habit and not simply due to the fact that a given picture always has the same spatial arrangement and hierarchy of features, thereby causing the feature detectors to initiate the various fixations always in the same order. According to them, if this were the case there would be much more similarity in the scanpath across subjects since presumably we all have more or less the same set and hierarchical arrangement of feature detectors. The between pictures differences in scanning pattern they use as further evidence that the scanpath must be intimately connected with the way in which we tell one picture from another. Also, the fact that the time spent on the scanpath jumps from 25% to 65% when we go from initial viewing to recognition indicates, they believe, that the eye movement pattern has something to do with relating the picture being viewed to one's memory of it.

Doubt, however, about the significance of eye movements to pattern recognition was cast by some work which Chris Gilbert and I did on the Mackworth Eye Camera and which was suggested by his M.A. thesis. For his thesis he made composite pictures of faces by splitting them down the middle and combining each half with its mirror image reversal, thus yielding two fairly normal looking pictures, one composed of two right halves and one composed of two left halves. He found that when he presented the original pictures to subjects and asked them to tell him which of the composites most resembled the person, Ss showed a significant tendency to choose the composites of the right halves of the original face (right halves of the original faces = left visual field when looking at the center of the original faces). It made no difference in performance whether the original face or its mirror image reversal was used as the inspection target; in both cases subjects chose the composite corresponding to the left visual field of the inspection target indicating that the effect was not caused by some imbalance in the targets themselves.

As a follow-up, the next step seemed to be to determine whether this greater importance of the right side was associated with a greater time spent looking at that side. We would not have been surprised to find either no difference or a greater time spent looking at the right side of the face, but the result was the one that no one would have predicted: Ss spent more time looking at the <u>left</u> side ($p < .001$) of the face (<u>right</u> visual field). Both the originals and mirror-image reversals of the originals were used as targets but the results were the same in either case; more time was spent looking at the right visual field. Also, the test which he had administered in his thesis was given again and the results came out the same; Ss chose the <u>right</u> composites (left visual field of the originals). There was no correlation between the amount of time which a subject spent viewing one side of the face over the other and his tendency to choose one composite over the other.

There was an extensive 1935 study by Buswell in which, using methodology similar to our own, he showed a large number of pictures to a large number of subjects and obtained records of the subjects' fixations superimposed on the paintings. Careful examination of his records yielded some interesting findings. For one, artists generally have little success in controlling or predetermining the fixation pattern of the observer in spite of art school talk about controlling the sweep of the viewers' gaze. The only picture which elicited more or less the same fixation sequence from every subject was a picture of a large wave in the ocean in which fixations tended to start at the bottom of the wave and move up and around to the tip.

One of his targets might be described as a section of typical wallpaper border. It was simply a wide, thin strip containing a row of identical dog forms (Figure 13). As can be seen from the fixation records, there is a strong tendency for Ss to immediately shift their gaze to the left and proceed to the right in step-wise fashion and then back towards the left, after which follows a series of smaller oscillations. In other versions of the same target, the dogs were all running to the left or right but the fixation pattern remained the same, again demonstrating little correlation between the sweep of the picture's motion and the pattern of eye movements.

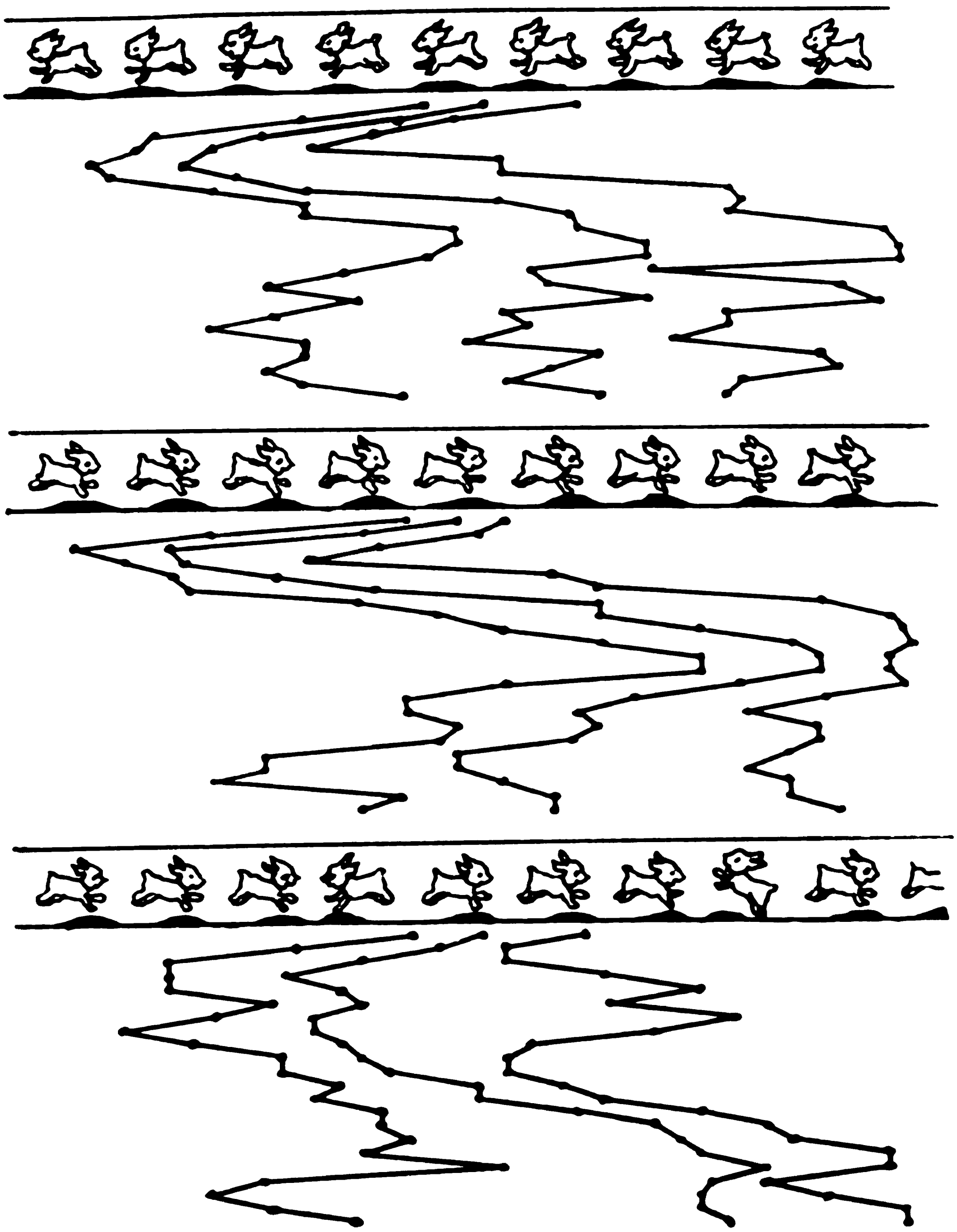


Figure 13.--Position of Median and Quartiles for First Twenty-two Fixations in Looking at Each of the Three Versions, Based on Fourteen Subjects. (From Buswell, How People Look at Pictures, 1935.)

Buswell notes in passing that his two nearly symmetrical pictures showed a greater number of fixations in the right visual field than in the left. The only other reference in the literature to a fixation bias for one hemifield over the other which I was able to find was in an article by Thomas (1963) in which he mentions that subjects look more to the right side (visual field) of symmetrical Rorschach cards than to the left.

In the present study, observers will be shown asymmetrical pictures of the type used by Bartley and co-workers as well as some symmetrical versions with strong depth cues. Of course, the very asymmetry of the scenes which we will be using would be expected to cause an imbalance in looking of one sort or another. This can be controlled by showing subjects both the original scenes and their mirror images. In this way, first one half of the picture and then the other half will appear on the left side and the same for the right side. The time spent looking to the right side totalled over the two different halves of the picture can then be compared to the time spent looking to the left totalled over the two halves. It is predicted that there is a bias for looking at the right side even with asymmetrical pictures which will emerge under these conditions. Symmetrical versions of these scenes will also be shown, and it is expected that there is an even stronger bias with symmetrical than with asymmetrical scenes. Because of the redundancy of the two halves of a symmetrical scene there is no need to look at the left half.

Bartley has commented on the immediacy of the lateral effects in his scenes and the possible significance therefore of the first fixation. It is predicted that because of the greater prominance of the left foreground more of these first fixations will fall on the left half than on the right.

In a further analysis, it will be determined whether there is any hint of a glance curve going from the lower left corner to the upper right corner as postulated by Wolfflin. Although it has already been shown that there is no distinct glance curve of this sort, it is possible that a weak effect of this sort exists. In order to determine this, the number of eye movements from the critical item in the foreground to the large background item in the original will be compared to that for the mirror-image reversal. If any sort of weak glance curve exists, one would expect more movements of this sort when the critical item is in the left foreground and the large background object is on the right side than vice-versa.

Also, the scanpaths à la Noton and Stark of both the original scenes and their mirror images will be examined for differences and similarities. Specifically, an attempt will be made to determine: (1) if the scanpath is as strong in the mirror-image reversal as in the original and (2) if the direction of movement in the mirror image tends to be in a direction opposite to that of the original.

In another analysis, the perception of the critical foreground item as affected by its physical relationship to the large background item will be examined more closely. Here, the subjects will be shown four different placements, right, right center, left center, and left of the critical foreground item with the rest of the scene remaining the same. It will be determined whether the number of fixations on the critical item changes in a systematic way as the critical item is moved from right to left. Additionally, it will be determined whether the number of eye movements from the critical item to the large background item changes in a systematic way as the critical item is moved from right to left. With respect to all of these questions sex and order effects will also be determined.

METHOD

Subjects

Sixty-four subjects (thirty-two male and thirty-two female) were chosen from the undergraduate population at Michigan State University.

Apparatus

Eye movements were recorded by means of a Mackworth camera (Figure 14). This camera utilizes the corneal reflex technique in which a light source is positioned so that its image reflects from the cornea of the left eye into a lens system which aims it towards the front (silvered) surface of a half-silvered type beam splitter. From there, it reflects into the lens system of a Beauliou movie camera. This image reflects off of the beam splitter at approximately a 90° angle but the exact angle depends, in a quite linear fashion, upon the angle of reflection from the cornea and hence eye position. Meanwhile, an image of the target which the subject views is directed by a system of mirrors towards the rear of the beam splitter. It passes straight through the beam splitter and into the lens of the camera. The result is a moving picture record of the target material with a white

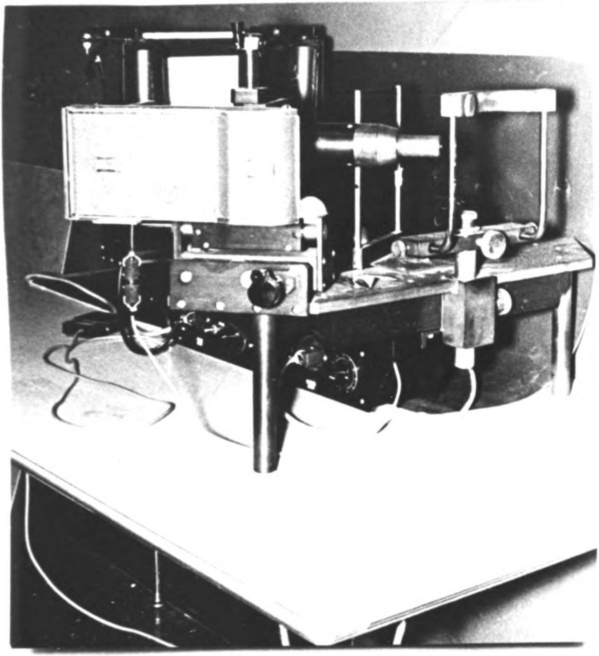


Figure 14.--Mackworth Camera.

dot (the reflected light source) indicating each fixation superimposed on it. The system is quite linear up to about 20°. A Hunter timer was hooked in series with the movie camera and its 6-volt power supply to provide exact timing for the recordings.

The target material consisted of three sets of four 4½" X 7½" pictures of outdoor scenes. In Set A (Figure 15) there was: (1) a picture of the type which has been found to maximally produce the lateral effects, i.e., a scene in which there is a small foreground item on the left and a large background item on the right, (2) the mirror-image of (1), (3) a scene in which both the small foreground item and large background item are on the right, and (4) the mirror image of (3). The four scenes of Set B (Figure 16) were identical except for the different placements, right, right center, left center, and left, of the foreground item. The first two pictures of Set C (Figure 17) were the same as pictures (1) and (2) of Set A. Pictures (3) and (4) were symmetrical scenes composed from prints identical to those of (1) and (2). Picture (3) was the result of joining the right half of scene (1) to left half of scene (2) and picture (4) resulted from joining the left half of scene (1) to the right half of scene (2). Care was taken to insure that the symmetry in Sets A and C was exact.

I.

II.

III.

IV.

Figure 15.--Pictures in Set A.

I.

II.

III.

IV.

Figure 16.--Pictures in Set B.

I.

II.

III.

IV.

Figure 17.--Pictures in Set C.

Procedure

Before each subject entered the room, all the targets were placed in the target holder so that whenever a target was withdrawn from the holder the next one was automatically revealed. When a subject was brought in, he was seated in front of the apparatus and the function of the biteboard explained to him. He was exhorted to attempt to keep his head still.

Dental impression compound was then placed on the biteboard and S bit down to form an impression. When it had hardened, he bit it again and fixated the center dot of a test pattern containing five fixation dots, one in the center and one in each corner. E then adjusted the optics until the marker light appeared superimposed upon the center dot. To insure the linearity of the system O then, on command from E, repeatedly fixated all the dots including the center one and E made further adjustments, if necessary, until the marker light was superimposed upon which ever dot O was fixating. At the end of alignment, O was instructed: "Your job in this experiment is simply to look at the pictures which I will soon show you."

After the instructions, all lights including those illuminating the target were turned off and the subject was told to get ready for the first picture. The test pattern was then removed from the target holder and the camera was turned on, followed a split-second later by the lights. The camera stayed on for exactly 6 seconds for each recording and ran at a speed of 16 frames/second. The first 8 men and 8 women were shown the pictures of Set A. The first male saw them in the order 1, 2, 3, 4; the second in the order 2, 3, 4, 1; the third, 3, 4, 1, 2; the fourth, 4, 1, 2, 3; the fifth, 1, 2, 3, 4; etc. The same procedure was followed with the women so that two men and two women saw the pictures in each of the four orders. The next 16 subjects (each group of 16 subjects contained 8 men and 8 women) were shown the pictures of Set B in the same manner. The third group was shown the pictures of Set C by the same procedure. In the final group of 16 subjects each person saw only one picture: 4 subjects (each group of 4 was composed of 2 men and 2 women) saw picture B2, 4 saw picture B3, 4 saw picture C3, and 4 saw picture C4. The final group was used to collect more observations on these four pictures since the first three groups yielded fewer observations on these pictures than on the others. That is, pictures A1 and A2 also appeared as C1 and C2 and pictures B1 and B4 also appeared as A1 and A3.

RESULTS

The data was scored by means of a Bell and Howell film analyzer. This projected the film onto a screen and allowed E to advance the film one frame at a time and record on a copy of the target the position of each fixation. Fixation time, the parameter used in the statistical analyses, is thus in units of one frame. Since the film speed used in recording was 16 frames/ second, each frame represents .0625 seconds. Of course, the shutter was not open during the entire .0625 second cycle so that where there was a movement between one frame and the next it may represent more or less than .0625 seconds.

First, a t-test was performed to learn whether there is an overall tendency to look more to the right side than to the left. Set A and Set C were used for this analysis since all the pictures in these two sets either were symmetrical (pictures C3 and C4) or had mirror images (pictures A1, A2, A3, A4, C1, and C2) so that the sideward differences in content were balanced out. Data from Set B could not be included since this set did not contain its own mirror images. In this test, data from Sets A and C were totalled across subjects and the expected time on the left half (50% of the total time spent on both halves divided by 32) was subtracted from the mean actual time spent on the left half and the difference divided by the standard error of the mean as determined from the left-half sample. No significant difference was found.

In order to gain information about sex and order variables as well as to gain more detailed information about the picture variable, separate analyses were performed on Sets A and C according to the following Latin square design:

Table 1.--Latin Square Design Used in Analyses of Variance.

		a	a	a	a
c	G	b_1	b_2	b_3	b_4
	G	b_2	b_3	b_4	b_1
	G	b_3	b_4	b_1	b_2
	G	b_4	b_1	b_2	b_3
c	G	b_1	b_2	b_3	b_4
	G	b_2	b_3	b_4	b_1
	G	b_3	b_4	b_1	b_2
	G	b_4	b_1	b_2	b_3

where time on the left side is the dependent measure and where:

a = Order

b = Pictures

c = Sex

G = Groups (pairs of the same sex seeing the same order of presentation--not to be confused with the groups of subjects defined earlier)

This analysis of Set A (Table 2) shows no significant Sex or Order effects but does show a significant effect for Pictures ($p < .01$). This significant F reflects, in part, the large differences in time spent on the left

Table 2.--Analysis of Variance of Fixation Time (No. of Frames) on Left Half of Pictures of Set A.

Source	SS	df	MS	F
Between Subjects	9,437	15	629	.87
Sex	564	1	564	.78
Groups within Sex	3,118	6	520	.72
Subjects within Groups	5,755	48	719	
Within Subjects	39,203	48	817	1.51
Order	1,313	3	438	.81
Pictures	14,178	3	4,726	8.74**
Order X Sex	1,015	3	338	.62
Pictures X Sex	1,630	3	543	1.00
Residual	8,093	12	674	1.25
Error	12,973	24	541	

*Denotes significance at .05 level.

**Denotes significance at .01 level.

side between pictures A1 and A2 (a total of 830 frames vs. a total of 522 frames, respectively) and between pictures A3 and A4 (a total of 709 frames vs. a total of 496 frames, respectively). It is not surprising that there should be a large difference between pictures A3 and A4 since in one (A3) of them nearly all the items are on the right side, whereas on the other (A4) nearly all of them are on the left. However, the direction of this difference might seem rather surprising, i.e., the majority of fixation time in both cases is on the relatively empty side. Also, it might be considered surprising that pictures A1 and A2, which are more balanced, should reveal an even larger effect of this sort. In fact, a Newman-Keuls test shows the difference between A1 and A2 to be significant while that between A3 and A4 is not. Figure 18 shows these differences graphically.

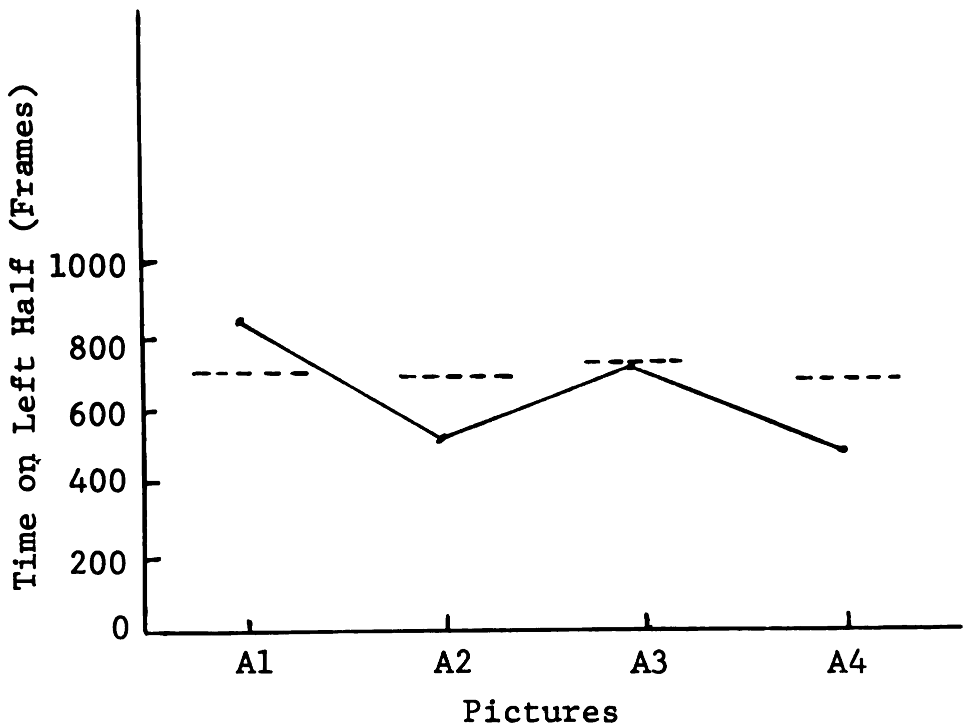


Figure 18.--Total Fixation Time on the Left Half of the Pictures of Set A. Dashed lines indicate the expectations at .50 probability of fixating on the left half. Expectations were obtained by dividing the total fixation time on each picture by 2.

The analysis of variance of Set B is shown in Table 3. Again, the only significant effect was that for Pictures ($p < .05$) although the Order X Sex interaction approached significance ($F = 2.59$).

Table 3.--Analysis of Variance of Fixation Time (No. of Frames) on the Left Half of Pictures of Set B.

Source	SS	df	MS	F
Between Subjects	30,875	15	2,058	.691
Sex	133	1	133	.045
Groups within Sex	6,921	6	1,153	.387
Subjects within Groups	23,821	8	2,978	
Within Subjects	48,298	48	1,006	1.189
Order	556	3	185	.219
Pictures	11,277	3	3,759	4.443*
Order X Sex	6,579	3	2,193	2.592
Pictures X Sex	3,840	3	1,280	1.513
Residual	5,734	12	478	.565
Error	20,312	24	846	

*Denotes significance at .05 level.

The difference across pictures is shown in Figure 19. Time on the left side is maximal with B2 and falls off on either side.

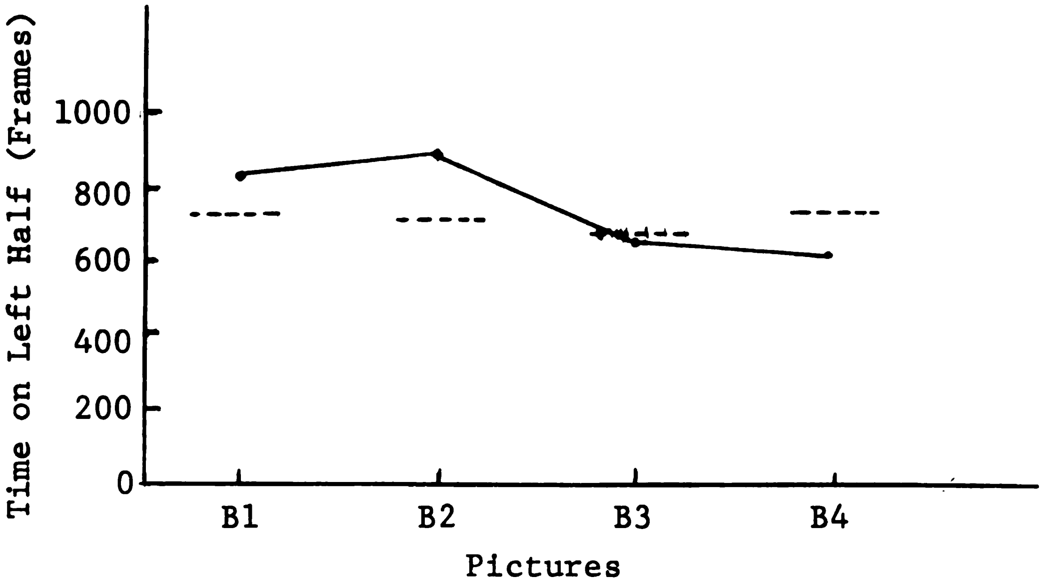


Figure 19.--Total Fixation Time on the Left Half of the Pictures of Set B. Dashed lines indicate the expectations at .50 probability of fixating on the left half. Expectations were obtained by dividing the total fixation time on each picture by 2.

In Set C (Figure 20 and Table 4) none of the Fs reached significance. Pictures C1 and C2 show the same order of difference (a total of 754 frames on the left for C1 vs. a total of 558 frames on the left for C2) as they showed in Set A (A1 and A2) but this effect does not reach significance because of the similarity of pictures C3 and C4 with respect to fixation time on the left side (610 frames vs. 543 frames, respectively).

Table 4.--Analysis of Variance of Fixation Time (No. of Frames) on the Left Half of Pictures of Set C.

Source	SS	df	MS	F
Between Subjects	17,957	15	1,197	1.211
C	963	1	963	.975
Groups within C	9,093	6	1,515	1.533
Subjects within Groups	7,902	8	988	
Within Subjects	31,911	48	665	.901
A	602	3	201	.272
B	5,242	3	1,747	2.367
AC	146	3	49	.066
BC	736	3	245	.332
Residual	7,482	12	624	.846
Error	17,702	24	738	

*Denotes significance at .05 level.

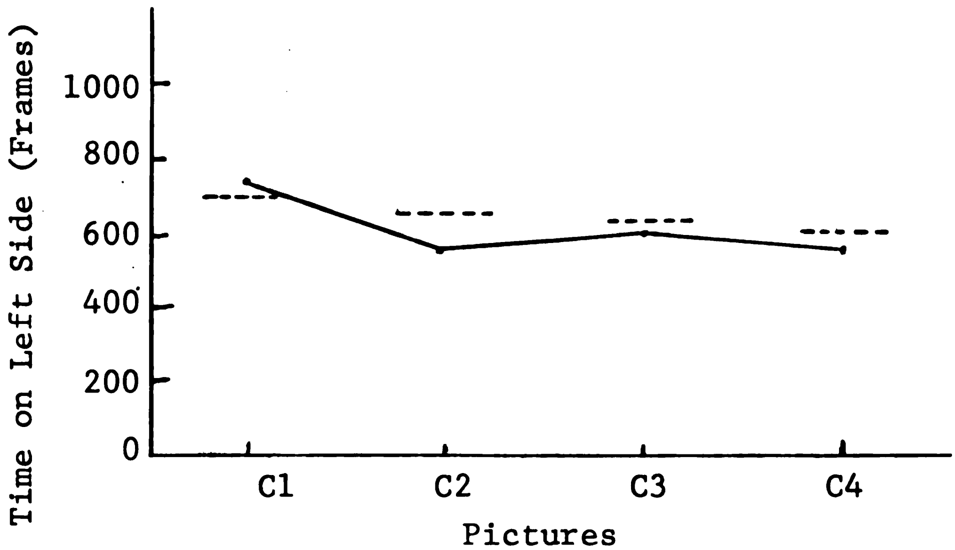


Figure 20.--Total Fixation Time on the Left Half of the Pictures of Set C. Dashed lines indicate the expectations at .50 probability of fixating on the left half. Expectations were obtained by dividing the total fixation time on each picture by 2.

In order to learn how the sex, order, and pictures variables influenced fixation time on the critical foreground item, another set of analyses was performed on Sets A and B using the same Latin square design. The only difference was that in this case the dependent variable was fixation time on the foreground item rather than fixation time on the left side. Neither Sets A nor B (Tables 5 and 6, respectively) showed any significant differences. Set C was not analyzed by this method since pictures C3 and C4 contained two foreground items.

Table 5.--Analysis of Variance of Fixation Time (No. of Frames) on Foreground Item for Set A.

Source	SS	df	MS	F
<u>Between Subjects</u>	3,532	15	235	1.11
Sex	248	1	248	1.18
Groups within Sex	1,594	6	266	1.26
Subjects within Groups	1,690	8	211	
<u>Within Subjects</u>				
Order	296	3	97	.87
Pictures	855	3	285	2.57
Order X Sex	276	3	92	.83
Pictures X Sex	692	3	231	2.08
Residual	1,144	12	95	.86
Error	2,666	24	111	

*Denotes significance at .05 level.

Table 6.--Analysis of Variance of Fixation Time (No. of Frames) on Foreground Item for Set B.

Source	SS	df	MS	F
Between Subjects	10,000	15	667	1.38
Sex	447	1	447	.93
Groups within Sex	5,692	6	949	1.97
Subjects within Groups	3,861	8	482	
Within Subjects	22,799	48	475	.97
Order	3,073	3	1,024	2.08
Pictures	397	3	132	.27
Order X Sex	1,193	3	398	.81
Pictures X Sex	1,944	3	648	1.32
Residual	4,378	12	365	.74
Error	11,815	24	492	

*Denotes significance at .05 level.

To further examine the question of whether fixation time on the foreground item varied in a systematic way with its position, a trend analysis was performed on the pictures of Set B. The pictures of Set B, it will be remembered, varied only with respect to the position of the critical foreground item; all other elements were held constant. Fixation time on the foreground item was the dependent variable and linear quadratic and cubic trends were tested. As Table 7 shows, no such trends were found.

Table 7.--Trend Analysis of Fixation Time (No. of Frames) on Foreground Item in Set B.

Source	SS	df	MS	F
Between	424	3		
Linear	367	1	367	.68
Quadratic	9	1	9	.02
Cubic	47	1	47	.09
Error	34,443	64	538	
Totals	34,867	67		

*Denotes significance at .05 level.

Nor were any effects of this sort found when the data from men and women were analyzed separately as shown in Tables 8 and 9.

Table 8.--Trend Analysis of Fixation Time (No. of Frames) on Foreground Item in Set B (Men).

Source	SS	df	MS	F
Between	1,893	3		
Linear	410	1	410	.58
Quadratic	3	1	3	.00
Cubic	102	1	102	.14
Error	22,806	32	713	
Totals	24,698	35		

*Denotes significance at .05 level.

Table 9.--Trend Analysis of Fixation Time (No. of Frames) on Foreground Item in Set B (Women).

Source	SS	df	MS	F
Between	304	3	154	.45
Linear	154	1	154	.45
Quadratic	3	1	3	.01
Cubic	137	1	137	.40
Error	9,637	28	344	
Totals	9,961	31		

*Denotes significance at .05 level.

Again using the pictures in Set B, a trend analysis was performed on the number of foreground item to background item (tree) and background item to foreground item movements. This was done to determine whether the number of such movements varied systematically as the foreground items moved from left to right. Table 10 shows that no such trends were found.

The next set of tests was directed at the glance curve question which meant looking for certain types of regularities across subjects with respect to the sequence of their fixations across subjects with respect to the sequence of their fixations. Specifically, this meant looking for any hint of the lower-left-to-upper right sequence postulated by Wolfflin, Gaffron, and others.

Table 10.--Trend Analysis of Foreground to Background and Background to Foreground Item Movements in Set B.

Source	SS	df	MS	F
Between	.093	3	.031	.323
Linear	.024	1	.024	.250
Quadratic	.040	1	.040	.417
Cubic	.021	1	.021	.219
Error	6.157	64	.096	
Totals	6.25			

*Denotes significance at .05 level.

In the first, a t-test was performed on the number of foreground item to background item and background item to foreground item movements in pictures A1 and C1 vs. those in A2 and C2. Picture A1-C1 would, according to Wolfflin and Gaffron, have good lateral composition since the major items in this picture fall along the glance curve whereas picture A2-C2 is an example of bad lateral composition since here the major items do not fall along this curve. It was expected that there would be more such movements in picture A1-C1 where the item placement and postulated glance curve are in harmony than in picture A2-C2 where they conflict. However, no such difference was found.

Although, as shown above, there is no hint of a lower-left-to-upper right movement tendency, further tests revealed a fairly strong tendency for the eyes to move initially from left to right when viewing a picture. Looking at the first fixation alone, we find that more of them fall on the left half of the pictures than on the right half. In this absolute sense of left half vs. right half the effect does not quite reach significance ($t = 1.62$). However, when the position of the first fixation relative to the second was noted, there was found a significant tendency for the first fixation to fall to the left of the second.

To analyze these sequential effects, binomial tests were used and the relative position of the first fixation to that of the second, i.e., to the right or left, was noted. Since only one score could be assigned to each subject in these tests, four identical tests (one for each of the four pictures viewed by most subjects) were run. One of these four tests (I) used data from the first picture viewed by each subject, another (II) used the data from the second picture seen by each subject, etc. Data from those subjects who viewed only one picture were included in (I). In all cases, there was a significant tendency for the first fixation to lie to the left of the second ($p < .01$, $p < .05$, $p < .01$, and $p < .05$, respectively).

Also, using only the first picture seen by each subject, a binomial test was performed comparing the absolute side of the first fixation to the side at which he looked most. Instances in which both of these fell on the same side were discarded, leaving 36 usable observations. There was a significant tendency for the initial fixation to be on the left half relative to the half which was looked at most (right half).

As in the Noton and Stark (1971) study, there was a strong tendency for subjects to repeat previous fixations rather than fixate on a new point every time. Each 6-second record was examined to determine the longest sequence of new fixations, i.e., the maximum number of movements made before returning to a previous fixation point. The average of these longest sequences over all subjects and all pictures was 2.08 new fixations before returning to a previous fixation point. The mode number of such new fixations was two, with one being the second most common and then three, four, five, and six in that order. The maximum number of these new fixations found in any record was six (there were two of these). In most cases, the previous fixation point returned to was the one immediately preceding the new fixation or fixations.

Generally, about four types of looking behavior could be seen in the records: (1) a relatively long period of time during which the subject simply fixated on one point, (2) a series of short, redundant movements covering perhaps two or three points of which the initial fixation point was one, (3) a series of new, exploratory fixations but again returning to the initial fixation point, and (4) a relatively long sequence of fixations covering anywhere from three to seven points repeatedly traced. A sequence of this latter type (4) was often momentarily interrupted for a backward movement to a previous fixation point. A variation on (3) was for the subject to move back to the initial fixation point after every single exploratory foray to a new fixation point.

The different looking behaviors generally tended to occur in the order listed, but all behaviors were by no means included in every record. In fact, it was more common for one or more to be omitted on any given record. Looking behaviors showed a great deal of consistency within subjects across pictures. It might also be noted that the one pair of brothers used in the study showed no particular similarities in looking behavior.

The final t-test was designed to learn whether observers tend to form a stronger scanpath (whatever the shape of that path) when viewing pictures with "good" lateral composition than when viewing pictures with "bad" lateral composition. The number of times a scanpath was traced in picture A1-C1 was compared to the number of such tracings in picture A2-C2. No significant difference was found.

In short, the results showed that: (1) there was no significant difference between time spent on the left and right halves, (2) the only evidence for any sort of a glance curve was the tendency to look first to the left and then, in a series of one or more fixations, move to the right, (3) there was no correlation between fixation time on the critical foreground item and its position in the picture and, (4) none of the tests of sex or order effects turned out to be significant.

DISCUSSION

The fact that the first fixation tends to fall to the left of later fixations indicates that first fixation may measure something different than does length of fixation. A study by Hackman and Guilford (1936) is of interest in this connection. In a study of eye movements and attnetion, they chose targets involving four of the well-accepted factors of visual attention: position, isolation, size, and novelty. The position slides contained nine letters (ordinary typewritten capital letters) arranged symmetrically in three rows and three columns with the center letter in the exact middle of the slide. The isolation slides contained one letter on one side of the slide and a group of letters (ranging from seven to twelve in number) on the other side. The size slides had ordinary capital letters on one side and large typewritten capital letters in a larger group on the other side. The groups of large letters and small letters were arranged each with five letters, two in the top row and bottom row and one in the middle, the whole slide being arranged like a domino with five spots on each side. The novelty slides had five ordinary typewritten capital letters (arranged in the same grouping as above) on one side and a group of five novel items, arranged in the same manner, on the other side. The novel items were colored or black geometric forms and typewritten digits. Both short (100 msec.) and long (10 sec.) exposure times were used and subjects were instructed to "observe the exposure field and report which part of the field is most prominent or most compelling, most intriguing or the part you feel most inclined to look at." As a double check, subject reports of attensity value were taken after each presentation and the portion of the slide intended by E to be the most attention-getting was nearly always the one reported.

They found that locus of the first fixation correlated more highly with reports of attensity than did length of fixation. Further, the average correlation between the first fixation and length of fixation was only .337. They, in fact, found some tendency for greater fixation time on the side of the field not containing the factor of attention, possibly due to the greater difficulty of cognition involved in the <u>small</u> letters, the <u>group</u> of letters opposite the isolated letter, or the <u>familiar</u> items, which were letters, as opposed to geometric figures and digits. They concluded that the length of fixation was the best indicator of what they called cognition. This was supported in a second part of the study in which subjects were instructed to "observe the exposure field and report what you have seen. Describe or name as many objects as you can observe." In this case, length of fixation correlated best with the objects reported. In a study to be described more fully later, Lewis, Kagan, and Kalafat (1966) also found the first fixation to be a better measure of differential attention than was the longest fixation.

If these results can be directly related to the present study it would seem that the left side of a picture is more attention-getting than the right side. This pattern of the first fixation being to the left of subsequent fixations was also quite pronounced in the face study described earlier. Beyond this, it remains, to be seen just how general this pattern is, i.e., how many different types of targets evoke this response.

No significant sex differences were found with the adult Ss used in the present study. Other eye movement studies have generally found sex differences when children were used as the subjects but not when adults were used. Hoats, Miller, and Spitz (1963), for example, found that normal eight-year-old boys had more perceptual curiosity than did girls of that age when such Ss could request either a simple or complex pattern during a viewing spell. Their evidence was that the boys chose the complex designs twice as often (50% of the occasions) as did the girls (25%). No such difference, however, was found in subjects aged 17 years.

In a habituation study by Mackworth and Otto (1970) subjects were presented with repeated viewings of a display of 16 circles, one of which changed from red to white on each trial. Boys spent 23% of the time inspecting this circle whereas the girls spent only 8% of their time on this circle. At the beginning of this test there was an even greater difference since the boys averaged 42% and the girls 12%.

A study by Lewis, Kagan, and Kalafat (1966) found that six-month-old female infants spent a significantly longer time looking at faces (one male, one female, and one schematic) than at non-faces (checkerboard, bulls-eye, bottle). The six-month-old boys, however, showed no differences. In a finding reminiscent of that of Hackman and Guilford (1936), they found the first fixation to be a more sensitive index of differential attention than was total fixation time, since the girls showed an even greater difference between the faces and non-faces when first fixation was used as the measure. Again, the boys showed no difference.

Whether any of the rather large inter-subject differences in scanning behavior found in the present study are related to intelligence or any other personal variables is not known. A study by Guba, Wolf, deGroat, Knemeyer, van Atta, and Light (1964) which dealt with much smaller eye movements found such a relationship. They recorded the eye movements of subjects viewing a TV screen and counted the instances of what they called NOMs (no observable eye movement from one frame to the next) and MINs (a movement of between 15 minutes and one degree of visual angle). They found that the intelligence groups differed sharply for NOMs and MINs; high intelligence subjects displayed more NOMs than MINs while low intelligence subjects displayed more MINs than NOMs.

The scanpaths noted by Noton and Stark were very much in evidence in the present study. Still, a great deal of time was spent in not tracing any predictable scanpath. This shift back and forth from the predictable to the unpredictable is perhaps best handled by the model proposed by Furst (1971). He used pictures of real-life objects and focussed in on the learning and habituation aspects of the scanning pattern, a process which he called automatizing of visual attention. He noted that as time went on the locii of eye fixations became more and more predictable and the rate of fixations dropped. This decrease in rate he called habituation. He also found a tendency for fixations of short duration to be followed by eye movements of short distance and for fixations of long duration to be followed by movements of a longer distance. He proposed an interesting model to account for his results:

> The significance of the finding that long fixations tend to be followed by long eye movements may be seen in terms of a speculative hypothesis about momentary shifts of attention. It is suggested that the difference in average transition distance reflects a difference in central attentional state which is signified by long or short fixations. Assume that there are two central states, corresponding to "attention" or "inattention" to the visual channel. Commands for a new fixation can occur from either of these states but the parameters of control of eye movements will be different for each state. Probably the commands from an "inattentive" state will be coarser and result in relatively longer movements. . . . It has previously been seen that average fixation time increases during habituation. If one can further assume that long fixations reflect periods of central inattention to the visual channel, the difference in average transition length between brief and long fixations is explained.

For purposes of the present study we can think of two central states, one giving rise to predictable movements and the other giving rise to unpredictable movements. If it is the case that long fixation durations and long movement distances are associated with predictable movements and short fixation durations and short movement distances are associated with unpredictable movements, then the results of the present study fit directly into this model.

The question of the relationship of eye movements to pattern recognition and memory remains open. For as Noton and Stark themselves point out, the regularities in scanning behavior do not prove that these movements are an integral part of the process by which we recognize pictures as their serial model states. Rather, they assumed such a model and set out to examine the implications of this assumption. Their stimulus conditions, in fact, were designed to promote serial processing; the stimulus pictures were dimly illuminated relative to the general illumination so that subjects could barely see any parts of the pictures not viewed foveally. It is noteworthy, however, that the same regularities in scanning behavior were noted with the more normal illumination conditions of the present study, thus indicating that the scanpaths they found were not just artifacts of their design.

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