FOREWORD

This report was prepared by the Presentation of Information Section, Human Engineering Branch, Behavioral Sciences Laboratory, 6570th Aerospace Medical Research Laboratories, under Project No. 7183, "Psychological Research on Human Performance," Task No. 718303, "Research on Human Intellectual Functions." It is the second of two reports dealing with human problem-solving behavior. The first, WADD TR 60-2, "Some Aspects of Problem Solving: I. Method and Materials," describes many of the characteristics of the material used in this study. The authors are grateful to Richard Buchanan and John Christian, who collected many of the data, and to R. H. Hoerner, Data Processing Branch, Data Services Division, and E. L. Godfrey, Analysis Branch, Digital Computation Division, Wright-Patterson Air Force Base, Ohio, for their valuable services in effecting computer analyses of the data. The experimental work was performed at the Engineering Psychology Research Project at Antioch College, Yellow Springs, Ohio, during 1959 and 1960 under Contract AF 33(616)-6095.

ABSTRACT

Performance on a forced-choice target detection task was examined in terms of the sequences of responses subjects made. In about 50 percent of all cases resulting in a correct detection, subjects made a specific error immediately before identifying the correct target. In about the same percentage of cases, but of failure to detect the correct target, that same error was given instead of the correct response. Practice on the task resulted in a general improvement in speed and number of correct detections, and also in a change in the proportional occurrence of certain errors: the most likely but wrong response (X) was given more often, and the least likely and wrong response (Z) was given less often, with practice. In addition, while the best 25 percent of the subjects detected more targets to criterion and detected them more rapidly than the poorest 25 percent, the proportional occurrence of specific response patterns was approximately the same in the two groups for the targets that were correctly detected. Scaled similarity of the alternatives was an important determiner of errors, while perceived orientation had no relation either to perceived similarity or to the response sequences. A mechanism is suggested for these sequential acts involving a decrease in probability of detecting specific kinds of forms following perception of another kind.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

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SOME ASPECTS OF PROBLEM SOLVING:

SEQUENTIAL ANALYSIS OF THE DETECTION OF EMBEDDED PATTERNS

INTRODUCTION

Certain kinds of problems can be solved by successfully applying certain rules. Sometimes a set of rules is defined explicitly to a subject, and the task then consists in choosing the proper ones to get from a set of givens to the goal (ref. 11). Sometimes the subject's task itself consists in detecting or defining the rules of operation (ref. 16). In either case there is a certain formalism about the problem and about the solving process, and when subjects' responses are partitioned, it may be found that certain transformations or certain strategies are preferred over others (ref. 13). Reflecting the "structure" of the problem, responses often converge at various stages of the solving process, and successful solution of the problem may occur only if certain steps are taken in a certain sequence. In some cases, in fact, it becomes possible to speak of a form of "threshold" for solving the problem, since the probability of ultimately detecting the correct solution increases with the number of correct steps taken toward it, even though the steps do not necessarily make equal contributions to the solving process (ref. 1). The solving process in these cases may be shown to have a specific shape or developmental sequence.

The question arises whether such phenomena of "cognitive" problem solving can be found in the simpler cases of target detection and "perceptual" problem solving. Do subjects' responses show some patterning, is there some evolutionary development or sequence of steps through which subjects must go in order to detect a target correctly? Does the mechanism involved in visual search have some preferred mode of operation with respect to various forms, which is revealed by specific response patterns? Miller and Frick (ref. 10) have described a method for looking at sequences of responses. This paper describes the application of qualitative aspects of this method to the case of detecting targets embedded in visual noise.

METHOD

Stimulus Materials

The stimulus materials were 100 cards on each of which two rows of geometric figures appeared. The bottom row contained four numbered figures, usually pentagons. Only one of the numbered figures appeared in all of three complex figures contained in the upper row. Four typical cards are shown in figure 1. The method for constructing these stimulus figures and some of their characteristics have been described elsewhere (ref. 8).

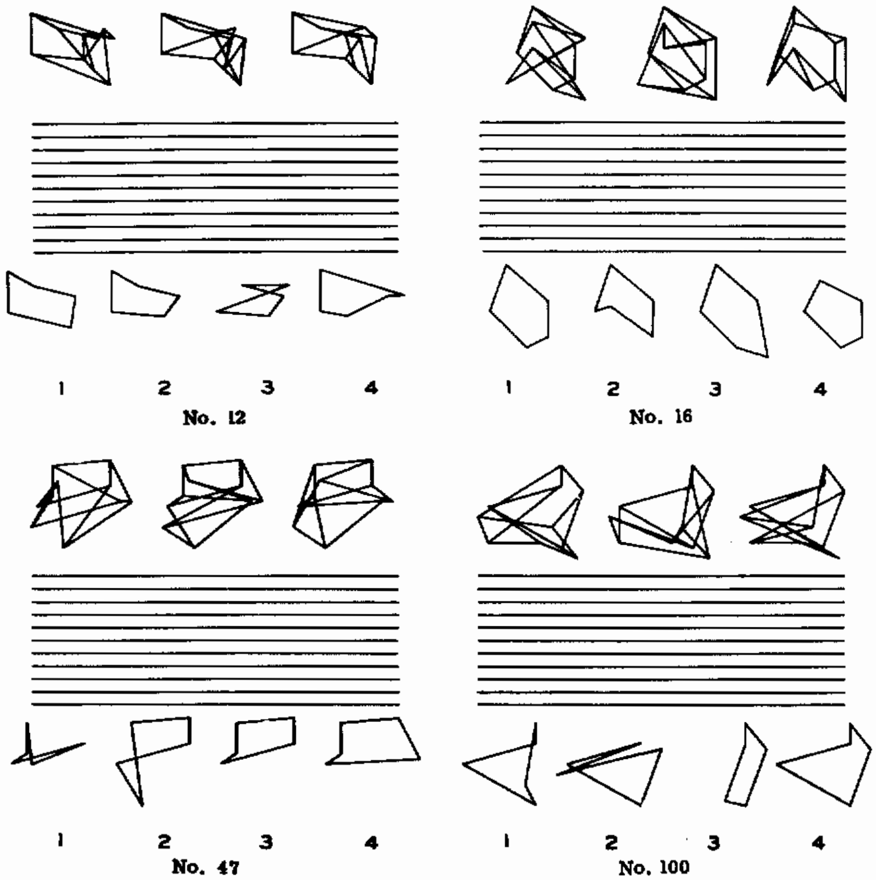

Figure 1. Four of the 100 Test Cards

On each card one numbered figure in the lower row appeared in all three figures of the upper row. The code numbers (12, 16, 47, 100) did not appear on the face of the cards.

Each stimulus card was displayed once every 4 seconds for 0.5 second by means of apparatus previously described (ref. 9). The stimulus cards were at an optical distance of 100 centimeters and the display on each occupied an area of 10 by 10 centimeters (5.7° square). Luminance of a display card was 2 footlamberts. Observation was dioptic with light-adapted eyes.

Subjects

Subjects were 24 male and 24 female undergraduates, paid volunteers. Each subject was assigned haphazardly to one testing sequence, and was tested individually three times.

Procedure

The 100 cards were divided into three decks of 33,33, and 34 cards, with one deck presented at each testing session. Two male and two female subjects were shown the cards in each of the six possible permutations of decks, in one order of presentation of the cards. Another group (two male and two female subjects) was presented the cards in the reverse order of each of the permutations. The effects of fatigue and practice were approximately balanced in this way.

The subject's task was to identify by number the one figure in the bottom row of each card that appeared in all three figures of the upper row. The basic experiment consisted of 25 consecutive 0.5-second presentations of a card at the rate of one presentation every 4 seconds. After each presentation the subject was required to call out his best guess of the right answer. Before beginning to answer to a card, however, the subject was shown the upper row of figures only, for three 0.5-second "pre-exposures." In a typical experimental session, a subject was shown 33 cards, to each of which he gave 25 consecutive reports. A 2-minute rest intervened between the fifteenth and sixteenth cards dividing the session into two parts. Thus, there were six testing periods, three sessions with two periods to each session. In each period the subject responded to about 16 cards, each of which was presented approximately 25 times. A period lasted about 30 minutes.

As there were four possible answers to each card, the chance probability of giving the right answer on any trial was 0.25. To insure that the subject had detected a target with more than chance success, the criterion was adopted that he must have given at least ten consecutive correct responses after the fifteenth trial. Ten consecutive correct responses given early in the sequence, but followed by incorrect responses, was considered a failure. However, if the subject had begun a series of consecutive correct responses after the sixteenth trial, presentations were continued beyond the twenty-fifth trial until the subject had given ten consecutive correct responses, or one wrong response.

Methods of Analysis

The results of two different analyses are presented. One, for cards solved to the criterion of ten consecutive correct responses after the fifteenth trial, is the proportion of correct detections on any trial, $p(r_c)$, taken across subjects and across cards. The other is the sequence of runs of responses made while trying to detect the target. The latter is more complicated and requires illustration.

The 25 responses made by two subjects to a sample card, the correct answer to which was 4, were as follows:

Subject A: 11 444 33333 22 111 4444444444

Subject B: 33 111 3 44444 2 1 333333 22 1111.

The two sequences have been broken into runs, six runs for subject A, nine for subject B. For subject A, the content of the ultimate wrong run was 1, of the penultimate, 2, and of the antepenultimate, 3. Subject B, while not solving the problem, also had the same answers as the contents of his last three runs.

The number of female subjects making each possible response on the last three wrong runs was tabulated for each card. Let X' stand for the most frequently occurring wrong response on any card made by the female subjects on the ultimate wrong run, Y' for the next most frequently occurring wrong answer, and Z' for the alternative that occurs least. Such determinations of X', Y', and Z', based principally on the contents of the ultimate wrong runs made by the female subjects to each problem, were used to evaluate the runs made by the male subjects.* Thus, the sequence of Z'Y'X'A indicates that, on a given problem, the subject gave as his first run of wrong responses an alternative chosen the fewest number of times in place of the correct one, improved this on his next run, then chose the alternative given most often in place of the right answer, and finally gave the right answer itself. Taken across all problems, the symbols will be used without primes.

RESULTS

The 24 male subjects, presented with 100 cards each, generated a total of 2400 cases (approximately 60,000 trials). Of these 2400 cases, 1812 were correctly detected to criterion and 564 were not. Errors in collecting the data were detected in the remaining 24 cases, which have been excluded from the analysis.

Of the 1812 successful cases, there were 511 in which the male subjects gave only correct responses to a card; such correct responses were symbolized as A. In addition, there were 500 cases in which the male subjects gave exactly one wrong run prior to the criterial run, 295 cases in which they gave exactly two wrong runs, and 506 cases in which they gave at least three wrong runs. These various forms of successful performance are segregated in column 7 of table I, and the proportions shown in that column are to the base 1812.

In this experiment, there are 3^n possible ways for the subject to give $\underline{n}$ wrong runs when successive identical responses are regarded as part of one run. Column 1 of table I shows the 27 possible ways to give three wrong runs, each pattern terminating in the correct response, A, and column 2 shows the frequency and proportion of occurrence of each pattern among the 1812 cases. In column 3, these four-letter patterns are collapsed to their common three letters, yielding nine patterns (see ref. 12). In addition, in the upper part of the table, these nine patterns are repeated and the number of cases are shown of only three-letter patterns (i.e., two wrong runs and the criterial run). In column 5, both of these sets are collapsed to the three patterns which show their common two letters, and the cases of only one wrong run prior to the criterial run also are shown. Column 7, as noted, shows the total number of cases. The first entry in column 7, A 511, indicates the number of cases in which the correct answer only was given.** The proportions in columns 2, 4, and 6 are based on the subtotals shown in column 7.

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*For 30 cards, the choice of X', Y', and Z' based only on the ultimate wrong run of the female subjects was ambiguous; that is, two or more alternatives were given equally often. For these 30, one of which was No. 100 in figure 1, the frequencies of the penultimate wrong run were arbitrarily added to those of the ultimate. On five cards, one of which was No. 12, the antepenultimate cases also were added. Independent groups of subjects were used to evaluate response sequences: one group to define X, Y, and Z, and another group on which these definitions were used. We know of quantitative differences between males and females (see Results) but, in fact, if the males were used both to define and to test X, Y, and Z, the proportions shown would be only very little different from what they are, so that the qualitative differences between males and females, so far as the ordering of the responses goes, are small.

**One tactic used by some subjects was that of calling out a single number many times over while searching for the correct target. The entry of 511 in the A-only cell includes the cases in which subjects, using this tactic, by chance picked the correct answer on the first trial, as well as those in which the target was detected correctly on the basis of the three pre-exposures.

TABLE I

FREQUENCY AND PROPORTIONAL OCCURRENCE OF VARIOUS PATTERNS

Solved Problems

1	2		3	4		5	6		7	
									A	511 .28
						XA	257	.51		
						YA	133	.27	A	500 .28
						ZA	110	.22		
			AXA	45	.15					
			YXA	55	.19	XA	150	.51		
			ZXA	50	.17					
			AYA	27	.09					
			XYA	39	.13	YA	83	.28	A	295 .16
			ZYA	17	.06					
			AZA	11	.04					
			XZA	31	.10	ZA	62	.21		
			YZA	20	.07					
XAXA	47	.09								
YAXA	32	.06	AXA	104	.20					
ZAXA	25	.05								
AYXA	20	.04								
XYXA	25	.05	YXA	74	.15	XA	237	.47		
ZYXA	29	.06								
AZXA	16	.03								
XZXA	16	.03	ZXA	59	.12					
YZXA	27	.05								
YAYA	16	.03								
XAYA	18	.04	AYA	48	.09					
ZAYA	14	.03								
AXYA	14	.03								
YXYA	14	.03	XYA	51	.10	YA	143	.28	A	506 .28
ZXYA	23	.04								
AZYA	8	.02								
XZYA	26	.05	ZYA	44	.09					
YZYA	10	.02								
XAZA	18	.04								
YAZA	13	.02	AZA	45	.09					
ZAZA	14	.03								
AXZA	11	.02								
YXZA	24	.05	XZA	42	.08	ZA	126	.25		
ZXZA	7	.01								
AYZA	5	.01								
XYZA	24	.05	YZA	39	.08					
ZYZA	10	.02								
p_e = .037			p_e = .111			p_e = .333				
Total										1812

Failed Problems

8	9		10	11		12	13		14
						X	38	.61	
						Y	11	.18	62 .11
						Z	13	.21	
			AX	24	.29				
			YX	11	.13	X	47	.56	
			ZX	12	.14				
			AY	5	.06				
			XY	8	.10	Y	23	.28	83 .15
			ZY	10	.12				
			AZ	5	.06				
			XZ	2	.02	Z	13	.15	
			YZ	6	.07				
XAX	52	.12							
YAX	29	.07	AX	102	.24				
ZAX	21	.05							
AYX	15	.04							
XYX	23	.05	YX	58	.13	X	201	.48	
ZYX	18	.04							
AZX	14	.03							
XZX	15	.04	ZX	41	.10				
YZX	12	.03							
YAY	18	.04							
XAY	13	.03	AY	49	.12				
ZAY	18	.04							
AXY	12	.03							
YXY	18	.04	XY	43	.10	Y	114	.27	419 .74
ZXY	13	.03							
AZY	7	.02							
XZY	4	.01	ZY	22	.05				
YZY	11	.03							
XAZ	14	.03							
YAZ	10	.02	AZ	39	.09				
ZAZ	15	.04							
AXZ	10	.02							
YXZ	12	.03	XZ	37	.09	Z	104	.25	
ZXZ	15	.04							
AYZ	11	.03							
XYZ	11	.03	YZ	28	.07				
ZYZ	6	.01							
p_e = .037			p_e = .111			p_e = .333			
Total									564

Columns 5 and 6 of table I show that the most frequently occurring two-letter pattern is XA, and p(XA), its proportional occurrence, is nearly the same (.51, .51, and .47), whether generated in two-, three-, or four-run sequences. Without regard to the number of wrong runs previously generated, subjects converge, in about 50 percent of the cases, on a specific error immediately before identifying the correct target. (This error, of course, varies from problem to problem.) In similar fashion, p(YA) is .27, .28, and .28 in the three sequences, respectively. Other comparisons of identical patterns also show considerable agreement, those patterns including X's generally occurring more frequently than those without X's. All of these proportions are based upon the independent frequencies shown in column 7.

The relations described so far have been for the targets detected to criterion only. A comparison of these successful detections with failures can be made after examining columns 8 through 14 of table I. Column 14 shows that there were 62 cases of failure to detect the correct target in which the subjects made only one run (that is, gave the same response to all presentations), 83 cases in which two runs were made, and 419 cases in which three or more wrong runs were made. Columns 12 and 13 show that, of the 62 cases of one wrong run, 38 had X as that run; similarly, of the 83 cases of two wrong runs, 24 had AX, and so on. Comparisons made across the two parts of the table show fair agreement in the proportional occurrence of similar patterns. It appears, therefore, that neither the number of runs made nor the eventual outcome seriously affects the proportional occurrence of the various patterns shown in columns 5 and 12.

Although many of the proportions in the body of table I are significantly different from the expected values (p_e) shown at the bottom of that table, there is little predictive value in the early wrong runs. A negative correlation ($r = -.45, p < .05$) between number of runs and number of targets detected to criterion and a positive correlation ($r = .80, p < .01$) between numbers of runs on failed and on solved cards suggest why: subjects tend to be consistent in the number of runs made to problems, and primarily the poorer subjects (those detecting fewer targets) make the greater number of runs. Failure also is characterized by more variability than is success. Comparing columns 7 and 14 shows that only 28 percent of the targets correctly detected, but 74 percent of the failed ones, had three or more wrong runs.

Several subsidiary analyses of the data were undertaken to explore the reliability and identify the determinants of the patterns shown in table I.

a. A comparison was made of the best and poorest 25 percent of the subjects. Figure 2 shows how the extreme quartiles differ on successive trials. Two curves are plotted for each group showing the absolute proportion of correct detections for all targets (triangles) and the proportion of correct detections for the targets detected to criterion (circles). Both level of performance and rate of improvement with trials clearly are greater for the best subjects. However, table II, which is similar in principle to the left of table I, indicates that these differences in speed and power do not affect the sequences of responses. (The four-letter patterns have been collapsed to their common three letters because of the small frequencies.) While columns 5 and 5' show that the best subjects tended to detect targets with fewer runs than did the poorer subjects, columns 1 through 4 and 1' through 4' show that, for a given number of runs, the proportional occurrence of specific patterns is approximately the same in the two groups of subjects. Columns 4 and 4' may be compared with each other as well as with column 6 of table I. Such comparisons again show a tendency toward equality in the proportional occurrences of similar patterns.

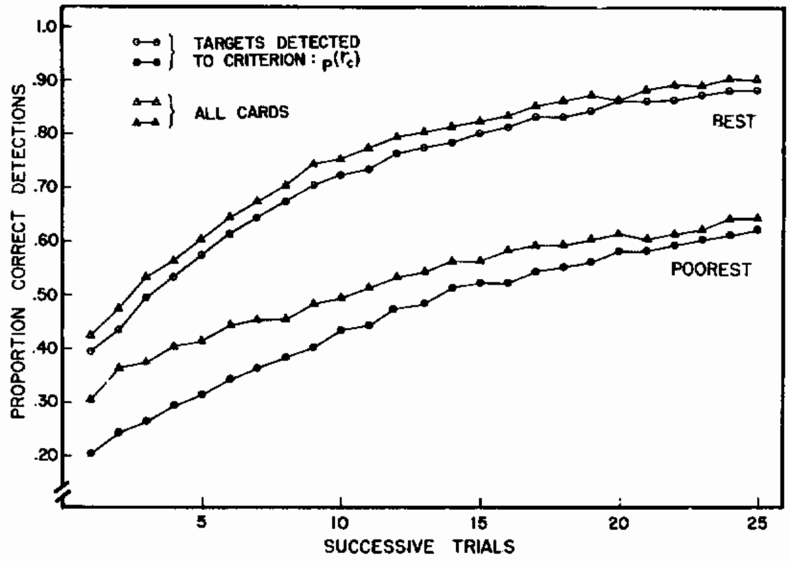

Figure 2. Comparison of Best and Poorest Male Subjects

The proportional occurrence of correct detections is plotted on the ordinate for the successive trials shown on the abscissa. The triangles show all correct detections; circles show the correct detections only for targets eventually detected to criterion. Each plotted point is based on 600 observations.

TABLE II

SOLUTION PATTERNS OF UPPER AND LOWER 25 PERCENT OF MALE SUBJECTS

	Best Subjects							Poorest Subjects						
	1	2		3	4		5	1'	2'		3'	4'		5'
							A 189 .36							A 79 .21
				XA	83	.49					XA	42	.44	
				YA	52	.31	A 169 .32				YA	28	.29	A 95 .25
				ZA	34	.20					ZA	25	.26	
3-letter only	AXA	15	.18					AXA	9	.15				
	YXA	13	.15	XA	45	.53		YXA	9	.15	XA	31	.51	
	ZXA	17	.20					ZXA	13	.21				
	AYA	5	.06					AYA	5	.08				
	XYA	11	.13	YA	25	.29	A 85 .16	XYA	9	.15	YA	17	.28	A 61 .16
	ZYA	9	.10					ZYA	3	.05				
	AZA	3	.04					AZA	1	.02				
	XZA	8	.09	ZA	15	.18		XZA	7	.11	ZA	13	.21	
	YZA	4	.05					YZA	5	.08				
Collapsed 4-letter patterns	AXA	22	.24					AXA	35	.24				
	YXA	11	.12	XA	44	.49		YXA	20	.14	XA	73	.51	
	ZXA	11	.12					ZXA	18	.12				
	AYA	9	.10					AYA	11	.08				
	XYA	9	.10	YA	25	.28	A 80 .15	XYA	13	.09	YA	36	.25	A 144 .38
	ZYA	7	.08					ZYA	12	.08				
	AZA	6	.07					AZA	13	.09				
	XZA	8	.09	ZA	21	.23		XZA	10	.07	ZA	35	.24	
	YZA	7	.08					YZA	12	.08				
	$p_e = .111$			$p_e = .333$				$p_e = .111$			$p_e = .333$			
	Total						523	Total						379

b. Since the data were collected over six testing periods, they were analyzed for the effects of practice. One of these effects appears as an increase in the occurrence of correct detections with succeeding trials. In figure 3 the proportional occurrence of correct responses for targets detected to criterion, $p(r_C)$, is plotted on the ordinate for the first, fifth, and each additional fifth trial, while testing periods are plotted on the abscissa. This quasi-inductive visual discrimination task yields data similar to those found with "learning sets" (ref. 7), and in other studies of target detection (refs. 2 and 6). Yet another effect of practice is the change, in successive testing periods, in the values of XA and ZA shown in figure 4. A general increase appears for p(XA) and a general decrease for p(ZA), the averages of the two-, three-, and four-letter patterns. Thus, with practice, subjects both improve their ability to detect the correct target, as shown in figure 3, and converge on the choice of error made prior to a correct detection, as shown in figure 4. The long "rise times" for these results, extending over 2500 trials per subjects, are notable. The sex differences shown in figure 3 describe an initially higher level of performance by the males, but a higher rate of improvement by the females.

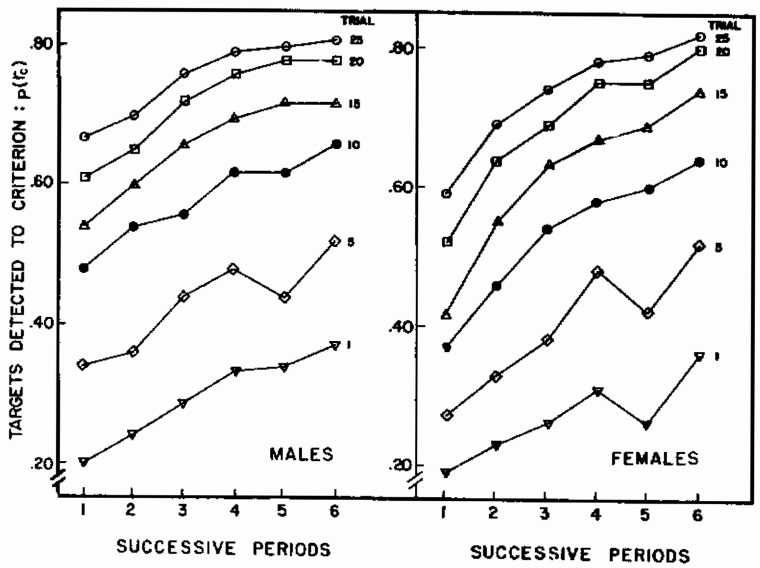

Figure 3. Effects of Practice on Correct Detections

The ordinates show the proportions of correct detections for targets detected to criterion. Successive testing periods are plotted on the abscissa. The parameter is the trial number. The figure shows that performance on all trials improves with successive testing periods. Note the difference in slope of the curves for the males and females. The curves may be read vertically within periods to show relations similar to those of figure 2.

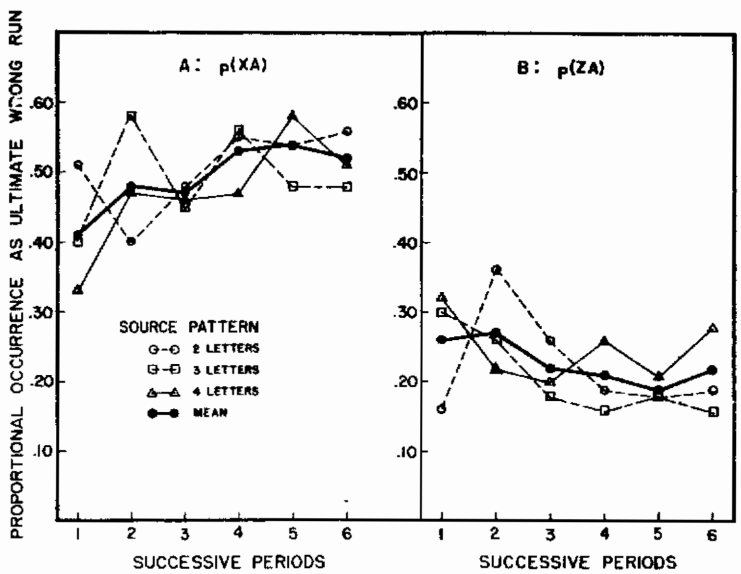

Figure 4. Effects of Practice on Choice of Ultimate Wrong Run

A. The proportional occurrence of X as the ultimate wrong run, p(XA), is shown on the ordinate for the successive testing periods shown on the abscissa.

B. The proportional occurrence of Z as the ultimate wrong run, p(ZA), is shown on the ordinate for the successive testing periods shown on the abscissa.

c. The influence of perceived similarity between alternatives on the choice of responses was evaluated in a manner analogous to the presentation shown in table I. For that evaluation, 36 male subjects judged the similarity of the four alternatives to each other for 30 cards selected at random. These results were used to evaluate the response sequences on those same problems for the 24 male subjects in the main experiment.

To obtain the similarity definitions, three forms at a time from each card were arranged as a triad and photographed on strip film. Each of the four figures on a card was the standard for one triad, with position of the alternatives counterbalanced among subjects. The subjects indicated, for each triad, which of the two alternatives was more similar to the standard. Each subject made 384 judgments of which the first 24 were practice. "Similarity" itself was not defined to the subject. Scaled distances of the three alternatives on each card from the correct target, A, were computed (ref. 18, p. 263 ff.). The most similar alternatives (closest to A) were defined as X', the next most similar as Y', and the least similar as Z'.

A sequence analysis, analogous to tables I and II, was made for the 24 male subjects for the 30 cards whose alternatives had been judged for similarity. A comparison of the proportions obtained by this "similarity definition" of X, Y, and Z with those obtained by the "frequency definition" used in tables I and II is shown in table III. The agreement on X between frequency and similarity determinations was high ($\frac{22}{30}$ = 73 percent), while a symmetrical inversion occurred for Y and Z. While overall similarity of the alternatives to the target accounts for a large portion of the coding, other factors also are important.

TABLE III

CONCORDANCE OF CODES BASED ON FREQUENCY AND ON SIMILARITY

		Similarity Definition			
		X	Y	Z	n
Frequency Definition	X	22	6	2	30
	Y	6	6	18	30
	Z	2	18	10	30
	n	30	30	30	

$\chi^2 = 44.8$, df = 4
$p < .01$

d. Similarities of orientation of the response alternatives might be thought to be an important influence in confusing them. The role of orientation was investigated in turn, both as a predictor of response sequences and as a predictor of judged similarity. No relation of orientation was found to either variable. The test was made as follows.

The response alternatives from the 30 cards used for the judgments of similarity described above, plus two other cards, were photographed one at a time on strip film. Four male subjects, tested individually, judged the same set of figures once each day on four successive days. The order of presentation of the figures was different on each day. The film strip was projected onto a white wall, one frame at a time at a distance which made the figures occupy from 10 to 25 centimeters squared. Presentation of the figures was automatic and occurred once each 10 seconds for 7 seconds. Immediately to the right of the projected figures was a pointer 8 centimeters long controlled by a Selsyn motor. On the appearance of a figure, the subject rotated a knurled knob at his desk until the wall pointer indicated the apparent orientation of the figure. The subject's setting was recorded by the experimenter and the pointer reset to due north before presentation of the next figure.

The objective orientation of each figure was defined as the slope of the line that minimized the squares of the perpendiculars from the points of the figure to the line.* The correlation coefficients between orientation so calculated and the subjects' mean settings, or perceived orientation, varied from $r = .70$ to $r = .84$ for the four subjects individually, and was .83 for the subjects as a group (for all of these values, $p < .01$). See figure 5. Thus, orientation calculated as above is a good predictor of perceived orientation.

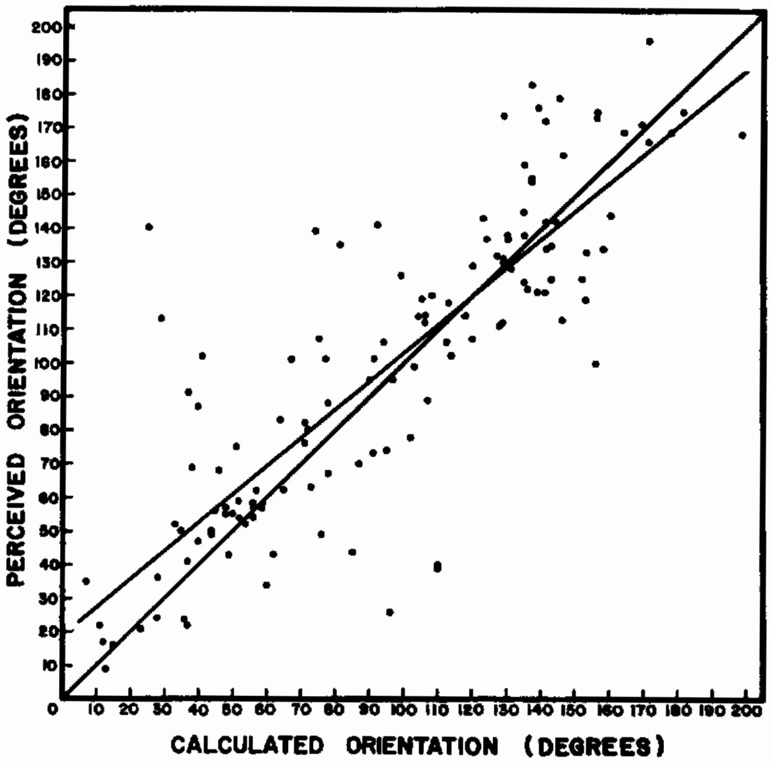

Figure 5. Perceived Versus Calculated Orientation

The plotted values of perceived orientation represent the mean of all settings made by the 4 subjects for a given figure.

*The line has the property of being invariant with rotation of the figure. The slope of the line is given by the equation

$$m = \frac{\sigma_Y^2 - \sigma_X^2 + \sqrt{(\sigma_Y^2 - \sigma_X^2)^2 + 4\sigma_{XY}^2}}{2\sigma_{XY}}$$

where σ_X^2 is the variance of the points projected onto an x-axis, σ_Y^2 the variance on the y-axis, and σ_{XY} is the covariance. The calculated slopes were converted to angular values between 0° and 180°. In obtaining subjects' mean settings, a value of 180° was sometimes added to some settings. This was done when the responses by a single subject to the same figure were, for example, 170°, 160°, 150°, and 10°. Thus, some of the plotted points in figure 5 exceed 180°. This rule of "add 180°" was invoked only when a difference of more than 135° separated the original values.

To determine whether perceived orientation was a dimension of perceived similarity, and whether it was a significant contributor to the response patterns shown in table II, the absolute differences in calculated orientation between a target figure and its three alternatives were found. These alternatives were labeled X', Y', or Z' in order of increasing difference from A. The 30 problems coded by similarity were recoded for orientation. A count of the concordance in choices between frequency and orientation, analogous to that of table III, indicated that orientation of the alternatives had no predictive value in identifying response confusions. A similar count of concordances in coding alternatives based on orientation versus similarity showed similar results. While calculated orientation of a plane figure is a good predictor of perceived orientation, there appears to be no significant relation between orientation and perceived similarity.

DISCUSSION

The principal purpose oι this experiment was to discover whether a behavioral sequence of a kind analogous to that found with certain cognitive problems also characterized perceptual problem solving. Stated otherwise, the question was whether the perceptual mechanism goes through some strategy in detecting targets, and whether, if such formal sequences occur, it is possible to define the characteristics of the stimuli which provoke them.

With respect to the first question, the answeı is an equivocal yes: in about 50 percent of all cases with at least one error, the subjects made a specific error before detecting a target correctly. In addition, in about 50 percent of the cases of failure to detect the correct target, that same error was given in place of the correct response (table I). Further, comparison of good and poor subjects indicates that, while the better subjects are characterized by greater speed and more power on the task, the two groups make a given error just before a correct detection about the same proportion of times: that is, p(XA) for the best and the worst subjects has about the same value (table II). Finally, the effects of practice were shown to be twofold: more targets were correctly detected more rapidly with practice and certain errors came to be preferred to others.

With respect to the second question, the characteristics of the stimuli which provoke these patterns, the judgments of similarity indicated that perceived similarity is a fair predictor of errors: alternatives most similar to the target are mistaken for it most often. One would expect no less. However, no relation was found between similarity and orientation. In view of subjects' sensitivity to orientation (ref. 4) this might be considered surprising, although orientation as a variable has been shown to have little effect on discrimination and transfer among adult higher animals (refs. 5, 17).

How do subjects detect a target? Figure 2 indicates that induction and hypothesis formation play some part. The figure indicates that the three "pre-exposures" yielded enough information for the better subjects to make $p(r_c)$ on the first test trial = .39. One subject, in fact, who eventually detected 98 of the 100 targets to criterion, gave the correct responses to 52 of those 98 on all 25 test trials. Taking advantage of the three pre-exposures to select elements out of the upper row to match them against the lower would give better than chance responding on the early trials. This seems to be what the better subjects did. Contrariwise, waiting for the answer figures and matching them against the upper row would yield only chance responding on the early trials. This seems to be what the poorer subjects did. See figure 3. Osler and Trautman (ref. 13) recently described another case of problem solving in which poorer performances were more stimulus-centered and better performances more conceptual. The large difference between the two curves shown for the poorer subjects in figure 2, as compared with the small difference for the better subjects, indicates that the poorer subjects can detect the correct target, but are poorer because they apparently fail to recognize that they have detected it.

In the main task described here, the subjects were required to operate on a complex visual display presented to them for 0.5-second exposures. This required them to move their eyes a good deal over the visual field. Such forms of scanning eye movements have been suggested as a kind of basis for all form perception (see, for example, ref 5). But the present results occur in a situation in which scanning eye movements (contour-tracing), even if the subjects had time enough to scan, would produce failure rather than success, since the figures of the upper row are filled with visual noise. In addition, other evidence has shown that whole figures can be seen without eye movements, ambiguous perspective figures continue to reverse in stopped image conditions, and parts of a contour deteriorate while other parts remain (refs. 14, 15). The scanning provides the logistic support for perception, getting eyes to where they need to go, while the perceiving is affected by other means. Finally, in answer to the question of how a target is detected, the occurrence of the patterned responses raises the possibility that some form of carom or rebound effect dominates the matching of parts that seems to occur. In the processing of serially presented information, the probability of perceiving a given kind of form may not remain constant, but may vary as a function of the kind of form already perceived, revealing a kind of perceptual refractory period or figural masking. We are currently attempting to investigate this question experimentally.

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