Reports

Mapping a Field of Short-Time Visual Search

Abstract. The binocular field of vision during short-time search of a stimulus matrix was mapped and found to be ovaloid, with the longer axis horizontal and with the center of the field above the fixation point. The field expands in area as a function of exposure time, and there are frequent irregularities in its shape.

At any instant, what is the shape and size of the visual field of search—classically called the field of attention? In our experiment we tried to answer the question (i) by establishing threshold values of form discrimination for a single set of contrasting forms (*1*); (ii) by applying these values in a mapping procedure; and (iii) by varying the duration of brief exposure. We tried to avoid the introduction of reading habits such as might be induced by verbal stimuli, and to avoid extended or long-time search involving a series of saccadic eye movements (*2*). In previous studies (see, for example, *3* and *4*), the discrimination of discrete parts or radii of the stimulus field have been compared, but only one of these studies has yielded systematic areal mapping.

Five experimental subjects (female) were used in our experiments. The subject sat in a dimly lighted room and looked with both eyes at a fixation point on a large white screen located 9 feet straight ahead of her. After a ready signal, a stimulus matrix appeared briefly, centered about the locus of the fixation point. The matrix, nine elements square, contained one solid white triangle in a field of solid white circles of the same apparent size as the triangle, all on a black background (Fig. 1, left). The subject's task was to find the triangle; under the conditions of our experiment she should find it quickly, without extended search (*5*).

The relevant constants of the matrix were as follows (the visual angle is given in brackets): diameter of each circle, 0.5 inch [16′]; side of the triangle, 0.69 inch [22′]; separation of the matrix elements, center-to-center, 1.13 inches [36′] in both dimensions; side length of the matrix, 9.5 inches [5°2′]; luminance of the elements, 2.75 foot-lamberts. The matrices were projected from still-films through an episcotister tachistoscope, which had a 4-foot disk rotating at 1.0 rev/sec. There were six durations of exposure: 10, 30, 50, 80, 130, and 200 msec. One-fourth second after the exposure, an erasing field appeared in the area that the matrix had occupied. It consisted of a jiggling marbleized pattern and lasted 1.0 second. The subject then reported whether or not she had seen the triangle. Positive responses were checked by having her point to the approximate location on a blank white field of the same absolute size as the matrix. As a further check, 10 percent of the matrices presented were composed entirely of circles. These checks yielded few instances of erroneous identification.

The durations of exposure were randomized in blocks within each day's session. For each of five subjects and six durations of exposure, the triangle appeared 16 times in each of the 81 positions of the matrix. The position was effectively randomized so that the subject would not know where the triangle would appear next. Since the psychophysical method was essentially a constant method in two dimensions, the total n is large: 38,880 observations, extending over 6 weeks.

Figure 1 (middle) shows, as an example of the computation, a frequency table of positive judgments (triangle seen) for one subject for one exposure time. There is one cell for each of the 81 positions in the matrix. Since n is 16, a point is plotted on a cell-boundary when the frequency on one side of the boundary is 9 or greater and the frequency on the other side is 8 or less. This constitutes a rough liminal determination: the subject saw the triangle more than half the time in one stimulus position, less than half in the other. The points so plotted are then connected with straight lines; because of the way in which the points were derived, the lines approximate a contour of equal (and liminal) correct identification.

The contours appear to be quite sharp, although the sharpness is relative to the interelement distance within the matrix. The shape revealed by the contours is most frequently ovaloid, with flattened sides. Some of the contours exhibit marked irregularities. There is no evidence of a lobe-shaped pattern such as that found in research on radial localization (*4*). The long axis of the ovaloid is the horizontal one; when all subjects and durations of exposure are considered, the maximum width is found to exceed the maximum height at the .001 level of confidence (*6*).

The subjects saw more triangles above the fixation point than below it. Of 30 comparisons between the top and bottom of the ovaloid, 20 are sig-

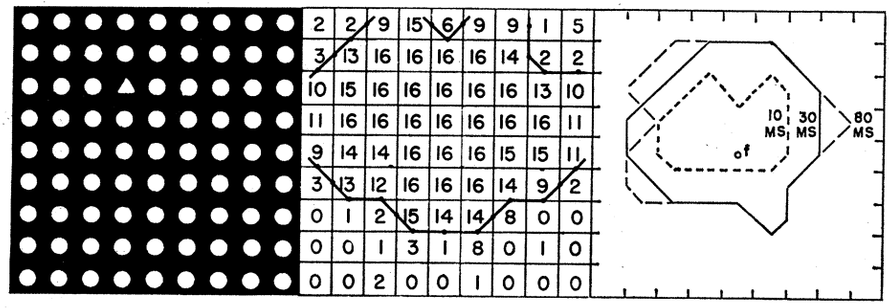

Fig. 1. (Left) A sample stimulus matrix containing one triangle. (Middle) A sample frequency table of positive responses (triangle seen), with liminal points and a liminal contour connecting them; the fixation point lies in the central cell. (Right) Three liminal fields for one subject, obtained with exposures of 10, 30, and 80 msec, respectively. *f*, Fixation point. The angular width of the 10-msec field is 2°23′, approximately the size of the fovea. Three other subjects had much larger fields at these short exposure times.

nificant at the .01 level. Three subjects saw more triangles on the left and two subjects saw more on the right at all exposure times. For only two of the subjects are these differences significant at all exposure times (.05 level). Thus, right-left asymmetry occurred under the conditions of our experiment but was not prominent (*7*).

Figure 1 (right) illustrates another clear finding: the field of search expands as a function of duration of exposure (luminance being constant). A sensitive measure of the effective size of the field is the total number of positive identifications for the cells lying within the liminal contour. When this measure is plotted against duration of exposure, there is a rapid increase in some undetermined interval in the 0- to 30-msec range and a slower increase in the 30- to 200-msec range for all five subjects (*8*).

Further research with shorter or longer exposure times, contrasting forms other than the circle and triangle, other discriminable variables (such as size and color), instructions that direct the subject's attention away from his visual fixation, or photographic monitoring of eye position and movement would help to test the generality of our results (*9*).

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References and Notes

1. Liminal measurements of the *range* of attention are well-known; see S. W. Fernberger, *Am. J. Psychol.* **32**, 121 (1921).
2. According to Fitts, a saccadic movement is unlikely to occur within the short times used in our experiment [P. M. Fitts, in *Handbook of Experimental Psychology*, S. S. Stevens, Ed. (Wiley, New York, 1951), p. 1322].
3. K. M. Dallenbach, *Am. J. Psychol.* **34**, 282 (1923); M. Mishkin and D. G. Forgays, *J. Exptl. Psychol.* **43**, 43 (1952).
4. H. W. Leibowitz, N. A. Myers, D. A. Grant, *J. Opt. Soc. Am.* **45**, 76 (1955).
5. H. R. Brody, H. H. Corbin, J. Volkmann, in "Visual search techniques" *Natl. Acad. Sci.–Natl. Res. Council Publ. No. 712* (1959), p. 48.
6. The shape is congruent with the square-span style of printing. See I. D. Nahinsky, *J. Appl. Psychol.* **40**, 37 (1956); N. S. Anderson and P. M. Fitts, *J. Exptl. Psychol.* **56**, 363 (1958).
7. Compare H. S. Terrace, *J. Exptl. Psychol.* **58**, 382 (1959) and the references given there.
8. Wever, in his experiments, found the threshold for the simplest figure-ground to be about 10 msec [E. G. Wever, *Am. J. Psychol.* **38**, 194 (1927)].
9. This research was conducted under contract No. AF 19(604)-3037, monitored by the Operations Application Laboratory, Electronic Systems Division. This report is publication No. ESD-TDR 62-215 of the Operations Application Laboratory.

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Origin and Biologic Individuality of the Genetic Dictionary

Abstract. Deoxyribonucleic acid contains sequences complementary to homologous amino-acid transfer ribonucleic acid molecules which serve as the translating device between polyribonucleotides and proteins. This implies that the RNA molecules have their primary origin in DNA. From the amount of DNA participating, one would infer that more than 20 complementary sequences exist per genome, a conclusion consistent with a degenerate code. The fact that complex formation occurs most readily with homologous RNA suggests that, while the language remains universal, each dictionary is uniquely identifiable with its own genome.

There are excellent reasons (*1*) for identifying the soluble ribonucleic acid (s-RNA) molecules with the genetic dictionary which permits translation from the four-unit language of the polynucleotides to the twenty-unit parlance of the proteins. It is of obvious interest to determine the relation between these RNA molecules and the genome. In particular, one would like to know whether sequences exist in homologous deoxyribonucleic acid (DNA) which are complementary to those which occur in the s-RNA molecules. Information on this question would illuminate a number of central issues, including problems of origin, uniqueness of sequences, and estimations of coding degeneracy.

A test for complementarity is specific hybrid formation between DNA and RNA. This criterion was used by Hall and Spiegleman (*2*) to demonstrate that RNA synthesized in *Escherichia coli* after infection by the bacteriophage T2 is complementary to the DNA of the virus rather than to that of the host. Identification of the hybrid structures was made by equilibrium density centrifugation in swinging bucket rotors, combined with isotopic labeling. The same procedures were used (*3*) to reveal sequences in DNA complementary to homologous ribosomal RNA and to show (*4*) that DNA sequences complementary to the nucleic acid of an RNA virus do not exist. The search for complementarity with ribosomal and viral RNA made it necessary to design experiments capable of detecting complexes which include between 0.001 percent and 0.01 percent of the total DNA. The sensitivity needed was achieved by labeling the RNA to the required specific activity. Confusion with "noise" in the form of either mechanical trapping, or chance coincidence in complementarity over short regions, was avoided by making use of the resistance of specific hybrids to degradation by ribonuclease. Nonspecific complexes are completely sensitive to such degradation (*3*).

The successful detection (*3*) of hybrids of ribosomal RNA and DNA encouraged us to extend the examination of homology of DNA and RNA to the species of s-RNA molecules. The sensitivities developed for the ribosomal and viral RNA investigations (*4*) made it certain that a definitive answer was attainable for s-RNA.

Isolation, purification, denaturation of DNA, and uniform labeling of RNA with either P^{32} or tritiated uridine were carried out as described previously (*3*). Soluble RNA was obtained from a cell extract from which ribosomes were removed by centrifugation for 3 hours at 100,000*g*. The RNA was isolated by the phenol procedure (*5*) and further purified by chromatography on columns of methylated albumin (*6*). The procedures of Hall and Spiegelman (*2*) for the formation and detection of hybrid structures in cesium chloride gradients were followed.

Preliminary experiments revealed that the temperature range (40° to 55°C) suitable for complex formation with either informational (*7*) or ribosomal RNA (*3*) did not lead to hybrids between s-RNA and DNA. In one sense this was fortunate since a simple method was thus provided for detecting contamination of s-RNA with ribosomal or complementary RNA.

Hybrid formation requires incubation at temperatures and under ionic conditions that allow formation of hydrogen bonds. It is perhaps not surprising

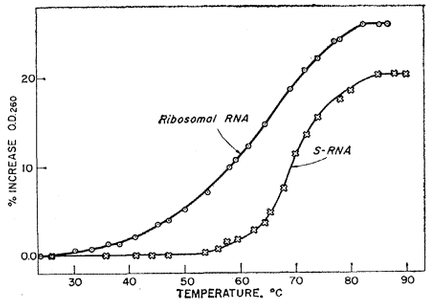

Fig. 1. Hyperchromicity of s-RNA and ribosomal RNA from *E. coli*. Solutions containing 30 μg/ml of nucleic acids in TMS (0.01*M* tris, 0.3*M* NaCl, 0.001*M* Mg^{++}, *p*H 7.3) were used. The $O.D._{260}$ readings at the ambient temperatures were made in stoppered quartz cuvettes in an Opticon spectrophotometer provided with controlled electrical heating. The temperature was increased at a rate of 0.5°C/min.