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VISUAL SAMENESS: A CHOICE TIME ANALYSIS OF PATTERN RECOGNITION PROCESSES [1]

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Ss judged the "sameness" of pairs of matrixes, each having several cells blackened at random. One group (Similarity search) classified matrix pairs as "same" if they had even one pair of blackened cells in corresponding locations. A second group (Identity search) classified pairs as "same" that were identical with respect to all blackened cell locations. Decision times of the Similarity-search group were much longer than those of the Identity-search group. While the performance of the Similarity-search Ss indicated they were engaged in a serial processing of the stimulus array that of the Identity-search Ss in some conditions closely approximated gestalt processing.

Human beings, like all pattern recognition devices, are frequently required to decide whether two stimuli are the same or different. Although these judgments of "same" and "different" constitute an important component of much of our behavior, the processes involved have only recently begun to receive direct treatment (e.g., Bindra, Williams, & Wise, 1965; Walk, 1966). Before constructing comprehensive theories of such judgments, it may be useful to explore the likelihood that all trials which terminate in same responses may not represent the operation of some invariant or unitary process. The length of time required for recognition of sameness can provide a sensitive index to the processes underlying that recognition (Sekuler, 1966). Research described in this report shows first, that humans can adopt any of several different modes of sameness recognition, and, second, that within certain limits imposed by the complexity of visual patterns to be processed, *S*s can often operate more efficiently by processing patterns as wholes rather than in terms of constituent parts.

That sameness recognition is not a unitary, invariant process becomes especially clear if it is considered how one might instruct a pattern recognizing machine to classify pairs of inputs as either same or different. There are two basic kinds of instructions one could give the machine. On one hand the machine might be required to classify in terms of all the discriminable characteristics of the input. It might compare two patterns along some exhaustive catalogue of details and, finding a mismatch for any of them, respond "different." This strategy is a search for *identity* between patterns and would, e. g., permit a machine to declare an italic *a* and a boldface **a** different. On the other hand, one might want to train the recognition machine to make its classification on the basis of a small number of critical details, ignoring those which are unimportant for the classification. In training a system to recognize and classify as same letters *a* written by a number of different people, one must train it to disregard certain noncri-

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terial differences among inputs, even though such differences were highly discriminable. This second kind of recognition process would constitute a search for *similarity* between patterns. The authors have explored the implications of these two kinds of pattern recognition strategies and the distinctive varieties of sameness which they represent by asking human observers to adopt such strategies in a visual pattern recognition experiment.

Method

The *S*s viewed pairs of matrixes arranged side by side. Each of the matrixes was four cells × four cells. In both members of a pair the same number of cells (1, 2, or 4) were blackened at random. Various numbers of cells in corresponding locations in both matrixes were blackened, e.g., with four cells blackened in the right hand matrix either 0, 1, 2, 3, or 4 of the corresponding cells in the other matrix were also blackened. Hereafter, corresponding cells filled in both matrixes will be said to be in register.

Two groups of six undergraduate *S*s each were used. The *S*s in the "Identity-search" group were told to classify two matrixes as the same if for *every* cell filled in one matrix the corresponding cell was filled in the other. The *S*s in the "Similarity-search" group were instructed to call two matrixes same if they had at least one filled cell in corresponding locations. Members of both groups were told to call matrixes different if their respective criteria for same were not met.

Stimuli were presented with a 16-mm. film strip projector equipped with an electromechanical shutter. The *S*s viewed the matrixes on a rear projection screen mounted in one channel of a tachistoscope viewing box. The other channel provided a constant background of about 1.5 ftl. The matrixes, viewed over a distance of 59 cm., each subtended a visual angle of 8° and were separated from one another by 4° of visual angle. Viewing was binocular.

For each group four film strips of 300 frames were prepared. In any strip the stimuli were so arranged that same and different stimuli occurred with approximately equal frequency and in random order. Programming equipment controlled the intertrial interval (3 sec.) and the advance of the film strip. The electromechanical shutter opened when *S*s pushed a button and closed when they responded "same" or "different" on a spring loaded toggle switch. A clock (Standard Electric) measured the interval between the presentation of the matrixes and *S*'s response. This interval and the "same" or "different" response on each trial was recorded by *E*. Each *S* was tested individually in 12 sessions, with three replications of every film strip. The order of film strips was randomized within blocks of 4 sessions. In order to counterbalance the potentially differential difficulty of throwing the response switch to one side or the other, half of the *S*s in each group used leftward switch throw to signal "same," rightward throw to signal "different." The other half of each group had the reverse assignments of response to switch positions.

Results

Figure 1 shows for each group and number of cells filled, the relationship between choice times and the number of cells in corresponding locations in the two matrixes. These data include only trials on which the correct response was made. Separate analyses of variance were performed on the mean choice times for *S*s in each group and condition of number of cells filled. In all of the analyses Replication was a

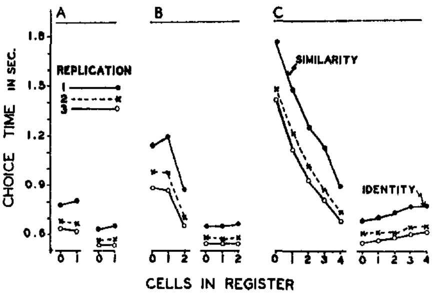

Fig. 1. Mean choice times for each group and replication. (The results for conditions of one, two, and four cells filled in each matrix are shown in panels A, B, and C, respectively. In each case the number of filled cells that occupy corresponding locations in both matrixes is shown on the abscissa.)

significant source of variance. Each panel in Fig. 1 shows choice times decrease systematically over the three replications. With only one cell filled (Fig. 1, Panel A) the choice times of either group are unaffected by the number of cells in register ($F < 1.0$ for both). The correct response for each group varied, of course, depending upon the number of cells in correspondence. For example, with one cell filled and none in correspondence the correct response for Similarity-search *S*s was "different"; with one cell in correspondence the correct response was "same." The fact that mean choice times do not differ with number of cells in correspondence suggests that, at least, in the single case where only one cell is filled, there is no basic asymmetry in times required to respond "different" or "same" (cf. Bindra, Williams, & Wise, 1965).

The results are somewhat modified when two cells in each matrix are filled (Fig. 1, Panel B). For the Similarity-search group there is a significant effect, $F\ (2, 10) = 32.80$, $p < .01$, of number of cells in register: choice times decrease with increasing numbers of cells in register. There is no significant effect, $F\ (2, 10) = 1.18$, $p > .25$, however, of number of cells in register for the Identity-search group. Choice times for these latter *S*s are equally fast with 0, 1, or 2 cells in register.

With four cells in each matrix filled (Fig. 1, Panel C), there is for both groups a significant effect of the number of cells in register. But the character of this relationship is quite different for the two groups. The Similarity-search group's choice times decrease, $F\ (4, 20) = 25.32$, $p < .01$, with the number of filled cells in register. Choice times of the Identity-search group increase, $F\ (4, 20) = 9.80$, $p < .01$, with the same independent variable. In addition to the difference between the signs of these relationships there is an obvious difference in absolute magnitude. Lines were fitted to each function shown in Panel C by the method of least squares. For the Similarity-search group the slopes of the best fitting lines were $-.21$, $-.18$, and $-.18$ for each of the replications while the corresponding values for the Identity-search group were $+.02$, $+.01$, and $+.02$. These differences in slopes between the two groups confirms the apparent differences in Fig. 1C: the effect of the number of cells in register is about an order of magnitude greater for the Similarity-search than it is for the Identity-search.

One additional noteworthy relationship can be seen in Fig. 1. Within any given replication of any condition it is true that all of the choice times for the Identity-search group are lower than the choice times for the Similarity-search group. Regardless of the number of cells filled or the number of such cells in register, Identity-search *S*s are performing more quickly than are their Similarity-search counterparts. Some previous experiments (e. g., Nickerson, 1966a) have shown that in some circumstances *S*s achieve faster choice times at the expense of increased error rates. To determine whether the overall superior speed for the Identity-search group was achieved at the cost of increased errors, analyses of variance were done which permitted direct comparisons of the error rates of the two groups of *S*s. A separate analysis of variance was performed on the error rate data for each condition of number of cells filled 1, 2, and 4. Entries in the analysis were percentage of errors made by each *S* within a given replication. The

TABLE 1

Correct Response Alternative, Number of Trials, *M* and *SD* of Number Wrong for Each Group, and Matrix Configuration

In Register	Number of Cells Filled									
	1		2			4				
	0	1	0	1	2	0	1	2	3	4
Similarity Search										
Correct Response[a]	D	S	D	S	S	D	S	S	S	S
Number of Trials[b]	582	576	579	309	306	582	174	168	186	162
Wrong Responses										
M	28.7	19.7	49.1	59.7	9.2	101.0	29.0	28.0	31.0	27.0
SD	21.5	9.3	23.2	10.0	4.0	39.0	7.2	4.0	2.9	1.0
Identity Search										
Correct Response	D	S	D	D	S	D	D	D	D	S
Number Trials	585	585	285	288	585	168	174	177	189	558
Wrong Response										
M	70.3	53.0	30.0	19.5	78.0	12.1	20.2	25.0	42.1	105.8
SD	54.0	14.9	7.4	6.4	28.5	4.4	5.2	7.2	4.3	31.9

[a] "D" = different, "S" = same.
[b] Number of trials for each *S* in each replication.

results of the analyses may be summarized as follows. In none of the three was the main effect of the identity-search vs. Similiarity-search a significant source of variance (all p's $>$ .10). In each analysis the number of cells in register proved to be a significant source of variance (all p's $< .05$). The interaction between search group and number of cells in register was significant ($p < .01$) with two and four cells filled but not with only one cell filled ($p > .50$). The interaction between number of cells in register and replications was significant ($p < .05$) for the analyses of both the one cell and two cell filled conditions but was was not a significant source of variance in the analysis of the four cell filled data ($p > .10$). The triple interaction, between search group, number of cells in register, and replications, was significant only in the case of two cells filled ($p < .05$).

Table 1 gives the mean error rates for each group and matrix configuration.

Discussion

The differences in the patterns of choice times for the two experimental groups show that they went about their respective pattern recognition tasks in quite different ways. For both two- and four-cell filled conditions, the choice times for the Similarity-search *S*s decrease with increasing number of cells in register between matrixes. This relationship between choice times and number of cells in register would be expected if the processes leading to *S*'s response included a major self-terminating, serial search component (Egeth, 1966). These results for the Similarity-search group can be compared to expectations derived from the following simple model. As the number of filled cells in correspondence between matrixes increases so does the likelihood that, for any randomly selected filled cell in one matrix the corresponding cell in the other matrix will also be filled. Since the discovery of one pair of filled cells in correspondence between matrixes satisfies the sameness criterion of the Similarity-search, the mean number of "cellwise" comparisons required to reach this criterion will decrease with increasing num-

TABLE 2

EXPECTED VALUE OF NUMBER OF CELLWISE COMPARISONS REQUIRED BY SIMILARITY-SEARCH *S*s TO CLASSIFY MATRIXES

Number of Cells Filled in Each Matrix of Pair	Number of Filled Cells in Correspondence				
	0	1	2	3	4
1	1.00	1.00	—	—	—
2	2.00	1.50	1	—	—
4	4.00	2.50	1.67	1.25	1.00

ber of cells in correspondence. One can calculate the expected value of the number of "cellwise" comparisons that would be required for *S*s in each condition. These expected values, given in Table 2, can be developed on the assumption that *S*s are using a serial self-terminating search strategy. To indicate how such values are derived consider the case of a Similarity-search *S* confronted with a pair of matrixes each having two cells filled but with only one of the pairs of filled cells in corresponding locations. Sampling randomly and without replacement from the two filled cells in one matrix, the probability that the corresponding cell will also be filled in the other matrix is .50. This means that on one-half of the trials a match will occur in the first "cellwise" comparison and the search terminated with a response of same. If a match had not been found, it assumed that *S* would resample, and on this second comparison, the two corresponding cells compared would with certainty both be filled. Thus the expected value of the number of comparisons required in this condition is $.5(1) + .5(2) = 1.5$. While it would be nice to be able to describe the behavior of the Similarity-search group in such simple terms as is implied by the entries in Table 2, it is clear that a more complicated formulation will be required. For example consider what happens when the data shown in Fig. 1 for the Similarity-search *S*s are replotted against another, altered abscissa. If the Similarity-search had proceeded, as Table 2 implies, in a series of "cellwise" comparisons of approximately constant duration the choice time functions should be linear when replotted against the appropriate expected value of Table 2. Plotting choice times against these expected values yields functions considerably further from linearity than those shown in Fig. 1. This suggests that *S*s did not conform perfectly to the details of the logic which underlies the expected values derived for Table 2. Such deviations from the model could arise from failure to meet any one on more of its assumptions. Data on the ability of *S*s, in channel capacity experiments, to recognize spatial position in stimulus contexts like our matrixes (see Garner, 1962, pp. 53–97) suggests that given enough time *S*s should not have had difficulty in sampling without replacement. That is, *S*s should have been able to distinguish perfectly cells already sampled and those not yet sampled. With a considerably greater number of cells, both filled and unfilled, it is obvious that *S*s, required to operate beyond channel capacity for recognition of spatial position, would tend to confuse cells already sampled and those not yet sampled. Under these circumstances the sampling for cellwise comparison could not be sampling without replacement.

There is another factor which probably contributes to the failure of the "cellwise" processing model. Egeth (1966) has discusssed the contribution of irrelevant information to performance in a task not too unlike our own. Egeth's data argue strongly that *S*s required to categorize stimuli on certain dimensions and not on the basis of others are very likely to be influenced in some measure by the presence of the latter, irrelevant stimuli. In the present experiment the unfilled cells in each matrix may constitute just such a set of irrelevant stimuli. The simple model outlined above therefore, may also be deficient because it neglects to consider the time required to locate filled cells in the matrix. This time to locate filled cells would clearly be some function of any time required to decide against further consideration of any of the unfilled cells.

The more interesting results in this experiment however are those from the other, Identity-search, group. The striking difference between the performance of the two groups that can be seen in Fig. 1 leads one to wonder what possible search strategy *S*s in the Identity-search group could have employed. With two-cells filled in both matrixes (Fig. 1, Panel B) the choice times of the Identity-search group are constant over conditions with 0, 1, or 2 filled cells in correspondence. This suggests that these *S*s were processing the matrixes as gestalts, comparing the whole of one matrix with the whole of the other. Their performance resembles what would be expected on the basis of some template matching process and is especially interesting because their choice times are always as short or shorter than the corresponding times for the Similarity-search group. This means that despite the apparent greater complexity of template matching over cellwise comparisons, *S*s with little or no practice in the task can process relatively complicated visual patterns as wholes in less time than is required to process any of the constituent parts of those wholes. This superiority in processing time may again reflect the fact that *S*s, using some kind of cellwise comparisons, must spend some part of the processing time on irrelevant stimuli, i.e., the unfilled cells.

There does seem to be rather severe limits on the complexity of patterns that *S*s can process as wholes. With four cells filled (Fig. 1, Panel C) the analysis of variance showed a small, but significant effect of the number of cells in register upon the choice times of the Identity-search *S*s. With four cells filled, *S*s in this group were not able, as they were with only two cells filled, to process the matrixes as wholes. Since the slopes of the choice time functions for the two groups differ by an order of magnitude, it is unlikely that *S*s in the Identity-search group used the same pattern recognition process as their Similarity-search counterparts. Any one of a number of "hybrid" pattern recognition strategies (i.e., combinations of serial processing and template matching) could accommodate the data from the four-cell filled condition in the Identity-search. In the absence of additional, more severely constraining data further speculation on the characteristics of such a hybrid process is not very useful.

The complexity of the relationship between error rate and choice time in this experiment can be seen by comparing corresponding values for each in Table 1 and Fig. 1. Consider, e.g., the relationships between error rate and choice time for the case of four cells filled. As Table 1 shows, for the Similarity-search group there is a tendecy for error rates to decrease with increasing number of cells in register. But, for the Identity-search group the error rate increases with the number of cells in register. Comparing these trends to the curves in Panel C of Fig. 1 it can be seen that in the case of the Similarity-search group the decrease in choice times with increasing cells in register is accompanied by a parallel *decrease* in error rate while for the Identity-search group there is a quite different relationship. For these latter *S*s the slight increase in choice times with number of cells in register is accompanied by an *increase* in error rate. This picture is further complicated by the data for two cells filled in which the curvilinear relationship between error rate and number of cells in register (Table 1) does not seem to be systematically reflected in the choice time data of Fig. 1B. The complexity of these relationships makes it abundantly clear that the problem of treating incorrect responses in choice time studies is far from general solution (cf. Egeth & Smith, 1967).

Some investigators have reported a systematic difference in the times required to judge stimuli the same as opposed to judging stimuli different (Bindra, Williams, & Wise, 1965). The differences between the performance of our two search groups are not related in any obvious way to differences between times required for same and different judgments. Consider, e.g., the data for the two cell filled condition (Fig. 1B). With either 0 or 1 cell in register the correct response for *S*s in the Identity-search group was "different." For the Similarity-search group "different" was the correct response to the O cells in register condition. Despite this commonality of response to these several conditions, Fig. 1B shows that the times required by the Identity-search group are substantially less than those for the Similarity-search group. The same argument applies to the case of two cells filled and two cells in register. For both groups the correct response to the stimulus was "same" but again the times required by the Identity-search *S*s, within each replication, are less than those for the Similarity-search *S*s. These data and the other relevant comparisons that could be made in Fig. 1A and 1C indicate that the differences between Similarity-search and Identity-search are not merely some function of differences between "same" and "different" judgment times.

The major point then, is that when there are not too many cells filled in each matrix, *S*s of the Identity-search group could process the patterns as wholes. This resembles the finding of Neisser, Novick, and Lazar (1963) that, after considerable practice, *S*s could search a list for any one of 10 alphanumeric target characters as quickly as they could for only one of them. Nickerson (1966b) recently proposed that Neisser's result could only be obtained when two experimental preconditions held. The first of these was sufficient practice with the task. (Neisser's *S*s required more than 20 days practice to develop their terminal behavior.) The second condition was ". . . the use of a paradigm which requires activation of the same set of feature-detecting operations trial after trial [1966b, p. 767]." The results in the present experiment argue against the necessity of Nickerson's suggested prerequisites. Identity-search *S*s showed behavior like Neisser's *S*s even within the first replication of the experiment, i.e., within Sessions 1–4. Moreover, the fact that cells in the matrixes were filled at random ruled out any appreciable trial-to-trial similarity among patterns shown to *S*s.

The authors' results then make it quite clear that *S*s can and do adopt distinctive modes of pattern recognition. When the complexity of the patterns permits, *S*s can process the patterns as wholes with a considerable saving in processing time. This reduced time does not seem necessarily to be purchased at the cost of increased error rate. While this experiment seems to suggest a surprisingly severe limit to the complexity of patterns that can be processed as wholes, this limit may be a product of the random patterns the authors used. Far more complicated configurations may prove amenable to gestalt processing provided such configurations conform to the stimulus requirements of feature analyzers responsible for the extraction of certain important stimulus characteristics such as visual orientation and position (Sekuler & Pantle, 1967).

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