Technical Memorandum

Human Engineering Information

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Office of Technical Services
Department of Commerce
Washington 25, D. C.

AECU-3217

92-55-51

A STUDY OF LOCATION TIMES FOR POSITIONS ARRANGED ON A PANEL IN A RANDOM AND AN ORDERED MANNER

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ABSTRACT

The results of an experimental pilot study on the location time, for a sequence of N specified positions on a panel, are given for $1 \leq N \leq 30$. The positions to be located were randomly arranged on one set of panels and arranged according to an ordering scheme on a second set of panels. The location time for N positions randomly arranged on a panel varies approximately as N^2 . In the case of an ordered arrangement the location time is essentially proportional to N . Even for as few as 30 positions, the location time for a random arrangement was twelve times greater than for an ordered panel. For 60 positions the ratio would be 19, and for 90 positions the ratio would be 26.

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May 25, 1955

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1. DESCRIPTION OF THE EXPERIMENT

This memorandum concerns an experiment on the time (averaged over a population of 25 people) consumed in locating a number of specified, nonoverlapping circular areas outlined on a rectangular panel. The experiment was performed in the following manner: A test subject was seated at a desk on which was placed a sheet of paper on which were outlined N nonoverlapping circular areas.* Each area was labeled with a designation consisting of a capital letter and a number, e.g., A-16, P-102, etc. The subject was furnished with a disc-box containing N metal-rimmed cardboard discs (1-7/8 inches in diameter) each of which bore a designation number corresponding uniquely to one circular area on the paper sheet. The discs were stacked in a random order.** The time required by the subject to properly position all N of the labeled discs, one at a time, was determined for $1 \leq N \leq 30$. The time required, by the same subject, to pick N unlabeled discs from the disc-box, one at a time, and place them on the circular areas was also measured. The difference between the average time to correctly position N labeled discs and the average time to position N unlabeled discs was taken as the average location time for a sequence of N specified positions on the panel.

Two different modes of arranging the circular outlines on the panel were used in the experiment:

1. A random arrangement with respect to both geometrical and symbolic order. (See Fig. 1.)
2. A row-column arrangement with the designation of areas in a given row having the same capital letter and the rows arranged in alphabetical order. The designations of areas in a given column had the same number and the columns were arranged in numerical order. (See Fig. 2.)

The order in which the 30 panels were presented to a subject was random. This method of presentation was chosen to eliminate fatigue effects in the time average. The random order of presentation was preassigned and different for each subject. The subject could not acquaint himself with the arrangement of the outlined areas on the panel prior to the timed run as each panel was equipped with a cover which was removed only during a run.

2. RESULTS FOR THE RANDOMLY ARRANGED PANEL

The results for the randomly arranged panel are plotted in Fig. 3. Curve I represents the time to correctly position N discs in the manner described in Section 1. Curve II represents the time to position N blank discs. Curve III is the difference between Curves I and II and represents the average location time for a sequence of N specified positions on the panel. Curve III can be represented approximately by the function.

$$t(N) = 0.0635N^{2.07}, \quad (1)$$

where $t(N)$ is the location time in seconds.

* The circular areas were 2 inches in diameter. The rectangular sheet was 16-3/4 inches wide and 27-3/4 inches long.

** In addition, the discs were stacked in the disc-box in such a way that the subject could see only one disc-label at a time. The subject received the specification of the particular area to be located by picking a disc from the disc-box.

Fig. 1 -- Random arrangement of positions on a panel of 16 positions

Fig. 2 -- Ordered arrangement of positions on a panel of 16 positions

Fig. 3 -- Results for randomly arranged positions

This form was suggested by noting that

$$t(2N) \approx 4.2t(N). \quad (2)$$

Equation 2 has the form peculiar to homogeneous functions* and so it may be written as

$$t(2N) = 2^{2.07} t(N). \quad (3)$$

Results of an experiment in which only one subject was tested led to the hypothesis that the average time required to locate the proper position for one disc in a field of N positions, $\gamma(1, N)$, is proportional to N . This hypothesis was checked against the results of the location experiment with a test population of 25 subjects. The check was as follows: By hypothesis assume

$$\gamma(1, N) = mN. \quad (4)$$

If this is true, then the time, $t(N)$, required to locate a sequence of N specified positions on a panel (the specification disc being left on the sheet once it has been placed) would be

$$t(N) = mN + m(N - 1) + m(N - 2) + \dots + m \cdot 2 + m \cdot 1. \quad (5)$$

By Euler's theorem for the sum of consecutive integers,

$$t(N) = \frac{m}{2} N(N + 1). \quad (6)$$

If one solves pointwise for m and takes the average one finds

$$\bar{m} = 0.152.$$

The resulting form for $t(N)$ on the basis of the assumption, $\gamma(1, N) = mN$ is then

$$t(N) = 0.076N(N + 1). \quad (7)$$

The agreement of Equations 1 and 7 with Curve III is given in Table I.

TABLE I

Comparison of Location Times Given by Equations 1 and 7 with the Experimentally Measured Location Time Given by Curve III (Fig. 3)

Number of positions N	Location time given by Curve III (sec)	Location time given by Equations 7 and 1 (sec)			
		Equation 7, $0.076N(N + 1)$	Deviation (percent)	Equation 1, $0.0635N^{2.07}$	Deviation (percent)
2	0.50	0.46	8.0	0.27	46
4	1.50	1.52	1.3	1.12	26
6	2.80	3.12	11.0	2.60	7.1
10	7.50	8.35	11.0	7.41	1.2

* A function $t(N)$ is homogeneous to degree n if

$$t(mN) = m^n t(N).$$

Hence the exponent 2.07 in Equation 3 is derived by noting that $2^{2.07} = 4.2$.

TABLE I (Cont'd)

Comparison of Location Times Given by Equations 1 and 7 with the Experimentally Measured Location Time Given by Curve III (Fig. 3)

Number of positions N	Location time given by Curve III (sec)	Location time given by Equations 7 and 1 (sec)			
		Equation 7, $0.076N(N + 1)$	Deviation (percent)	Equation 1, $0.0635N^{2.07}$	Deviation (percent)
14	15.50	15.95	2.9	14.90	3.9
18	25.50	26.00	2.0	25.00	2.0
22	38.00	38.40	1.0	38.20	0.5
26	54.00	53.30	1.3	54.20	0.4
30	74.50	70.60	5.2	73.20	1.7

The equation based on the $\gamma(1, N) \propto N$ hypothesis (Equation 7) has an average error magnitude of 4.9 percent over $2 \leq N \leq 30$. The other form

$$t(N) = 0.0635N^{2.07}$$

is not appropriate for $N < 6$ and has an error magnitude of 2.4 percent for $6 \leq N \leq 30$.

Tests made on smaller sheets indicate that the proportionality hypothesis becomes less appropriate as the panel size decreases. This can be explained as follows:

1. Decreasing the panel size forces a greater density of outlined areas for a given value of N . This means that more outlined areas lie in the search region covered by the subject's eyes as he scans the panel.
2. The diminution of the panel size also brings in the edges, so to speak, to provide a reference for searching by pairs or triplets instead of singly. If one tries to search a large panel by pairs, the tendency is to 'get lost' and search an area more than once. If the boundary of the panel is within view a mental 'reference grid' can be superposed over the panel.

The $\gamma(1, N)$ curves for a given panel size tend to be linear for small values of N (low density) and to flatten out for large values of N (high density).

3. RESULTS FOR AN ORDERED PANEL

The results for an ordered panel are plotted in Figs. 4 and 5. Curve I represents the time to correctly position N discs in the manner described in Section I. Curve II represents the time to position N blank discs. Curve III is the difference between Curves I and II and represents the average location time for a sequence of N specified positions on the panel. Curve III can be represented approximately by the function

$$t(N) = 1.384N^{1.064} - 1.54N + 0.78. \quad (8)$$

Fig. 4 -- Results for an ordered arrangement of positions;
time to position N labeled and N unlabeled discs

Fig. 5 -- Results for an ordered arrangement of positions;
location time for N discs (Curve III)

9

The ratio of location time for a randomly arranged panel to the location time for an ordered panel is given in Fig. 6. It is interesting to note that for as few as 30 positions the location time for a randomly arranged panel is 12 times greater than the location time for an ordered panel.

Fig. 6 -- Ratio of the location time for N randomly arranged positions to the location time for N positions in an ordered arrangement

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Case No. 418.01
May 25, 1955

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