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THE EFFECTS OF TARGET SPECIFICATION ON OBJECTS FIXATED DURING VISUAL SEARCH [1]

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ABSTRACT

When a person searches for a target in a cluttered visual field his fixations typically fall on objects. Specifying the target characteristics will affect the probabilities of fixating different classes of objects. It was found that for fields containing objects differing widely in size, color, and shape, a high proportion of fixations were on objects of specified color, but only a moderate proportion were on objects of specified size or shape. When two or more target characteristics were specified fixations were generally based on a single characteristic.

It is suggested that the specification of the target creates a perceptual structure which *S* explores. The study of visual fixations, in effect, is the study of that structure.

1. INTRODUCTION

The subject of this paper is the search for targets in cluttered visual fields. The question being asked is: how do characteristics of the target and the background affect the search process? The general answer to the question is that when certain characteristics of the target are specified the searcher attends to objects having those characteristics and he attempts to visually fixate those objects.

Overtly, search consists of a sequence of fixations which typically fall on objects. The process can be viewed as a sequence of two alternating activities, identification and acquisition. Identification is the classification of the foveally imaged object as being the target or not (usually it is not). Acquisition is the selection of the new object from the extrafoveal field to fixate and the movement of the eyes to actually fixate that object.

The present paper is concerned with the acquisition process; namely, the searcher's ability to selectively fixate objects which are similar to the target as specified. In the experiment the target's size, color, and/or shape were specified to determine how subjects were able to utilize these types of information singly and in combination. The experimental paradigm was to specify the target and to determine the proportions of fixations on objects of each size, color, and shape.

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2. Method and procedure

Each search field contained 100 forms of a given size (about 2.8, 1.9, 1.3 or 0.8 degrees in visual extent), a given color (blue, green, yellow, orange, or pink), and a given shape (circle, semicircle, triangle, square, or cross). A different two-digit number, about 0.3 degrees in height, was printed within each form. The fields were displayed on a 1.22-meter square rear projection screen 1.72 meters in front of the subject. The screen subtended horizontal and vertical visual angles of 39 degrees.

S's task was to locate a target defined by a specific two-digit number. He was also provided with varying amounts of information about the size, color, and shape of the target. Thus, *S* always knew the target number, either alone or along with one or more other characteristics.

The 35 mm slides from which the stimuli were projected were arranged in pairs. The first slide of each pair contained the target specification in the form of a two-digit number and a verbal description of the size, color, and/or shape in that order. For the four sizes, the terms very large, large, medium and small were used. These instructions were then repeated in the center of the second, or search field, slide. Each trial lasted until *S* pressed a button indicating that he found the target. *S* could present as many as 40 consecutive trials to himself by pressing a response button which controlled the slide projector, the automatic camera, and associated apparatus which recorded the eye fixations. There were 200 different search trials in all per *S* with a different search field being used for each trial.

Eye fixations were measured by the corneal reflection technique first used by Dodge and Cline (1901). In the procedure used in our laboratory *S*'s left eye was largely occluded. An infrared light source produced a virtual image in that eye which was photographed through a magnification system. The eye fixation record for each trial consisted of a series of time exposures of 4 sec duration.

Each *S* required two sessions of two to three hours duration. Thirty male *S*s from colleges and universities in the Minneapolis-St. Paul area took part in the experiment. All *S*s possessed normal acuity and color vision as indicated by tests using a Titmus Professional Vision Tester prior to the experiment.

The raw data consisted of the filmed records of the eye fixations. The records were transformed into tabulations of what *S*s looked at during each trial by projecting each frame of film (containing about 13 fixations) on the search field, and by using correction procedures to reduce the error. The records from about one-sixth of the trials were not tabulated for two main reasons: the photographs were not in proper focus or the calibration photographs needed for tabulation were unsatisfactory.

Each fixation was tabulated as: (a) falling on a specific object in the field (61 %); (b) at the center of the field containing the information about the target (2 %); (c) between objects in the field (4 %); (d) a double fixation (when the fixation fell on the object which was just previously fixated, 3 %); (e) unscored (where the tabulator was not confident enough to classify the fixation into one of the above three categories, 29 %). The above percentages are the approximate proportions of fixations within each category.

The accuracy of the eye movement measurement procedure is not a completely determinate quantity, mainly because the ultimate criterion - - where the observer was actually looking - - is usually not independently known. An indication of the accuracy of the technique used here is provided by the following procedure. When other *S*s were instructed to look at specific objects in test fields equal in density to those used in the present study, the data tabulator's 'relatively confident' object identifications were correct 95 or 98 % of the time (depending on which of two alignment procedures he used.) This should not be taken to suggest that 95 or 98 % of the objects in Category (a), above, were correctly identified, since in the calibration study just discussed *all* fixations were on objects, whereas in the present study it is presumed that only a fixed proportion were.

3. Results

3.1. *Fixation data*

The approximately 115 000 fixations that could be classified as falling on specific objects (Category (a), above) will be the subject of discussion. These data will be treated separately for each type of instruction.

When only the two-digit number was specified, the fixations were unrelated to the color, size or shape of the objects in the field (table 1, bottom row).

When only the color of the target (in addition to the two-digit number) was specified, there was a strong tendency to fixate objects of that color. When only the size was specified, the tendency to fixate targets of specified size was strong for the largest targets and moderate for the others. When only the shape was specified, the tendency to fixate objects of specified shape was slight.

When the color and size of the target were specified, *S*s tended to fixate objects of the specified color just as when color alone was specified. Only when the target was specified to be of the largest size did *S*s apparently also use size as a basis for fixation. Although the proportions in table 1 suggest that *S*s also used other sizes as a basis for fixating objects, it is likely that those proportions are increased as a result of finding the target on the last fixation. To show this, assume that *S*s used only color and completely ignored size. The number of fixated objects required to find these targets is usually small—a mean of about 18 objects. If let us say, 18 objects are fixated, and the first 17 objects ar selected independently of size, then the expected number of specified size would, therefore, be $17 \times \frac{24}{99} + 1 = 5.12$. The proportion $5.12/18 = .28$ is of comparable value to those in the table for sizes other than the largest.

When the color and shape were specified, there was a strong tendency to fixate objects of specified color, and little or none (considering the argument in the last paragraph) to fixate objects of specified shape. When size and shape were specified, *S*s fixated objects on the basis of both size and shape.

When color, size, and shape were specified, fixations were only related to

TABLE 1
Proportion of fixations on objects having the specified characteristics *

Specification	Color					Size (degrees of visual extent)				Shape				
	Bl	Gr	Ye	Or	Pi	2.8	1.9	1.3	0.8	Ci	Sc	Tr	Sq	Cr
Color	.61	.56	.59	.71	.60									
Size						.59	.29	.28	.35					
Shape										.26	.24	.24	.23	.29
Color + size	.59	.65	.67	.66	.59	.52	.30	.30	.30					
Color + shape	.64	.64	.66	.59	.59					.24	.26	.27	.24	.28
Size + shape						.57	.30	.29	.35	.27	.25	.26	.24	.30
Color + size + shape	.54	.55	.55	.62	.54	.49	.31	.29	.28	.26	.28	.25	.26	.26
Number only	.20	.20	.20	.18	.22	.25	.25	.26	.24	.20	.20	.20	.20	.20

* To illustrate, when color-plus-size was specified, then for yellow targets 67% of the fixations were on yellow objects. When color alone was specified, then for yellow targets 59% of the fixations were on yellow objects. The bottom row shows the proportion of fixations on objects of each characteristic indicated by the column label when only the two-digit number was specified.

color, the other information being ignored except when the target was also specified to be very large.

Another question of interest involves what *S* looks at when he does not look at objects having the specified characteristics. With the color specification there is no systematic tendency to look at any other color. However, with the size specifications, table 2 shows that the likelihood of fixating an object depends on its similarity to the specified size. For three sizes, observers are most likely to fixate objects of specified size. For the 'large' specification the peak has shifted to the largest size. This may be a result of the specific words used in the instructions.

TABLE 2
Proportion of fixations on objects of different size for each size specification.

Specified size	Size of fixated object			
	Very large	Large	Medium	Small
Very large	0.59	0.24	0.11	0.07
Large	0.35	0.29	0.21	0.15
Medium	0.23	0.26	0.28	0.22
Small	0.13	0.20	0.31	0.35

3.2. *Search times*

The mean times required to find targets for the eight different specifications are shown in table 3. As can be seen in the table, the specifications divide themselves into four classes: color specified, size but not color specified, shape but not color or size specified, and number only specified. The search times are increasingly greater for the four classes. These data correspond directly to the efficiency of looking as measured by the proportion of fixations on objects having the specified characteristics as shown in table 1.

TABLE 3
Mean time to find target for different types of specifications.

Type of specification	Mean time (seconds)	Number of trials
Color	7.6	455
Color + size	6.1	463
Color + shape	7.1	571
Color + size + shape	6.4	1178
Size	16.4	468
Size + shape	15.8	457
Shape	20.7	461
Number only	22.8	579

4. DISCUSSION

The results can be summarized as follows: for a field containing objects differing widely in size, color, and shape, subjects selectively fixated objects much better on the basis of color than on size or shape. Further, when provided with information about two or three target characteristics, *S*s generally fixated objects on the basis of a single characteristic, namely color if provided.

There are two alternative hypotheses for interpreting these data. One is that the selection of each new object to fixate is a choice reaction task for the subject. At any moment in time he is likely to be looking at a given object or point in the field. After having decided that that object is not the target, the next object is selected from the many visible ones in the extra-foveal field. The objects in the field can be seen with diminishing clarity with increasing distance from the fixation point. The hypothesis is that *S* makes a choice of one such object on the basis of the target specifications in at most about 300 msec (since he typically makes more than three fixations per second).

The other hypothesis is that *S*'s percept of the total field is determined by the target specifications. When, for example, he searches for an orange target he perceives a patterning of orange objects on a background of other colored objects. He tries to look at different parts of this pattern until he comes to the target. Thus, the data presented here indicate that when *S* searches for an orange square the figural structure consists of orange objects rather than orange square objects, simply because he is incapable of structuring the field in terms of both characteristics.

At this time the data do not conclusively support one of the hypotheses to the exclusion of the other. The author tentatively accepts the perceptual structuring hypothesis since the alternative has a major weakness with respect to the time constraints. Although up to 300 msec may be available for the choice reaction task, it is likely that only a part of this interval can actually be used since time is required for object identification and for eye movements. Since the simple reaction time for visual stimuli is about 180 msec (WOODWORTH and SCHLOSBERG, 1954), it appears that there may be insufficient time for the hypothesized complex choice reaction.

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