STRUCTURED VS. UNSTRUCTURED SCAN PATH IN STATIC VISUAL SEARCH PERFORMANCE

by

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My sincere thanks to all the subjects who endured the eye strain to make this study possible.

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INTRODUCTION

There has been a tremenduous advance in manufacturing techniques over the last decade. However, most inspection methods still rely on the ability of the human operator to detect defects. Hence effective means of visual inspection is very important to industry.

Harris and Chaney (1969) define three basic categories of inspection tasks: those involving scanning or visual search, measurement and monitoring. This study deals with visual search to detect a defect or target.

A good deal of visual inspection involves static visual search. Objects whose images remain stationary on the retina whatever movement the eye makes are conventionally known as a "static visual field".

Visual search and eye movements are very closely interlinked. Hence it is logical to study eye movements to learn about viusal search.

Eye movements and scan patterns.

Visual search is the act of an observer looking for a target or targets within some type of background. During this process of search, the eye fixates on a point and then jumps rapidly to another point of fixation. The rapid movement of the eye from one point to another is termed a saccade. The time taken for a saccade is very short. It moves through an angular distance of 15° in approximately 1/20 second (Yarbus, 1967). Some movements of the eye are generally involuntary. But for the most part the observer determines in some manner where the next fixation will be located.

In studies of visual search it has been found that search performance and peripheral visual acuity are related. This correlation has been found with targets presented amongst competing nontargets (Smith, 1961, Johnson, 1965, Bloomfield and Howarth, 1969), for targets presented against a plain background (Bloomfield, 1970) and for textured targets embedded in a textured background (Bloomfield et al 1974).

The main factors pertaining to the eye during a static visual search are: duration of eye fixations, number of eye fixation, scan path or the eye fixation path, and interfixation distances.

Duration of eye fixations. Gould (1969) reported that the eye normally fixates approximately three times a second, but that the fixation duration is dependent on the nature of the task, training of the subject and the similarity of the pattern with the background. Gould and Dill (1969) reported an increase in eye fixation duration with an increase in the number of elements in the target. Gould (1967) also found that the number and duration of eye fixations increased as the target patterns became more similar to nontarget patterns. The mean fixation duration was 0.37 sec. Ford and White (1960) found a mean fixation duration of 0.35 sec in a simulated radar search.

Location of fixations. Enoch (1959) in his study with photo-interpreters searching aerial maps found that (1) coverage of the display was not uniform (2) fixations were concentrated in the center of the display (3) the display periphery was generally ignored, and (4) the lower right quadrant received more attention than the upper-left quadrant, with the other two quadrants receiving some intermediate degree of attention.

Ford et al (1959) used a single target display while Enoch (1959) used an aerial map. Ford et al found that the display was not uniformly searched and that the center of the display was neglected. Fixations were concentrated in a circular band located approximately midway between the center and the periphery of the display.

Schoonard et al (1973) conducted a study using integrated circuit chips which subtended a visual angle of 18°. They found that there were few fixations on the edges of the chips; the duration of the fixations differed considerably when different features of the chips were fixated; that fixations were clustered where the chips were most complex and that there were few refixations. They were unable to pick out repeated patterns of eye movements, nor find differences in the patterns of the different inspectors.

Interfixation distances. Enoch (1959) found that as the display size decreased, duration of fixations increased and interfixation distances decreased. Thomas and Lansdown (1963) in their study of radiologists reported a great variation among subjects, ranging from a mean interfixation distance of 1.69 in to 3.49 in, or roughly 2.22 to 4.17 arcdegrees for a viewing distance of 48 in.

Scan paths and eye fixation patterns. Locher and Nodine (1974) in their study of the role of scan paths in the recognition of random shapes observed that scan paths exist regardless of the shape complexity and although scan paths did not influence recognition performance, their occurance implicates them as a potential factor in the recognition process.

Enoch (1960) listed some possible search patterns, spiral, up and down and closing square pattern, and a combination of these. Enoch (1960) also suggested that the search pattern can be divided into an orientation phase and a specific search phase. Ford and White (1960) found that the shape and extent of the field of search determine how an observer will search in a given situation.

Frith Uta (1975) found that scanning from left to right through an array of shapes was slower with vertical than with horizontal lines. The reverse was true for scanning from top to bottom. Thus lines lying across the direction of scan appear to act as barriers. Lines along the scan appear to aid the scan.

Enoch and Towns (1959) studied eye movements under conditions of free search as well as with an automatic scanning apparatus. In addition, the subjects were instructed to search by scanning in a boustrophedon pattern similar to the pattern presented by an automatic scanning machine (left and right oriented square waves). Half of the group obtained enhanced feedback information by means of an after image method (exposed to a bright "X"). They concluded that an individual's search pattern may be modified to provide more uniform coverage and that the after image feedback techniques enhanced search effectiveness.

Fry and Towns (1960) in their investigation of an automatic scanning device for aerial photographs concluded that automatic scanning results in a more uniform coverage of the display than free search and that automatic scanning is best for low visibility targets. They also felt that free search is more efficient for detection purposes when targets have high visibility.

Reading and eye movements.

Reading also involves a type of search and it is interesting to consider whether reading ability and visual search can be related.

McConkie et al (1976) found that the perceptual span in reading is asymmetrical rather than symmetrical. They found that none of the subjects appeared to use visual information more than four character positions to the left of the fixation point though all of them acquired visual information substantially farther than that to the right.

Hawley et al (1974) studied eye movements during reading. They found that in relatively skilled readers fixation duration for the fixation pause prior to, during, and immediately following a regressive eye movement are significantly shorter than those associated with "normal" reading patterns. The first fixation pause following the return of the eye to a new line is significantly longer than those associated with "normal" reading, while duration of the last fixation pause on a line is more variable than the other fixations. The study identified five eye movement patterns which can be discriminated both qualitatively and quantitatively from normal forward going reading patterns.

Stennett et al (1972) investigated the relationship of eye-movement measures to psychomotor skills and other elemental skills involved in learning to read. They concluded that efficient eyemovement behavior during reading is primarily a result rather than a cause of good reading. Taylor (1965) stated "Eye movements are neither the cause nor the effect of good or poor reading. The eyes do not dictate to the mind what it shall understand; neither does the mind dictate to the eyes where they shall look. Instead there exists an interaction and interdependence between the oculomotor activity and the central processess, each function indirectly influencing the other". However, Carroll in Singer and Ruddell, (1970) has interpreted efficient eyemovements primarily as a consequence of good reading. Tinker (1958) concluded that efficient oculomotor behavior is a requirement for good reading.

Researchers have found variability of fixation duration and saccade length within a passage of text. Gilbert (1959) found that poor readers often show longer fixation durations, more fixations, and more regressions than good readers. Recent studies by Goltz, (1975); Heiman & Ross, (1974); Rubino & Minden, (1973) have also found that poor readers show shorter saccades, longer fixations, and more regressions. Rubino et al (1973) have suggested that perhaps oculomotor training would improve the reading efficiency of poor readers.

Reading and visual search have a common parameter of eye movements. Although reading involves a cognitive process it is worthwhile to see if reading rate could be an indicator of good visual search performance. In search performance the cognitive process is greatly reduced as it just involves recognition of a defect or a pattern.

PROBLEM

Previous research has indicated that there is a relationship between eye movements and visual search performance. It has also been found that good readers have efficient eye movements. In this research an attempt will be made to inter-relate reading rate with visual search performance. In addition to search time, number of fixations, fixation durations, and interfixation distances will be used as a measure of visual search performance.

One hypothesis in this research was that people with a higher reading ability will have a better search performance. This means that the people with lower reading ability will have longer fixations and shorter saccades.

The other hypothesis tested was that a structured scan path gives a better search performance than an unstructured scan path.

METHOD

Task and Design.

In this study the task is a static visual search for incomplete O's embedded in a matrix of O's. The experiment is a completely randomized design. There were two search conditions, a structured search and an unstructured search. Each subject was exposed to only one condition. For unstructured search the instructions are given in Figure 1 and for structured search the instructions are given in Figure 2. The unstructured path was essentially an uninstructed condition wherein the scan path followed was left entirely to the subject's viewing preference. The structured path consisted of viewing line by line in a boustrophedon pattern. (See Figure 3). Each condition was replicated three times.

Apparatus.

The 1992 S eye view monitor and TV pupilometer system with free head movement manufactured by GW Applied Science Laboratories, Massachusetts, was used to detect eye movements. This system measures vertical eye-movements over a range of 25° (± 12.5°) and horizontal eye movements over a range of 30° (± 15°). The left eye was monitored for vertical and horizontal movements. Yarbus, 1967 has shown that the eyes are aligned coaxially.

The measurement of eye movement works on the principle of corneal reflection. The radius of curvature of the cornea is approximately 8 mm, and that of the eye about 12 mm (Yarbus, 1967). The center of curvature of the cornea is displaced 3-5 mm relative to the center of rotation of the eye. The cornea, like the convex surface of a lens, reflects part of the light falling on its surface as the corneal reflex (the sparkle of

INFORMED CONSENT AND INSTRUCTIONS FOR SUBJECTS

This research determines the relationship between reading rate and visual search performance. Please proceed as per the following instructions.

1. The experimentor will test your visual acuity, reading rate and then calibrate the equipment to measure your eye movements.

2. Your are required to look at the matrix of O's and search for incomplete O's.

When you detect an incomplete O please write on the paper provided in which portion the gap is observed.

Incomplete O	The gap is	Write
O	to the top	T
O	to the bottom	B
O	to the right	R
O	to the left	L

3. This will be repeated thrice with three different matrix displays.

Thank you very much for your co-operation. If you have any questions or comments please feel free to convey them.

There are no dangers or risks involved in this experiment. However, if you feel very uncomfortable during the experiment you are free to stop at any time. I will appreciate if you will complete the experiment. If you are ready for the experiment please sign the consent form attached.

Once again, I thank you for your co-operation.

Figure 1. Instructions for subjects for unstructured search.

INFORMED CONSENT AND INSTRUCTIONS FOR SUBJECTS

This research determines the relationship between reading rate and visual search performance. Please proceed as per the following instructions.

1. The experimentor will test your visual acuity, reading rate and then calibrate the equipment to measure your eye movements.

2. You are required to look at the matrix of O's and search in a regular pattern for incomplete O's. The path or pattern your eye should follow is shown on the next page.

When you detect an incomplete O please write on the paper provided in which portion the gap is observed.

Incomplete O	The gap is	Write
O	to the top	T
O	to the bottom	B
O	to the right	R
O	to the left	L

3. This will be repeated thrice with three different matrix displays.

Thank you very much for your co-operation. If you have any questions or comments please feel free to convey them.

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Once again, I thank you for your co-operation.

Figure 2. Instructions for subjects for structured search.

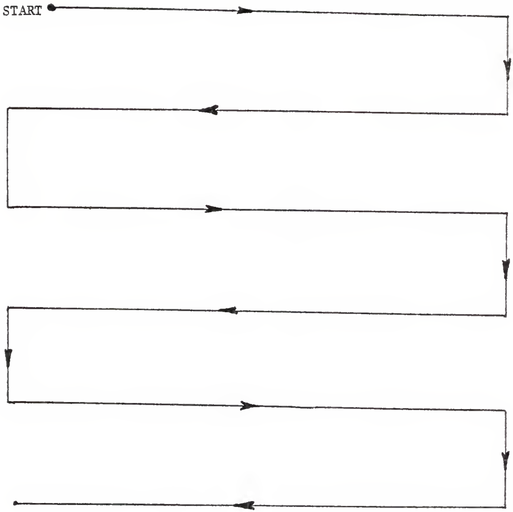


Figure 3. Search pattern (boustrophedon) which subjects under structured search were asked to follow.

the eyes). Since the center of rotation of the eye and the center of curvature of the cornea do not coincide, the angle at which a stationary source of light is reflected in the cornea changes during a movement of the eye so that the corneal reflex or corneal bright spot moves when the eye moves. The 1992 S Applied Sciences, Laboratories' eye view monitor system uses a light source which is near infra-red. Near infra-red does not hamper the visual ability of the subject. Figure 4 shows a schematic of the experimental set up.

Eye monitoring system. The 1992 S eye view monitor (Figure 4) consists of a TV camera which tracks the eye, an illuminator which generates the corneal reflection, a scene monitor camera which covers the display and control and computation circuits which gives the analog output of the eye movements.

Recording devices. The analog output of the eye movement was recorded on a model 7035 B X-Y recorder manufactured by Hewlett Packard. This gave a tracing of the eye movements. The movements which were also available as the horizontal and vertical components were recorded on a Texas Instruments heat sensitive chart recorder model 161684-006A.

Calibration.

Calibration grid. For each subject the equipment is calibrated using a calibration grid. The calibration grid consisted of a total number of nine points. See Figure 5. The extreme horizontal lines were at a distance of 4 arcdegrees and the vertical lines at a distance of 6.7 arcdegrees. These extreme points extended well beyond the corner points of the display.

Discriminator setting. The subject was seated comfortably on a height adjustable chair with his head positioned in the head rest.

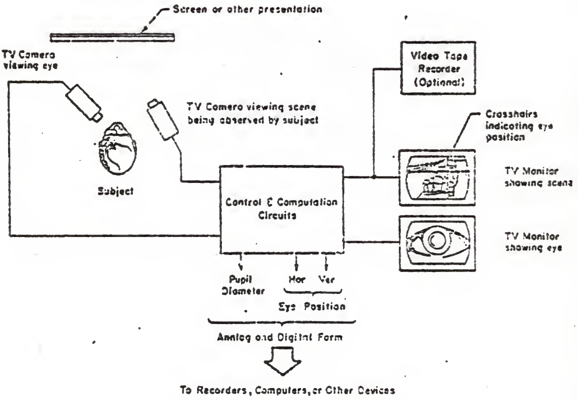


Figure 4   EYE VIEW MONITOR SYSTEM

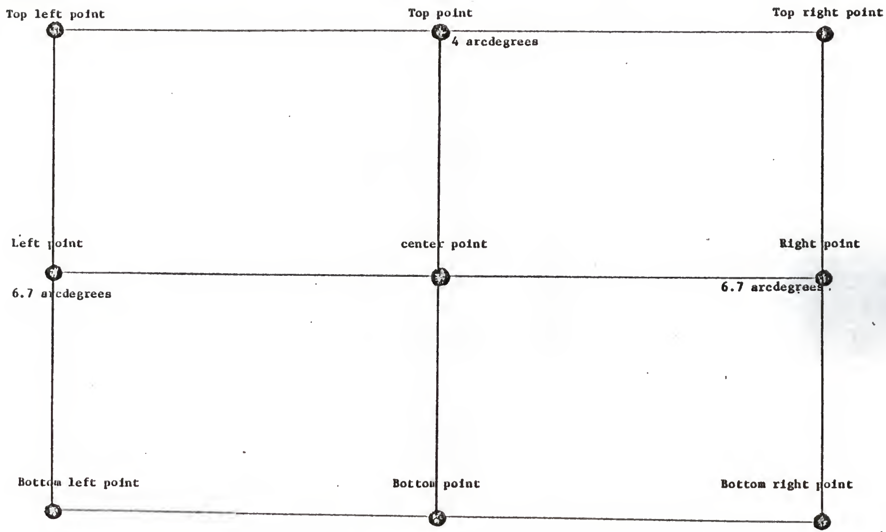
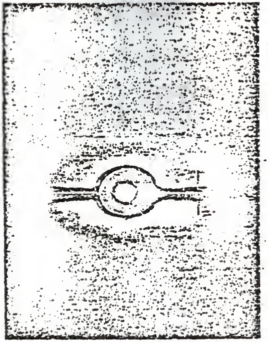


Figure 5. The calibration Grid.

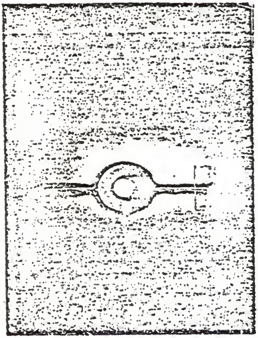
The movable platform and the height of the TV pupil camera was adjusted to get a sharp image of the eye on the eye view monitor screen. The f stop was generally set at 5.6 and the pupil camera at an angle of 60°. The fine focus adjustment on the pupil camera was used to make the finer adjustments. The illuminator position was adjusted to center the illumination pattern around the pupil. The illuminator adjustment was the most critical of all the settings. The correct illuminator alignment is shown in Figure 6. The subject was then asked to view the extreme points on the calibration grid. For each of the extreme points the pupil discriminator setting was checked. Proper setting gave an appearance similar to Figure 7a. The proper discriminator setting consisted of always obtaining pupil delimeters which are tangential to the pupil diameter and a pupil cresent. The next step consisted of a proper corneal reflection discriminator setting shown in Figure 7b. Proper corneal reflection discriminator setting consisted of always obtaining a corneal reflection crescent, and a corneal reflection centerline. Improper settings which are to be avoided are shown in Figures 8a,b,f,g,h.

The experimentor found that it required a good degree of skill to do the above settings on the subjects' eye. The experimentor obtained best results when the equipment was set using a model pupil (model pupil remains stationary, unlike the human eye, thus facilitating setting) and then making minor adjustments for the subject. Best results were obtained when the eye was positioned centrally on the eye monitor screen.

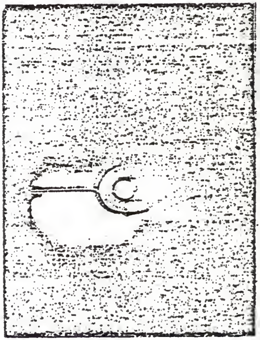
Special problems. Out of a total of thirty eight subjects, eight subjects could not be calibrated. Two subjects wore hard contacts which interfered with the pupil cresent. Two subjects wore thick glasses.



a. CORRECT APPEARANCE



b.
INCORRECT APPEARANCE



c.
INCORRECT APPEARANCE

Figure 6 ILLUMINATOR ALIGNMENT.

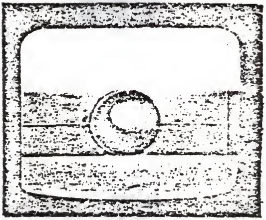


Figure 7a CORRECT APPEARANCE OF MODEL PUPIL WITH PUPIL DISCRIMINATOR BEING SET.

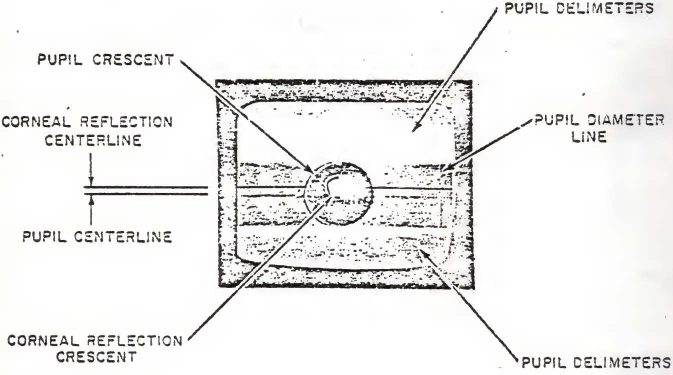


Figure 7b <u>CORRECT APPEARANCE OF MODEL PUPIL WITH BOTH PUPIL AND CORNEAL REFLECTION DISCRIMINATORS SET.</u>

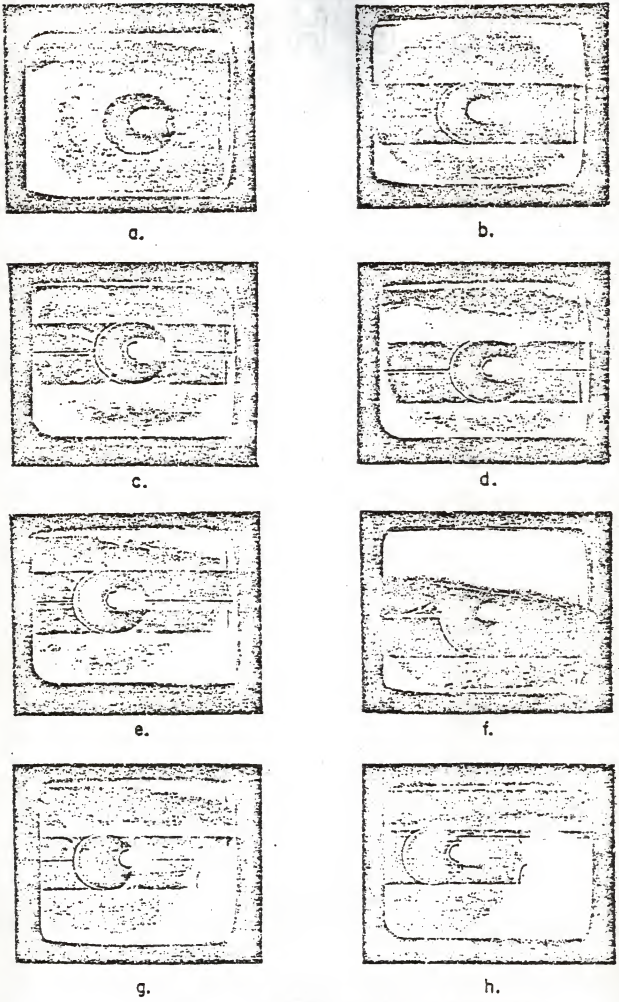


Figure 8 DISCRIMINATOR SETTINGS.

The frames obstructed a significant portion of the illuminator light and a good measurement could not be obtained. One subject wore hard contacts and had permanent eye lash makeup which caused the pupil delimeters to settle on the makeup rather than on the pupil. The delimeters identified the eye lash makeup as the pupil. The other subject when requested to return after removing eye lash makeup did not return. The eyes of two other subjects failed to give a linear output and hence could not be calibrated. This could be due to some form of eye defect.

Special settings. In subjects wearing thin glasses, interference in discriminator setting due to reflection off the glass surface was observed. This was overcome by turning the camera support arm beyond 60° till the shiny spot disappeared from the eye monitor screen. Subjects whose eye lashes drooped on the eyes were asked to open the eyes wide and stare for short periods of time. The display was also raised. Adjustment of the f stop and the height of the pupil camera also helped.

Calibration procedure. The subject was asked to view the center point, the top right point, the top left point, the bottom right point and the bottom left point in the calibration grid and the discriminator settings were checked for each of these points. When the subject viewed the center point the crosshairs were adjusted to the center point by adjusting the vertical and horizontal position knobs. Next the subject was asked to view the top right point. If the crosshairs fell short of the top right point the vertical and horizontal gains were turned clockwise. If the crosshairs overshot the point the vertical and horizontal gains were turned counterclockwise. Next the bottom right point was calibrated. The vertical linearity gain was turned in the direction DN, if the crosshairs fell short and in the direction UP, if the cross hairs over shot the bottom right point. In a similar manner the top left and the bottom left points were calibrated. The calibration was checked for the right point, the left point, the top point and the bottom point.

Display.

Preparation. The display consisted of a 10 x 18 matrix of O's with 8 incomplete O's randomly distributed among them. There were 2 incomplete O's in each quadrant. (The display was divided into 4 quadrants for the purpose of distributing the defects). A master matrix of O's was prepared on an IBM selectric typewriter. Three copies of the master were taken and the O's were made incomplete by the application of correction fluid. To keep the gap constant the correcting fluid was spread over the O by means of the slot in an IBM punched card. The incomplete O's were randomly distributed by means of random number tables. The opening or incompleteness in the O was restricted to the top, bottom, right or left position. Figures 9, 10 and 11 show the three displays.

Mounting. The displays were mounted on a rectangular cardboard with holes on the corner points. The rectangular cardboards were in turn mounted on to a wooden board with equally spaced holes drilled at a distance of 10 mm apart. See Figure 12. The equally spaced holes permitted moving the display left, right, top or bottom when it became extremely difficult to obtain proper pupil cresent setting. Moving of the display to the top helped in the case of subjects who had drooping eye lashes. The display was fixed on the wooden board by means of 4 mm diameter pins.

Size and position. The display subtended a total visual angle of 7.7 arcdegrees vertically and 10.75 arc degrees horizontally. The display

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 9. <u>Display</u>

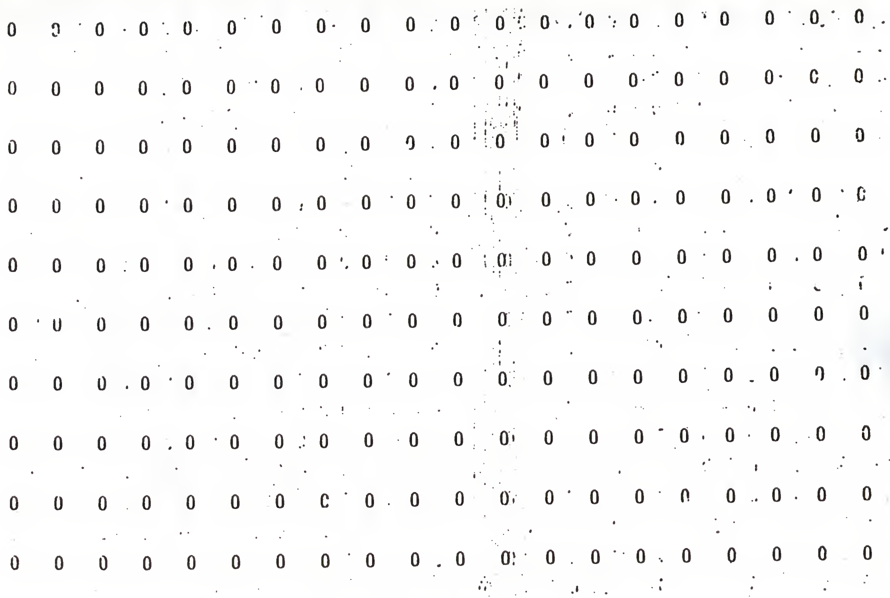


Figure 10. Display

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 11. Display

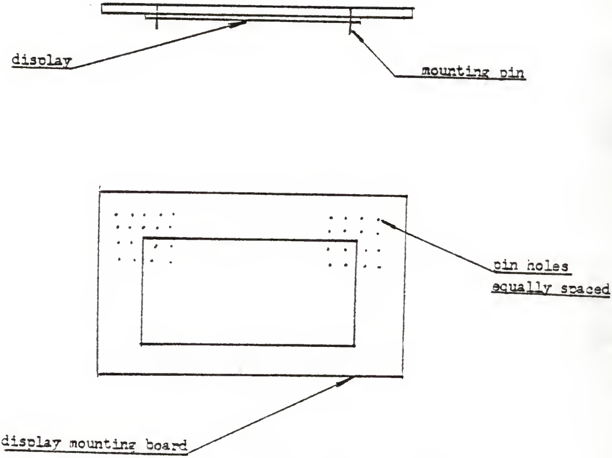


Figure 12. The display mounting board

size was 160 x 225 mm. The viewing distance was kept constant at 118 cm. The illumination level on the display was 28 foot candles.

Subjects.

Thirty eight subjects, all of them students, were recruited for the experiment. Most of them were randomly selected from those who had voluntered during summer registration. They were paid $5.00 for a maximum time of one and three quarters of an hour. Subjects wearing thick glasses and hard contacts were generally avoided as this presented special problems during calibration. Female subjects were specifically requested to remove their eye lash makeup as this interfered with the discriminator setting.

The age of the subjects varied from 18 to 30 years with a mean of 23 years. The male-female ratio was 1.

Experimental procedure.

Subject running. Based on a random sequence each subject was assigned either an unstructured search or structured search condition. For unstructured search subjects were asked to read the instructions given in Figure 1 and for structured search subjects were asked to read the instructions given in Figure 2. The subjects were tested for their visual acuity on a Titmus Vision Tester. On completion of the vision test the subjects were administered the Nelson Denny reading rate test published by Educational Testing Services, Princeton. The test took one minute to administer and the subject's reading rate in terms of word per minute was recorded. The reading rate test consisted of a passage with the number of words marked at the end of each line. In order to discourage the subjects from just glancing through the passage subjects were informed that they would be required to answer comprehension questions after reading the passage. After one minute the line on which the subject was gives the reading rate. The comphrension test was then waived.

The subject was then asked to sit comfortably with his head butting against the head rest and the chin wedged between the chin rest and the chin stop. When excessive head movements were observed the subject's head was fastened to the head rest by means of an elastic band.

Each experimental run was preceded by a calibration procedure which has been described. The calibration grid was manually removed and the display positioned in its place. The subject was asked to continue looking at the center point and to start the search after hearing the signal "start" from the experimentor. The subject was instructed to write the nature of the defect depending on the position of the opening or incompleteness in the O (T-top, B-bottom, etc see Figure 1 and 2) on the paper provided on the side of the subject's preferred hand.

Response measurements.

Recorder adjustments. While the subject continued to look at the center of the display the marker pens on the X-Y recorder and on the strip chart recorder were adjusted to the center of the recording paper. The start signal was then given to the subject and the recorders and a stop watch were simultaneously switched on. Figures 13 and 14 give a sample output from the chart recorder. The search time was measured using a decimal minute stop watch and the search time was recorded on a data sheet.

Figure 15 shows an output from the chart recorder using a model pupil. A fixation was defined as the time during which both the

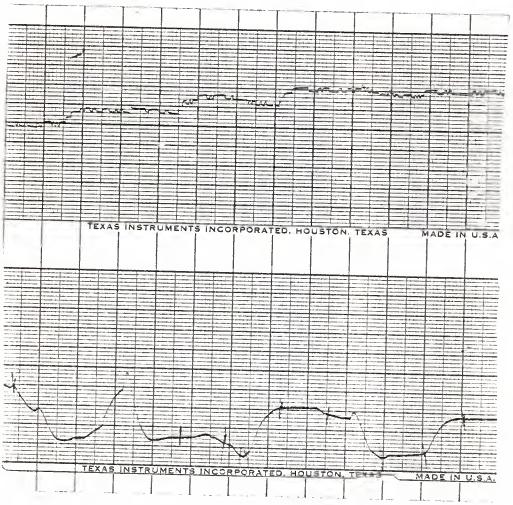


Figure 13. Sample chart recorder output for unstructured search

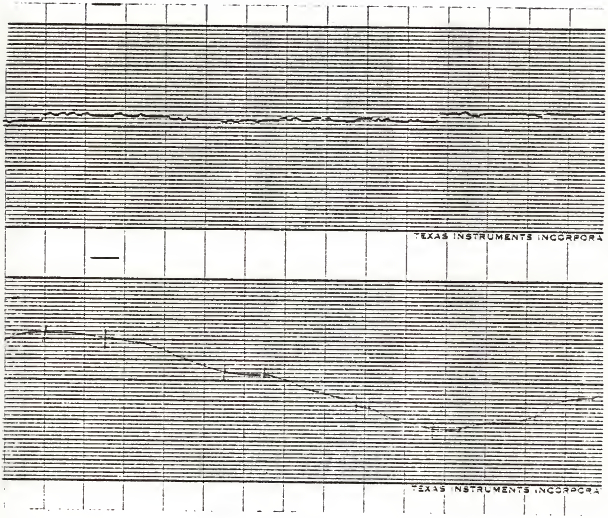


Figure 14. Sample chart recorder output for structured search.

vertical and horizontal axis remained parallel. The eye is never stationary. There are micro-saccades, and tremor of the eyes which constitute a movement of about 25 arcminutes. (Yarbus, 1967) The scale on the chart recorder corresponded to 1mm = 27 arcminutes. Hence non-parallelity within one scale division was accepted as a fixation and this was a limitation on the accuracy of the experimental setup.

RESULTS

There were three replications for each subject. The data was percentage accuracy, search time, fixation duration, number of fixations and interfixation distance. The reading rate was also recorded for each subject. Each of these parameters are defined in Appendix 1. Tables 1 and 2, give the data. The fixation duration, number of fixations and interfixation distances were obtained from the chart recorder output. A fixation was defined as the period over which the vertical and horizontal output are parallel within one scale division of the graph output (See Figure 15). The "1992S" eye view monitor has a measurement resolution of 1 part in 100 horizontally and vertically. One scale division of the graph output corresponded to 0.45 arcdegree or 27 arcminutes which constituted the experimental precision achievable with the existing experimental setup. The graph output also gave the vertical and horizontal co-ordinates of each fixation point. The square root of the sum of the squares of the vertical and horizontal components gave the interfixation distance which was later converted to arcdegrees. The graph scale limitation gave a precision of 0.45 arcdegree on the interfixation distance. The mean fixation time and the mean interfixation distance were then determined. For the fixation time, as the paper output was run at a speed of 25mm/s, one division equalled 0.04 s and this constituted the precision to which each fixation time could be determined. System inaccuracies have given rise to a cumulative error in that the search time does not very well

TABLE 1

Data for unstructured search (Means over replications for each dependent variable)

Subject No	Reading rate words/min	Percent accuracy	Search time seconds	Eye fixation time-seconds	No of fixations	Interfixation distance-arcdeg
1	170	95.8	41.6	.389	73.7	2.73
2	230	50	39.2	.321	99	3.10
3	266	91.7	59.2	.420	126	1.84
4	278	91.7	60.4	.375	120.7	2.33
5	252	93.7	50.6	.416	92.5	3.26
6	230	66.7	54.8	.391	91.3	2.01
7	291	66.7	90	.395	82.7	1.90
8	195	79.2	61	.528	64.3	2.15
9	301	91.7	48	.357	73	2.79
10	357	83.3	68.8	.479	90.3	3.82
11	182	87.5	43	.425	61.7	2.48
12	232	58.3	28.6	.339	55.7	3.10
13	207	79.2	51	.547	95	3.24
14	219	70.8	53	.343	113	3.07
15	291	83.3	64.6	.446	100	2.42
Mean	246.7	79.3	51.8	.411	89.9	2.68
Std dev	50.9	13.8	10.6	.086	20.4	0.58

TABLE 2

Data for structured search (Means over replications for each dependent variable)

Subject No	Reading rate words/min	Percent accuracy	Search time seconds	Eye fixation time-seconds	No of fixations	Interfixation distance-arcdeg
16	161	95.3	41.2	.378	75.7	3.83
17	291	62.5	41.2	.422	59	3.32
18	266	89.6	33.9	.388	61.7	3.41
19	207	91.7	44.8	.358	82.7	3.26
20	325	91.7	46	.427	69	3.35
21	219	75	32.6	.398	51.7	3.50
22	252	62.5	32.3	.294	78.3	2.85
23	266	79.2	34.2	.303	73.7	2.57
24	94	70.8	37.8	.381	59	2.56
25	387	70.8	24.9	.313	67.3	3.75
26	301	66.7	29	.334	54	3.60
27	207	75	44.2	.398	75	2.81
28	116	79.16	54	.369	112.5	3.55
29	325	83.3	39	.326	65.3	3.44
30	241	87.5	39.2	.437	53	3.59
Mean	243.8	78.7	38.4	.368	69.2	3.29
Std dev	79.8	10.8	7.5	.046	15.4	.41

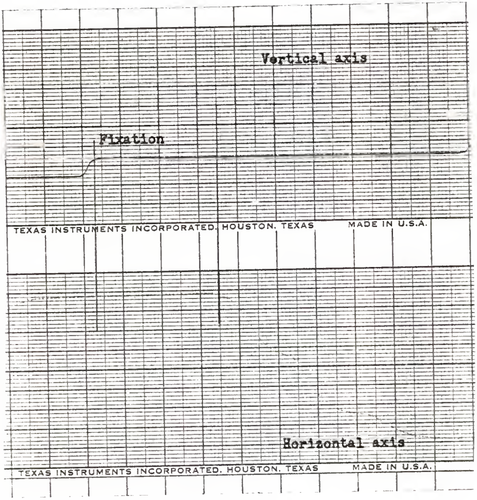


Figure 15. <u>Sample chart using a model pupil</u>

correspond to the mean fixation time multiplied by the number of fixations. Enoch et al (1959) in their study on instructed pattern search determined a mean fixation time of 0.417 s with 67 fixations for a search time of 29.2 s. (In some cases Enoch accounts for 100.03%. This does not give any time for eye movement or saccadic time). In Enoch's study the product of mean fixation time and number of fixations equalled 96 percent of the search time which is quite accurate.

In this study the mean fixation time for structured search was 0.368 s and the mean number of fixations were 69.08 for a mean search time of 38.4 s which accounted for 66 percent of the search time. In the case of unstructured search the mean fixation time was 0.411 s and the mean number of fixations were 89.92 for a search time of 51.35 s which accounted for 71.3 percent of the search time. Researchers have found that eye movement or saccades take up approximately 10 percent of the search time. The error could be due to the time lag in switching on the chart recorder, precision limitations of the graph output and human error in intrepretation of the fixation points.

One hypothesis in this research was that people with greater reading ability will have a better search performance. To evaluate this an analysis of covariance with reading rate as a co-variate was performed for each of the dependent variables. The other hypothesis tested was that a structured scan path gives a better search performance than an unstructured scan path. To evaluate this an analysis of variance and a one-tailed t test on the dependent variable means was used.

Percent accuracy

The overall mean percent accuracy for unstructured search was 79.3 percent and for structured search was 78.71 percent. The analysis of variance (Table 3) shows that there is no significant difference in the mean inspection accuracy between an unstructured and structured search condition.

The analysis of co-variance of inspection accuracy with reading rate as the co-variate is shown in Table 4. It is seen that reading rate and reading rate by treatment are statistically non-significant. The correlation coefficients between reading rate and accuracy for unstructured and structured search are (r 0.0898 and r 0.1286 respectively Tables 13 and 14) and are non-significant.

Search time

The analysis of variance (Table 5) shows that there is a significant difference in the mean search time for structured and unstructured search. The overall mean search time for unstructured search was 51.85 s and for structured search was 38.4 s.

Table 6 gives the analysis of co-variance for the mean search time with reading rate as the co-variate. Treatment and reading rate by treatment are significant (Alpha level 5%). Reading rate has a significant correlation with search time ($r + 0.54$ for unstructured search and $r - 0.52$ for structured search. See Tables 13 and 14). It is interesting to note that the correlation coefficients have opposite signs. This implies that good readers have a lesser search time or are more efficient in terms of time taken for visual search when instructed

TABLE 3

Analysis of variance for mean percent accuracy

Sources of variation	df	Mean Square	F Value	Alpha hat
Treatments	1	2.61	0.02	0.89
Error	28	156.42		
Total	29			

TABLE 4

Analysis of covariance of inspection accuracy with reading rate as the covariate

Sources of variation	df	Mean square	F value	Alpha hat
Treatment	1	38.42	0.23	0.64
Reading rate	1	1.32	0.01	0.93
Reading rate x Treatment	1	45.79	0.27	0.61
Error	26	166.56		

TABLE 5

Analysis of variance for mean search time

Sources of variation	df	Mean square	F value	Alpha hat
Treatments	1	3754.25	15.95	0.0004
Error	28	235.33		
Total	29			

TABLE 6

Analysis of covariance for mean search time with reading rate as the covariate

Sources of variation	df	Mean square	F value	Alpha hat
Treatment	1	793.78	4.40	0.045
Reading rate	1	291.49	1.62	0.214
Reading rate x Treatment	1	1899.53	10.54	0.003
Error	26	180.29		

to follow a structured path but not with unstructured search path. This aspect and the reasons are covered in detail under discussion.

Eye Fixation Time

The unstructured search had an overall mean eye fixation time of 0.411 s and the structured search 0.368 s. The analysis of variance is shown in Table 7. It is seen that the mean eye fixation times for the treatments are significantly different. A one tailed t test shows that the mean eye fixation time for unstructured search is greater than that of structured search (t 2.99 with 1 df).

Analysis of covariance (Table 8) shows that reading rate does not affect the mean eye fixation time in a visual search. The correlation coefficients between reading rate and eye fixation time for structured and unstructured search (r 0.235 and r 0.029 respectively) were non-significant.

Number of eye fixations

The unstructured search had a mean of 89.92 number of eye fixations and the structured search a mean of 69.18. The analysis of variance (Table 9) shows that there is a significant difference in the mean number of eye fixations between the structured and unstructured search conditions. A one tailed t test (t 2.99 with 1df) shows that the mean number of eye fixations for unstructured search is significantly greater than the mean for structured search.

The analysis of co-variance for mean number of eye fixations with reading rate as the co-variate is shown in Table 10. It is seen that

TABLE 7

Analysis of variance for mean eye fixation time

Sources of variation	df	Mean square	F value	Alpha hat
Treatments	1	1046.07	8.99	0.0056**
Error	28	116.33		
Total	29			

** significant at 5% level
p 0.05

TABLE 8

Analysis of covariance for mean eye fixation time with reading rate as the covariate

Sources of variation	df	Mean square	F value	Alpha hat
Treatments	1	0.00015	0.04	0.84
Reading rate	1	0.00073	0.23	0.64
Reading rate x Treatment	1	0.00024	0.07	0.79
Error	26	0.0034		

TABLE 9

Analysis of variance for mean number of eye fixations

Sources of variation	df	Mean square	F value	Alpha hat
Treatment	1	3023.24	8.99	0.0056 **
Error	28	336.22		
Total	29			

** significant at 5% level
p 0.05

TABLE 10

Analysis of covariance for mean number of eye fixations with reading rate as the covariate

Sources of variation	df	Mean square	F value	Alpha hat
Treatment	1	223.92	0.63	0.42
Reading rate	1	21.05	0.06	0.80
Reading rate x treatment	1	814.49	2.43	0.13
Error	26	328.16		

reading rate and reading rate by treatment are non-significant. Correlation coefficients (r 0.253 and r 0.346) were non-significant.

Interfixation Distances

The unstructured search had a mean interfixation distance of 2.68 arcdegrees and the structured search 3.29 arc degrees. The analysis of variance (Table 11) shows that there is a significant difference between the mean interfixation distances for unstructured and structured search. A one tailed t test (t 3.29 with 1 df) shows that the mean number of eye fixations for unstructured search is significantly greater than the mean for structured search.

Table 12 gives the analysis of co-variance for mean interfixation distance with reading rate as the co-variate. It is seen that reading rate and reading rate by treatment are non-significant. The correlation coefficients (r 0.151 for unstructured and r 0.275 for structured search) between reading rate and interfixation distances are non-significant.

Regression equations

Tables 13 and 14 show that search time is significantly correlated with eye fixation time, number of eye fixations and reading rate. The regression equations predicting search time 'S' are given below.

$S_1 = -45.329 + 146.53E_1 + .36N_1 + .151\ RR$ the subscript 1 stands for unstructured search condition.

$S_2 = -43.613 + 182.31E_2 + .62N_2 - .11RR$ the subscript 2 stands for structured search condition.

where:-

S - Search time in seconds

E - Eye fixation time in seconds

N - Number of eye fixations

RR - Reading rate in words per minute

The regression equations for search time gave an R-square of .77 and .87 respectively.

TABLE 11

Analysis of variance for mean interfixation distance

Sources of variation	df	Mean square	F value	Alpha hat
Treatment	1	2.74	10.85	0.0027**
Error	28	0.25		
Total	29			

** significant at 5% level
p 0.05

TABLE 12

Analysis of covariance for mean interfixation distance with reading rate as the covariate

Sources of variation	df	Mean square	F value	Alpha hat
Treatment	1	0.191	0.73	0.39
Reading rate	1	0.252	0.97	0.33
Reading rate x treatment	1	0.002	0.01	0.91
Error	26	0.261		

TABLE 13

Correlation matrix for unstructured search

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 15

	ACCURACY	SEARCH_T	EYE_FIX	NO_FIX	I_F_DIST	R_RATE
ACCURACY	1.00000 0.0000	0.38158 0.1605	0.33778 0.2182	0.13519 0.6310	-0.06990 0.8045	0.08983 0.7502
SEARCH_T	0.38158 0.1605	1.00000 0.0000	0.53339 0.0406	0.54424 0.0360	-0.18472 0.5099	0.54381 0.0361
EYE_FIX	0.33778 0.2182	0.53339 0.0406	1.00000 0.0000	-0.00689 0.9805	0.02238 0.9369	-0.02971 0.9163
NO_FIX	0.13519 0.6310	0.54424 0.0360	-0.00689 0.9805	1.00000 0.0000	-0.10724 0.7036	0.25168 0.3655
I_F_DIST	-0.06990 0.8045	-0.18472 0.5099	0.02238 0.9369	-0.10724 0.7036	1.00000 0.0000	0.15099 0.5912
R_RATE	0.08983 0.7502	0.54381 0.0361	-0.02971 0.9163	0.25168 0.3655	0.15099 0.5912	1.00000 0.0000

TABLE 14

Correlation matrix for structured search

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 15

	ACCURACY	SEARCH_T	EYE_FIX	NO_FIX	I_F_DIST	R_RATE
ACCURACY	1.00000	0.40637	0.32219	0.17934	0.34361	-0.12865
	0.0000	0.1328	0.2415	0.5225	0.2099	0.6477
SEARCH_T	0.40637	1.00000	0.48807	0.62677	-0.05550	-0.52392
	0.1328	0.0000	0.0649	0.0124	0.8443	0.0450
EYE_FIX	0.32219	0.48807	1.00000	-0.25151	0.18770	-0.23588
	0.2415	0.0649	0.0000	0.3659	0.5029	0.3974
NO_FIX	0.17934	0.62677	-0.25151	1.00000	-0.03966	-0.38647
	0.5225	0.0124	0.3659	0.0000	0.8884	0.1548
I_F_DIST	0.34361	-0.05550	0.18770	-0.03966	1.00000	0.27478
	0.2099	0.8443	0.5029	0.8884	0.0000	0.3216
R_RATE	-0.12865	-0.52392	-0.23588	-0.38647	0.27478	1.00000
	0.6477	0.0450	0.3974	0.1548	0.3216	0.0000

DISCUSSION

It was hypothesized that people with a higher reading ability will have a better search performance. This was observed only with regard to search time. The other hypothesis that a structured scan path gives a better performance than an unstructured scan path was observed for the search parameters of search time, mean eye fixation time, mean number of eye fixations and mean interfixation distance. The hypothesized effects of reading rate on search parameters for search types (structured or unstructured) and the effect of search types on search parameters are discussed.

Effect of scanning type on search parameters.

Percent Accuracy No significant differences in the mean percent accuracy for the two search conditions were observed. It is reasonable to expect accuracy to be affected by search pattern. The structured search pattern was systematic and methodical. A systematic search should improve the chances of detecting a defect as the possibility of not scanning a particular area is greatly reduced. The reason that this was not observed in this study could be due to the fact that the search task was rather simple. Methods play an effective role only when the complexity of the task increases. The visual task subtended a visual angle of 7.7 arcdegrees vertically and 10.75 arcdegrees horizontally. The small size of the display could also be a contributary cause.

<u>Search time</u> While accuracies were the same, the structured search took significantly less time than the unstructured search. This means that the structured search was more efficient than the unstructured search. Subjects under the unstructured search condition generally followed the following patterns. All of them searched from left to right (as in reading). Some (twentyfive percent) divided the display into four quadrants and searched left to right in each quadrant. The initial display was divided into quadrants and the subjects were asked to identify the defects by describing in which quadrant they found them. It was observed that this could lead to a bias in the study and was discontinued.

Some (twelve percent) divided the display into two halves and searched left to right in each half. One subject partially followed the boustrophedan pattern and then switched to a reading type of search. Scanning as in reading took more time because for each line a right to left movement is non-productive. This might be due to strong reading habits and needs further research.

Search time is essentially made up of eye fixation time and saccadic time (eye movement time). The mean eye fixation time, mean number of eye fixations and mean interfixation distances were significantly different for the two search conditions. Since the components of search time are different the search time is also different. Significant correlations were observed between search time and eye fixation time and search time and number of eye fixations. (r 0.49 and r 0.63 for structured search and r 0.53 and r 0.54 for unstructured search). It is reasonable to expect this as the total and its parts should be correlated. It is also interesting to note that search time and interfixation distance are uncorrelated. The saccadic time is very small. For angles less than one degree the saccadic time is 0.02 s (Yarbus, 1967). This means that search time is not explained by saccadic or interfixation time. This is in accordance with Yarbus' finding.

Eye fixation time The mean eye fixation times for unstructured and structured search were 0.411 s and 0.368 s respectively. Enoch (1959) found that the mean eye fixation time for his structured search was 0.417 s. The general range of eye fixation time is in conformity with the findings of other researchers. However a direct comparison cannot be made as eye fixation time is dependent on the characteristics of the display, display size and visual angle, contrast and luminance of the display.

The differences in eye fixation time for the two search types is in general agreement with Boynton et al (1958) that good searchers make brief fixations whereas poorer searchers make longer fixations.

Number of eye fixations Enoch et al (1959) in their study on structured search had determined 67 mean number of fixations for a mean search time of 29.2 s (eye fixation time 0.411 s). In this study the mean number of eye fixations is found to be 69.18 for a mean search time of 64.4 s. The mean number of eye fixations for unstructured search was significantly greater than the mean for structured search. This agrees with the hypothesis that a structured search is better than an unstructured search. While search accuracies were the same subjects under structured search could extract the same information with lesser number of fixation points. Correspondingly the interfixation distances increased for the structured search. For search efficiency to increase the fixation time should decrease, the number of fixations should decrease and the interfixation distance should increase. This enables the eye to scan the maximum area in a minimum of search time. This is observed in the results between structured and unstructured search.

Some possible explanations for why the fixation time is greater for unstructured search are discussed.

Researchers investigating eye fixation and reading have found that when a subject has difficulty in understanding the text there is an increase in eye fixation time. (Rayner & McConkie, 1976). Figure 16 shows an example of the eye movement plotted by the X-Y plotter for unstructured search. The search pattern is disorganized. This makes it difficult for the subject in comphrending the defect. This causes the eye fixation time to increase since the cognitive processing occuring during this time increases.

A structured scan path gives better eye guidance than an unstructured path. Figure 17 shows an example of the eye movement plotted by the X-Y plotter for structured search. The better eye guidance makes it possible for a better perceptual input which in turn results in shorter eye fixation time as the efficiency with which the eye operates increases

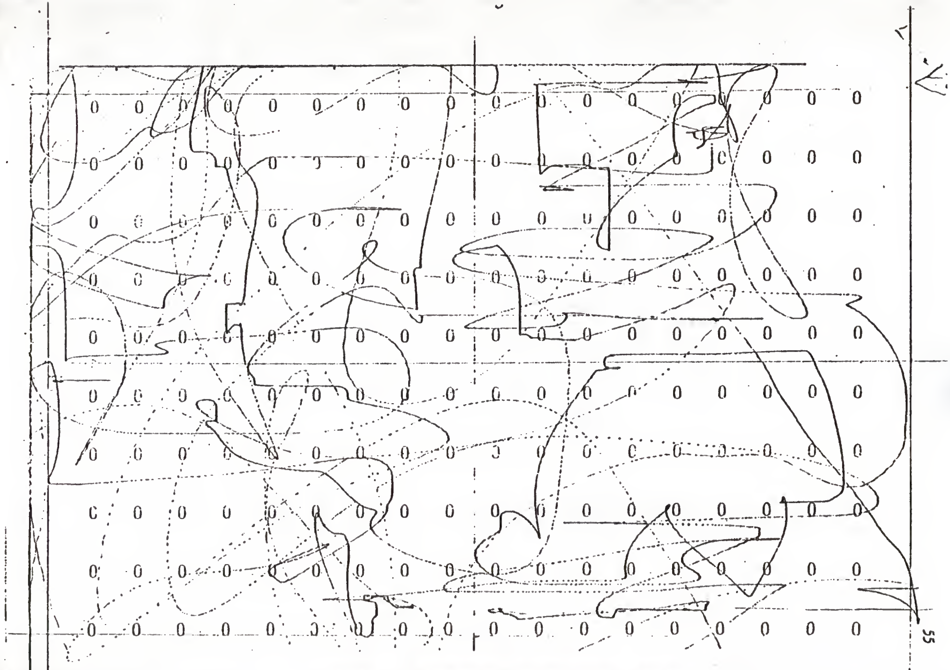


Figure 16 Eye movement of unstructured search

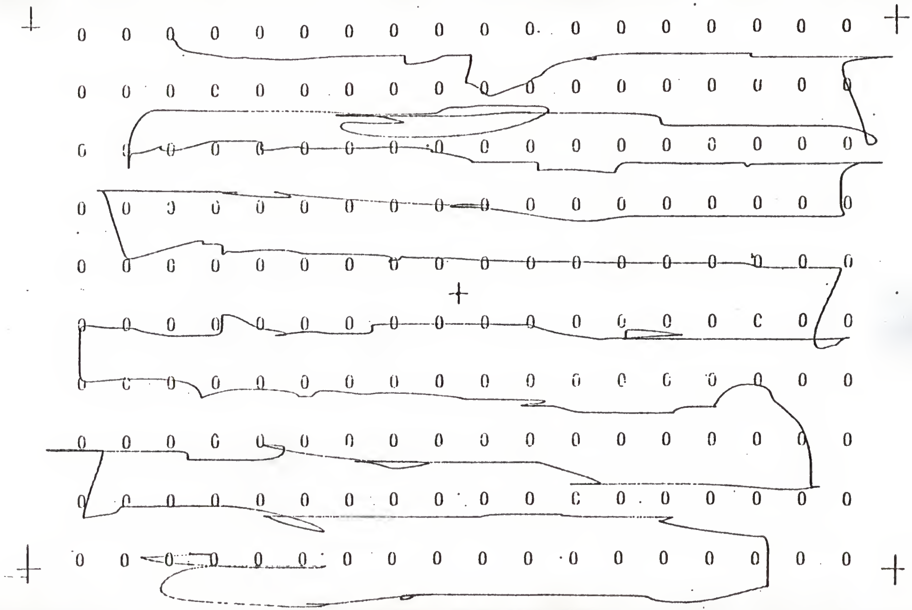


Figure 17 Eye movement in structured search

in a structured search.

Researchers (Haber & Hershenson, 1973; Hawley et al 1974; Carpenter & Just, 1978) have found that when subjects have difficulty in understanding a text there are greater number of regressions and corrective saccades of the eye. Since these characteristics were not separated out (it is not possible to separate these characteristics with the existing recording accuracies) these could have contributed to longer fixation time in unstructured search. Further research in this area is suggested.

Effect of reading rate on search parameters

The hypothesized effects of reading rate on search parameters are discussed below.

Percent accuracy No significant effect of reading rate on search accuracy was observed. This could be due to the search task being simple. However while the reading rate test depended on the ability of the subject to scan the text, no comphrension test was given. This means that the subject's cognitive ability was not tested. A visual search task involves a certain amount of cognitive ability though not on the same plane as in reading. In the search task the subject has to recognize the pattern searched for, whereas in reading a semantic processing of the text along with the perceptual input of the stimulus material is required. Hence it is worthwhile to see if reading comphrension ability will effect the search accuracy.

Search time Reading rate had a significant effect on the search time. The correlations between reading rate and search time (r +0.544

for unstructured and r -0.524 for structured search) were significant. Reading rate had a positive slope for unstructured search and a negative slope for structured search (See Figure 18). This means that for unstructured search subjects with a higher reading rate had a longer search time whereas for a structured search subjects with a higher reading rate had a shorter search time. Further research is recommended to confirm this finding.

One possible explanation for this could be that subjects under the unstructured search condition followed a reading type of search that is the better readers always searched from left to right due to strong reading habits and then made a rapid sweep again to the left to search the next line. It is also true that good readers have an ability to scan line by line. This ability was put to the optimum use when these good readers were instructed to follow a structured scan path. The unproductive sweep from left to right was eliminated reducing the search time.

We have also seen that the structured search had fewer number of fixations, shorter fixation durations and longer saccades. This enables the eye to scan the maximum area in the minimum time. This also explains the difference in search time.

Further research is required to confirm whether a reading rate test could be used as a criterion for selection of people engaged in visual search.

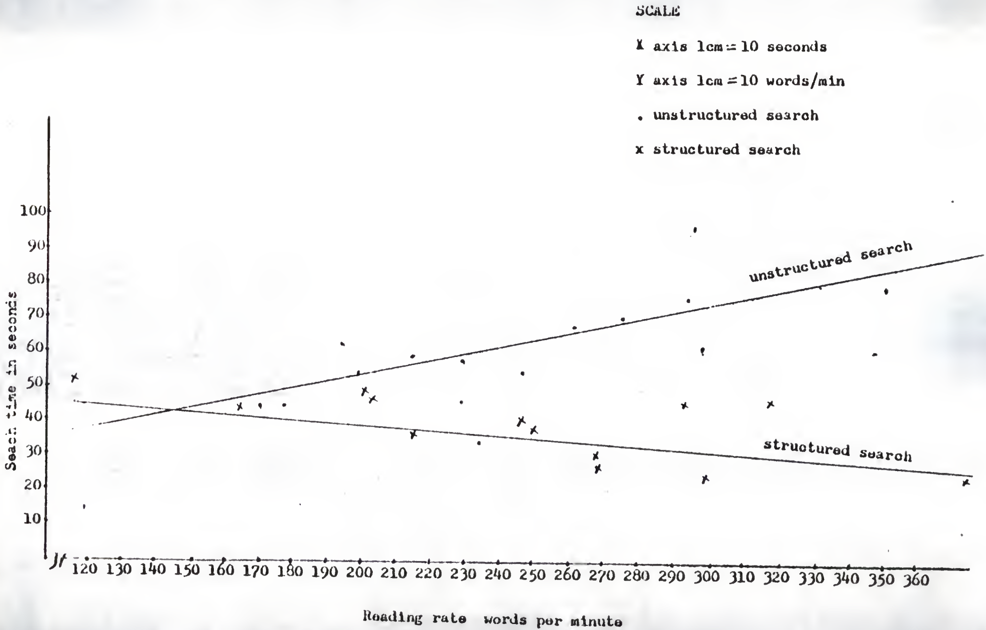


Figure 18. Mean search time Vs Reading rate for unstructured and structured search.

Eye fixation Researchers (Goltz,1975; Griffin, Walton, & Ives, 1974; Heiman & Ross, 1974; Rubino & Minden, 1973) have generally found that poor readers often show longer fixation durations, more fixations, and more regressions than good readers. No significant effect of reading rate on fixation duration was observed. This could be due to many reasons. The possibility of recording inaccuracies could have contributed to the insensitivity of reading rate on fixation time. The other possibility is that poor readers have a lower reading rate due to lower vocabulary and comphrension abilities. Since these two factors are not present in a visual search it may be reasonable to expect that reading rate has no significant effect on fixation time in a visual search. However further research is required before conclusions can be made on the effect of reading rate on the fixation time in a visual search.

No significant effect of reading rate on number of fixations was observed. This could be due to the fact that poor readers have a lower reading rate due to lower vocabulary and comphrension abilities. Since these two factors are not present in a visual search it may be reasonable to expect that reading rate has no effect on the number of fixations in a visual search. However further research is required.

General Results

It was observed in general that a structured search was more efficient than an unstructured search for the given visual task. The boustrophedan search pattern will be most suitable for visual

search tasks whose elements are arranged in a matrix form.
In the structured search the eye fixation time decreased, the number of fixations decreased and the interfixation distances or saccades increased thus reducing the search time.

The effect of strong reading habits was observed in subjects under the unstructured search condition. Most of them followed a left to right scan as in reading and made a left to right sweep with the eyes before starting on the next line.

Reading rate had a significant effect on the search time. Hence reading rate could be used as a possible criterion for selection of people engaged in visual search.

Future Research

Further research is needed to confirm the findings of this study about the effect of reading rate on visual search and the nature of the characteristics of eye movement for structured and unstructured search conditions.

Researchers interested in the relationship between eye movements and reading have carried out studies dealing with saccadic latency or reaction time of the eyes, perceptual span in reading, eye guidance in reading, control of fixation duration and regressions. Some of the above factors could be considered for further research in visual search.

The three important components of eye movements in reading are the saccade, the fixation pause and the regression. For English readers the vast majority of saccades are in a left to right direction.

A regression is a right to left movement and occurs 10 to 20 percent of the time in skilled readers. Regressions are assumed to occur when the reader has difficulty understanding the text, when the reader misinterprets the text and when the reader overshoots the target. In this study the regressions were not separated out from the other eye movements. Poor readers have more regressions than good readers. It is suggested that future research investigate the relationship between reading rate, regressions and visual search.

Two major positions have traditionally been taken with regard to the fixation pauses during reading. The first position which is generally referred to as the cognitive lag hypothesis suggests that the eye movements are so rapid and the durations of the fixations so short that the semantic processing of the text must necessarily lag behind the perceptual input of the stimulus material (Kolers, 1976; Morton, 1964). The second position which is referred to as the process monitoring hypothesis suggests that the fixation durations are affected by the cognitive processing occuring during the time period of the fixation (Rayner & McConkie, 1976). Thus more difficult words and passages should lead to longer fixation durations. Further research in these areas will help determine how to control fixation duration and thus reduce the search time.

Practical Implications

An important finding of this study is that reading rate could be used as a criterion for selecting people to perform a structural visual search in the minimum of time.

In the field of computer and numerical printouts, the printouts are generally in an arrayed or matrix form. People are employed to proofread and see that no garbage is fed into the computer as "garbage in is garbage out". In such areas of selecting and training people a reading rate selection criterion could be developed.

Visual search occurs in the areas of radar scanning, aerial map interpretation, inspection of integrated circuits, inspection of printed patterns, and in microelectronic circuitry. Reading and structural scanning techniques could find applications in these fields.

In general, the concept outlined in this research can be applied to situations where the study of visual search task is involved.

Inaccuracies in this study

Two independent response measures were obtained. The search time was recorded using a stop watch (The time study watches of Industrial Engineering Department have an accuracy of one decimal minute or .01 minute equalling 0.6 s). There were no known inaccuracies in recording the search time.

The other response measure involving the eye movement was recorded on a strip chart recorder and an x-y plotter. The product of mean eye fixation time and number of eye fixations accounts for 66 percent of the search time. The remainder is unexplained and accounts for the inaccuracy in this study. This could be due to the time lag in switching on the chart recorder, inertia of the recorder, precision limitations of the graph output and human error in intrepretation of the fixation points.

This error of 10 to 20 percent raises the question about the validity of this tudy. (Comparing to other researchers it is found that the number of fixations are less by 10 to 20 percent). The search times were timed using a stop watch and were independent of the recording device outputs. The mean search times were found to be significantly different. The eye parameters that contribute to search time are total eye fixation time (product of mean eye fixation time and mean number of eye fixations) and the total time taken for eye movements. If the search times are significantly different the components or one of the components of search time should be significantly different. In this study the mean eye fixation times for the two conditions, the mean number of fixations and the mean interfixation distances were found to be significantly different. Hence we can accept the conclusions of this study but cannot accept the times and the number of eye fixations to be accurate.

CONCLUSIONS

1. Subjects under the unstructured search condition searched from left to right as in reading thus indicating the effect of strong reading habits.

2. A structured search was found to be more efficient than an unstructured search in a visual task in terms of search time.

3. Reading rate could be used as a predictor in selecting people to perform search in less time.

4. Eye movement data provide a means of understanding the processing activities involved in a particular task.

5. The technique of using an online computer will be a powerful tool to study important questions about visual search and to confirm the results of this study. (See Appendix 2)

6. Suggestions for future research were made. It was suggested that the factors affecting reading rate like saccadic latency or reaction time of the eyes, eye guidance in reading, control of fixation duration and regressions should be extended to the field of visual search and a comparison made.

APPENDICES

APPENDIX 1

Percentage accuracy (No of defects detected - No of good classified as defective)/(Total number of defects)

This definition of percentage accuracy takes care of type I and type II errors.

Search time - Total time in seconds taken for the search task

Fixation duration - The mean time the eye fixated during the search. Defined as the time for which the horizontal and vertical components of eye movement were parallel within one scale division of the graph output.

Number of fixations - The number of times the eye fixated during the search.

Interfixation distance - The mean distance between two fixation points.

Reading rate - Rate in terms of words per minute read. Determined by the Nelson-Denny reading test.

Appendix 2

Equipment limitations

Out of 38 subjects, 30 or approximately 79 percent could be calibrated satisfactorily on the 1922 S eye view monitor system. Though the area and resolution were reduced to suit the recording system, (the x-y plotter and the strip chart recorder), the recording system were the main causes of the system inefficiencies.

Calibration accuracy The accuracy of calibration was limited by the visual judgement of the experimentor and the inability of the subjects' eye to focus steadily on the calibration point.

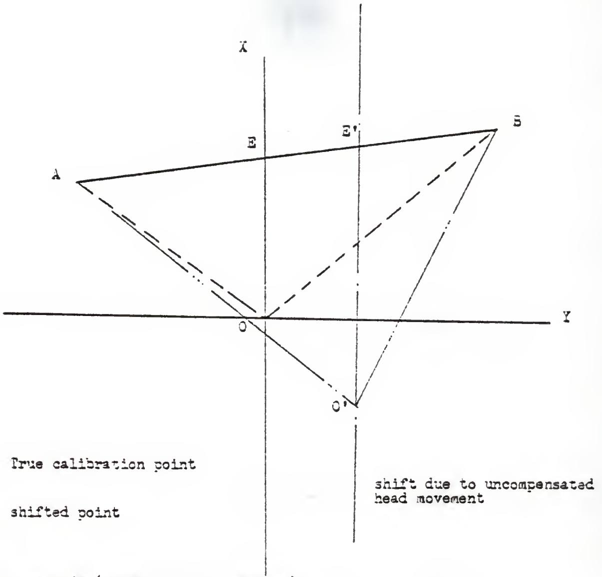
Head movements Movement of the subjects' head did not effect the linearity of calibration, but shifted the reference point. This caused the x-y plotter to shift the eye movements to one side of the recording sheet. Head movement could be restrained by bite bars. The head movement compensation of the equipment needs to be checked. If a subject is looking at a point and then shifts his head but continues to look at the same point, the point of gaze shown by the eye monitor should not change. This was not observed by the experimentor in the equipment. Often when the calibration was checked inbetween displays the experimentor found that the point of gaze shown by the eye monitor screen had shifted though the subject claimed to look at the central calibration point. Adjustment of the position knobs brought the point of gaze on to the calibration point. The calibration was found to hold good. Since the interfixation distances were determined from the x-y co-ordinates a shift in the zero point will not contribute to any error. Figure 19 shows a schematic of the zero point and a shift in zero point, and the analysis of the shift. If a true position or a quadrant analysis of the eye fixation is to be done, head movement compensation is important.

Displays The calibration grid was removed and the display mounted manually. During this period there is a possibility of the subjects being distracted and hence shifting their position which in turn causes a shift from the calibration point. If the calibration grid and the displays are projected on to a screen using a slide projector, the change from the calibration grid to the display is almost instantaneous and the experimentor does not come in front of the subject. This will not distract the subject and hence the chances of the subject shifting his position is reduced. Greater positional accuracy of the displays with respect to the calibration matrix could thus be achieved.

Chart recorder Reading of the graph output to determine fixation times and the number of fixations is tedious. Errors in judgement occur as fixation was defined when the horizontal and vertical components of the eye movement were parallel within one scale division. In order to get needed time precision, approximately ninety meters of paper output had to be read. If the chart recorder speed is increased for greater precision the paper output to be read will be correspondingly increased. The stylus oscillates on the paper as the eye jumps from one fixation point to another. It has to be checked whether the existing strip chart recorders can cope with the speed of the eye movement as all the three chart recororders broke down (only one chart recorder was used at a time).

This recording limitations can be overcome if an online mini-computer or microcomputer is attached to the system which analyzes the analog output and then displays the mean fixation times, the number of fixations, interfixation distances and regressions of the eye. This calls for the development of the computer software and could be taken up as another project. Acquiring a minicomputer will increase the precision of the fixation time to milliseconds.

X-Y recorder The human eye is never stationary. Hence it is very difficult to position the pen of the chart recorder exactly to the same point where the subject is looking. This causes a shift in the X-Y recorder output. The eye movements are not exactly recorded on the xerox copy of the display. This reduces the usefulness of the X-Y recorder output.



O True calibration point

O' shifted point

AB - saccade (interfixation distance)

Shift in O does not produce an error in AB

Figure 19. Effect of head movement on interfixation distance

Appendix 3 Nelson-Denny reading rate test
COMPREHENSION TEST

I

Like Horace, Virgil was possibly drawn from his studies into battle. The struggle, then at its height, was between Caesar and Pompey. Certainly, his pitiful pictures of the dead on the battlefields of Pharsalia could well have been made by one who had fought under the triumphant standards of Caesar. It is possible also that he saw rather stormy service on the Adriatic Sea with Mark Antony. There are signs that some detested bully of an officer made camp life, none too pleasant at best, quite unendurable for the poet who was never blessed with vigorous health. And the winter of 49 B.C., severe enough to leave even Caesar shaken, may well have shattered Virgil. At any rate, if he served for a time, he returned soon to his books. From the outset, his heart could but little rejoice in the struggle which was making brother fight brother and draining Italy of her best blood.

After his withdrawal from the war, some contend, Virgil made a single and unsuccessful appearance as lawyer before the Roman court of law. This is of considerable interest when we reflect that the orators in his great poem, the *Aeneid*, are all fluent but dreary fellows. We hear of him in Rome, a tall, dark, gaunt man, suffering much in his stomach, throat, and head, sometimes spitting blood; in food and drink most cautious – even at the abundant board of his patron Maecenas, to whom, with such happy results, he had presented his friend Horace. Like Horace, he, too, seems to have lost his lands in the wars, but the poems he had now begun to write made him known and honoured, and other lands were given to him, so that he had enough money to live comfortably. Some scholars detect in one of Horace's satires a reference to Virgil as he might have been just then – a person with a rural haircut, an ungraceful toga, and untied shoelaces. However, it is equally possible that Horace had himself in mind. It was just the sort of thing he liked to do – caricaturing his whimsies and his hayseed locks and his flapping coat.

We can picture the two poets on a now famous journey they took with Maecenas, going to Brundisium. There are Horace with his black eyewash (a lotion for his weak eyes), and Virgil with his black headache, both of them snoring while Maecenas and his company hopped about after the tennis balls. And there was a voyage to Athens which Horace celebrated in another poem. But the two followed their separate ways. Both had a passion for philosophy and a passion for the country in common, but each took his solitude and often his social life in his own fashion.

The first poems Virgil wrote were about the earth and the farmers and the shepherds and the simple things of their life. These poems he called Eclogues. They took the outward form of the pastorals of Theocritus and the other Greek poets of the Alexandrian school. In them Virgil sang the radiance of the seasons, the tenderness of Italian landscapes, the charm of Italian friendships. All of April and the delicate tintings of the wild flowers and the glossy-leafed orchards and his own deep love of home and his tranquil memories and his longing for peace in a troubled world and the melancholy beauty of love – all these things went into the Eclogues. They were different from the Greek pastorals (aside from language) – using the beauty of the earth only as an introduction to a romantic understanding of the larger life beyond the glades and meadows. And with what exquisitely chosen phrases, with what fullness and rhythm and force the new poet sang! Rhyme Virgil never used, and his metre was different from ours.

I

1. *Reference was made to what game?*
   A. Chess
   B. Quoits
   C. Tennis
   D. Skittles
   E. Baccarat
2. *Specific reference was made to*
   A. Marcus Aurelius.
   B. Pliny.
   C. Mark Antony.
   D. Hercules.
   E. Plotinus.
3. *Virgil and Horace apparently visited*
   A. Achaea.
   B. Athens.
   C. Pharos.
   D. Messina.
   E. Adrian.
4. *It was said that Virgil did not use*
   A. blank verse.
   B. rhyme.
   C. personification.
   D. metre.
   E. the heroic couplet.
5. *This passage is mainly about*
   A. poetry.
   B. Virgil.
   C. nature.
   D. history.
   E. Eclogues.
6. *In discussing the two poets, most emphasis was placed on their*
   A. similarities.
   B. differences.
   C. friendship.
   D. patriotism.
   E. attitude toward war.
7. *This passage is primarily*
   A. historic.
   B. analytic.
   C. biographic.
   D. satiric.
   E. eulogistic.
8. *You would infer from the reference to the orators in Virgil's Aeneid that Virgil himself would be best described as what kind of speaker?*
   A. Dull
   B. Lively
   C. Inspiring
   D. Commonplace
   E. Original

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STRUCTURED VS. UNSTRUCTURED SCAN PATH IN STATIC VISUAL SEARCH PERFORMANCE

by

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Structured Vs. Unstructured scan path in static Visual search performance

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This study investigated the effect of scan path and reading rate on the search parameters in a static visual search task. Two types of scan paths were used. They were: a structured scan path and an unstructured scan path. Thirtyeight subjects were tested and each subject was randomly assigned only one condition of scan path. The search parameters recorded were, percent accuracy, search time, eye fixation time, number of fixations and interfixation distance. The reading rate was determined by the Nelson-Denny reading test. Significant differences in the search parameters (except percent accuracy) for the structured and unstructured search conditions were observed. Reading rate had a positive correlation with search time for unstructured search and a negative correlation for structured search. Use of reading rate as a predictor in selecting people to perform search in less time is discussed. It was also observed that subjects under the unstructured search condition searched from left to right as in reading thus indicating the effect of strong reading habits. Implications for tasks involving structured scanning are discussed.