Parallel visual processing: Constant same-different decision latency with two to fourteen shapes

DON DONDERI AND BRUCE CASE²
McGILL UNIVERSITY

Fourteen Os were shown 2, 5, 8, 11, or 14 geometric shapes at a 200-msec exposure. The maximum visual extent was the same for all numbers of shapes. The stimulus conditions were: all shapes identical, 1 shape different from the rest, and, for 5 to 14 shapes, 3 shapes different (4 shapes in all). The number of shapes, the condition, and the shapes used varied randomly through the sequence of 160 exposures. Decision latency to correct same or different response was independent of the number of shapes presented. Correct same and three-different decisions were faster than one-different decisions, but with two shapes different decisions were faster than same. The results suggest that same-different decisions are made with information processed in parallel from many stimuli.

Donderi and Zelnicker (1969) reported that it took as long to make a same-different decision for 13 shapes as it did for 2, when the shapes were presented over a constant visual extent and when the various numbers and arrangements of shapes were presented in random order. Their task required Os to push a button labeled "same" if all the shapes presented in a 50-msec exposure were identical and to push a button labeled "different" if any one of the shapes was different from the rest. There were only two kinds of stimuli: all the shapes were identical or one shape was different from all the rest. What would happen if there was more variety among the "different" stimuli? The decision latencies in the Donderi and Zelnicker experiment were quite long: from 1.0 sec to 1.5 sec. Would the constant decision-latency result occur if performance was faster overall? The experiment reported here was designed to answer those questions, and thus to test the generality of the two-stage explanation proposed by Donderi and Zelnicker for their results: Parallel processing of shape information into shape categories and a subsequent signal-detection process for response of same (one category) or different (two categories) as proposed by Bindra, Williams, and Wise (1965).

Fig. 1. Typical stimulus cards used in the experiment.

METHOD

There were 14 paid high school and college student Os (one female). Each O had the same task—to respond by pushing a "same" or "different" lever on each 200-msec presentation of a series of 160 stimuli. Each stimulus was a set of 2, 5, 8, 11, or 14 black geometric shapes on a white background. The shapes were (1) all the same, (2) 1 was different from the rest, or (3) with 5-14 shapes, 3 were different from the rest and from each other (4 different shapes in all). Four examples are shown in Fig. 1.

The Os were instructed to respond as quickly as they could on each stimulus presentation but to work accurately and make as few errors as possible. The "same" lever was to be pressed when Os thought that all the shapes were identical and the "different" lever when they thought that one or more shapes were different from any other shape. Each O was tested individually. Before the experiment began, the O was told what kinds of stimuli might appear on any exposure—how many shapes and in what possible combinations (1, 2, and 3 above) they might occur. He was given 10 practice trials on stimuli selected by chance from among the experimental

stimuli. Then he was tested on a randomly ordered series of 160 experimental presentations. Each stimulus presentation was signaled by a 2-sec tone of moderate intensity which began 5 sec before the stimulus onset. Decision latency was measured from the stimulus onset. Decision latency and response to each presentation was recorded, but O was not informed of his results. The experiment lasted 40-45 min for each O, including a 10-min rest after the 80th experimental presentation.

There were 32 stimulus presentations for each number (2, 5, 8, 11, and 14) of shapes. Sixteen presentations were same and the rest were different. In the two-shape presentations, all possible combinations of circle and square in diagonally opposite corners of the stimulus card were presented equally often. There were eight same, four one-different, and four three-different cards for each number of shapes used between 5 and 14. Each of four shapes (circle, square, triangle, and semicircle) was used twice in making the eight same cards. Each type was used as the one-different shape once. Each type was used as the more numerous shape on the one-different stimulus card equally often

2 shapes-same

8 shapes-3 different

11 shapes-same

14 shapes-1 different

Fig. 2. Mean correct same-different decision latency as a function of stimulus condition and number of shapes presented.

over the 40 presentations of this kind with 5 to 14 shapes. Each shape was used as the more numerous background in the three-different cards once for each number of shapes presented. The position of shapes on all cards was chosen haphazardly, with the condition that there were always shapes as far apart in the vertical (8 deg) and horizontal (13 deg) dimensions as possible. The dimensions in visual angle of the shapes used were: side of square, 1 deg; diameter of circle and semicircle, 1 deg 12 min; side of triangle, 1 deg 32 min. Each of the 16 cards just described was exposed twice.

Os rested the index finger of their right hands about 1 in. behind and directly between two response levers, each $\frac{3}{4}$ in. wide, with centers $1\frac{1}{2}$ in. apart. The levers and Os' forearm rested on a table at a comfortable height. The stimuli were viewed in a three-field tachistoscope. Preexposure, exposure, and postexposure field brightnesses were 1.28 fL.

Two randomly ordered presentation lists of 40 stimuli were prepared. Each list included four same and four different presentations of two-shape stimuli, and four same, two one-different, and two three-different presentations with 5 to 14 shapes. Each list was used twice in succession, and the order of use of the lists was reversed between Os.

RESULTS

The average decision latency of a correct response for each type of stimulus and for each number of shapes was calculated separately for each O. The grand mean for all Os as a function of these variables is plotted in Fig. 2. Notice that average decision latency does not increase as the number of shapes in the stimulus increases.

The significance of differences among mean correct decision latencies was studied using the analysis of variance. The basic datum was an individual O's mean correct

decision latency for each stimulus condition and each number of shapes presented. Analysis 1 was made on the data for same and one-different stimuli over the entire range of 2 to 14 shapes. Analysis 2 was made on the data for same, one-different, and three-different stimuli over the range from 5 to 14 shapes. The three factors in both analyses were: number of shapes presented (N), stimulus condition (C), and observers (O). There was a significant interaction between stimulus condition and number of shapes presented in Analysis 1, which results from the reversal of decision latencies between same and one-different conditions when two shapes were presented, compared with the order of latencies obtained for all the other numbers of shapes (Fig. 2). There was not a significant difference between the presentation conditions or among the different numbers of shapes presented. There was a significant difference among the three stimulus conditions tested in Analysis 2. There was no significant difference among numbers of shapes presented and no significant interaction between stimulus conditions and the number of shapes presented. *t* tests of the differences among mean correct decision latencies separate the one-different (825 msec) from the same (782 msec, $t = 2.7$, $p < .02$) and three-different (775 msec, $t = 4.7$, $p < .001$). The latter two conditions are not significantly different from each other ($t = .36$). Tables 1 and 2 summarize the analyses of variance.

The conclusions we draw from these analyses are that (1) there is a reliable reversal of decision latencies for same and one-different categories between the two-shape presentation and the other numbers of shapes presented, (2) over the range of 5 to 14 shapes, the one-different decision latencies are uniformly slower than either the same or the three-different latencies, which are indistinguishable; and (3) there is no change in decision latency as a function of the number of shapes presented over the entire range from 2 to 14 shapes.

The total number of errors (88) was .035 of the total number of responses. The distribution of total errors is very uniform, with some predominance of errors to two-shape different presentations. Nine of the 14 Os had as many or more errors in the two-shape category as in any other. But there was little clustering of errors in the performance of individual Os. The largest number of errors recorded for any single type of stimulus was six errors for one O in the two-shape different category. The distribution of total errors is summarized in Table 3.

Table 1
Analysis of Variance 1

Source of Variation	df	Mean Square x 10 ⁵	F
Number of Shapes Presented (N)	4	448	2.28
Stimulus Conditions (C)	1	1150	2.56*
Observers (O)	13	9923	
N X C	4	2173	10.1**
N X O	52	196	
C X O	13	449	
N X C X O	52	214	

* $p < .1$, ** $p < .001$

Note—data entered in seconds

Table 2
Analysis of Variance 2

Source of Variation	df	Mean Square	F
Number of Shapes Presented (N)	3	4100	1.29
Stimulus Condition (C)	2	40947	4.78*
Observers (O)	13	128737	
N X C	6	879	0.02
N X O	39	3188	
C X O	26	8560	
N X C X O	78	53306	

* $p < .05$

Note—data entered in seconds

Table 3
Distribution of Total Errors Over Stimulus Conditions

Stimulus Condition	Number of Shapes Presented				
	2	5	8	11	14
Same	11	8	10	10	8
One-Different	20	4	3	4	1
Three-Different		1	5	1	2

Note—There were 32 presentations per O in the one-different condition for two shapes. All other different conditions had 16 presentations each; all same conditions 32 presentations.

DISCUSSION

The results of this experiment and the previous Donderi and Zelnicker (1969) experiment indicate that over a small binocularly observed visual area the latency of a same-different decision following brief exposure does not depend on the number of geometric shapes exposed, over the range from 2 to 14. The importance of this result is with respect to where and when parallel or serial information processing occurs in visual-motor behavior. Parallel processing means evaluating inputs simultaneously to make a decision; serial processing means evaluating them successively. Neisser (1967) has suggested that parallel processing occurs in simple sensory-motor tasks but that serial processing is required for more complicated cognitive ones.

The most rapid decision latency in our experiment was about 700 msec after the onset of the stimulus. It is possible to imagine a serial process that might go to completion within that psychologically relatively long time. Since both the area of visual field filled by figures and the decision latency were constant over all numbers of shapes presented, one explanation may be that the visual system accepts and uses this kind of information serially at a rate that is constant for a given area of visual field to be searched. This hypothesis is consistent with the results of Neisser's experiments on visual search, where search times increased slightly with the length of the stimulus but often did not increase with the complexity of the task (Neisser, 1963). If this explanation is true, then same-different decision time should increase with the area to be searched, independently of the number of shapes presented.

Serial processes that end in "different" decisions might terminate before all the stimuli have been processed. If O retains memories of previous shapes and compares each successively scanned shape with them, he can stop and press the "different" button as soon as one input does not match a previous one. The greater his initial chance of scanning a different stimulus, the more quickly he should complete the task. If O scans area at a constant rate, his chances of finding a different shape decrease from the three-different to the one-different to the same condition within each number of shapes presented. However, the one-different decisions take longer than three-different or same decisions, contrary to this expectation.

The plausible interpretation for our results is that shape information is accepted at a constant rate from a given visual area, regardless of the number of

shapes, but that the processing does not stop with a "different" response when it is logically possible for it to do so. If we allow the rate per unit area to become sufficiently large, this becomes indistinguishable over a small area at least from "parallel processing." This explanation comprehends the independence of decision latency from the number of shapes and defers the explanation of the latency differences between stimulus presentation conditions to a second part of the decision process: the model proposed by Bindra, Williams, and Wise (1965) and based on signal detection theory.

To apply the Bindra et al explanation, we imagine that the O first categorizes the entire stimulus into one of three distributions along a decision continuum. He does this independently of the number of shapes in the stimulus. It is done by what we have just called "parallel processing." In our experiment, the three distributions correspond to the same, the one-different, and the three-different types of stimuli. Although there are three kinds of stimuli, there are only two responses, same or different. There is one criterion point that divides the decision continuum into one region for a "same" and one region for a "different" response. Bindra et al postulate that latency to respond to a stimulus increases inversely with the distance along the continuum from the stimulus to the criterion point. From the latency data of our experiment, it appears that the one-different distribution is closest to the criterion point of the decision continuum. The same and three-different decisions would fall equally far away on opposite sides of the criterion. To test this proposal quantitatively requires a decision experiment with a sizable number of errors, because the proportions of various types of errors define the distance between

the hypothesized stimulus distributions and enable a direct comparison of obtained distance and obtained decision latency to be made.

The relative decision latencies using this explanation depend as much on the location of the decision criterion as on the discriminability of the stimuli. We think that changes in the decision criterion are responsible for the reversal in relative decision latency of same and one-different decisions between this experiment and the previous one (Donderi & Zelnicker, 1969). The other outstanding difference between the results of this experiment and the earlier one is that the average latencies in the first experiment were unusually long for this type of situation. We attribute this difference only to an unusual regard for caution produced in the first experiment's Os by the instructions and the way in which they were presented. The latencies of our new experiment are similar to latencies found in other work of the same type (e.g., Bindra et al, 1965).

REFERENCES

- BINDRA, D., WILLIAMS, J. A., & WISE, J. S. Judgments of sameness and difference—Experiments on decision time. *Science*, 1965, 150, 1625-1627.
- DONDERI, D. C., & ZELNICKER, D. Parallel processing in visual same-different decisions. *Perception & Psychophysics*, 1969, 5, 197-200.
- NEISSER, U. *Cognitive psychology*. New York: Appleton-Century-Crofts, 1967.
- NEISSER, U. Decision time without reaction time: Experiments in visual scanning. *American Journal of Psychology*, 1963, 76, 376-385.

NOTES

1. This research was supported by a grant from the National Research Council of Canada.
2. Address: Department of Psychology, McGill University, Montreal 110, Canada.

(Accepted for publication January 16, 1970.)