Information gathering in diagnostic problem solving as a function of number of alternative solutions¹

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Abstract

Three groups of 12 Ss each were given 6 successive problems with 8, 16, or 32 possible solutions from which they were to determine the unique solution by getting information concerning as few elements of a pattern of 8 binary elements as possible. All groups then did 2 problems with 32 possible answers. Number of information getting moves and time to solution were an increasing linear function of number of possible solutions. There were no differences among groups with respect to type of information getting move selected or in transfer to the last two problems.

Problem

The amount of information, I , in bits needed to select uniquely one from among n alternatives is $I = \log_2 n$. Thus, a subject confronted with many alternatives needs more information than one confronted with few and he will probably spend more time gathering it. The present study was designed to determine the effect upon information gathering in a relatively content-free diagnostic problem-solving task of number of alternative solutions. "Information gathering" is evaluated in terms of number of information-getting moves, solution time and quality of information.

Method

The experimental task, which has been described elsewhere (Neimark, 1961), consisted of a 9-in square problem board in which a pattern of 8 black or white circles, equally spaced around the diameter of an 8-in circle, was concealed beneath 8 moveable shutters. S also received an answer sheet containing 8, 16, or 32 of the 2⁸ possible patterns of 8 binary elements and was told that one of these patterns was concealed in the board; his task was to determine it by opening a minimum number of shutters. A schematic of the problem task for a board with 5 shutters and an answer sheet with 4 possible solutions appears in Fig. 1.

Each time S moved a shutter he was to write the letter designating its position on his answer sheet and also across the face of all possible answers eliminated by information received on that move. He proceeded in this fashion until he knew the answer, whereupon he wrote the number of the solution on his answer sheet, closed all the shutters, removed the problem from the board, and went on to the next problem and its answer sheet. Eight problems, each in a tabbed poly-film envelope, were loaded into the board before the start of the experiment and S also received a stack of 8 different answer sheets.

Three groups of 12 volunteers from a summer Introductory Psychology class served as Ss. All groups did 6 successive problems with answer sheets containing 8, 16, or 32 possible answers and 2 final problems with 32 alternative answer sheets. Ss were individually run and time to the nearest 1/2 sec. was recorded from start of the first problem to completion of the last.

The k possible answers on an answer sheet were selected so that on each problem 4 shutter positions were black on half the patterns, 2 were black on 1/4 of the patterns and the remaining 2 were black on 1/8 of the patterns. Patterns in which infrequent black positions appeared were never selected as problems. Different answer sheets were obtained by random permutation of the basic arrangement. An

Fig. 1. A. Schematic of a problem board containing five movable shutters with shutters E and C open. B. Array of four patterns which might be presented in the problem board. Only pattern 4 can be the answer to the problem in the board at A.

additional group of 12 Ss was run with answer sheets containing 16 randomly selected patterns; this group did not differ significantly from the other 16 groups and, therefore, will not be reported.

Results

Response measures employed were time to solution and number of shutters opened (moves) in the solution of each problem. Number of correct solutions was not analyzed since there were few errors (4, 5, and 3 on the first 6 problems and 2, 5, and 3 on the last two for Groups 8, 16, and 32 respectively out of 72 or 24 possible correct). In addition, we attempted to assess the quality of information gathering by means of a "strategy score." The strategy score was obtained by computing the expected informational outcome of each move and getting the mean over all moves on a given problem. For example, if S started with A in Fig. 1 he would get 2 bits of information if a black circle appeared and only .415 bits if a white circle appeared. Since the a priori

Table 1. Mean and standard deviation of number of moves to solution on 8 successive problems for each group.

Group	Problem						Total	7	8
	1	2	3	4	5	6			
8	x	3.58	3.58	3.17	3.50	3.25	3.08	5.50	5.33
	σ	.77	1.05	.36	.87	.59	.31	.74	1.04
16	x	4.67	4.33	5.08	4.58	4.42	4.67	5.50	5.17
	σ	.44	.87	1.13	.88	.62	.93	1.12	.73
32	x	5.58	5.92	5.58	5.16	4.92	5.08	5.38	4.92
	σ	.88	.93	.90	.45	.46	.53	.74	1.02
									.61

Table 2. Mean and standard deviation of strategy scores on 8 successive problems for each group.

Group	Problem							
	1	2	3	4	5	6	Total	7 8
8	$\bar{x}$	.890	.875	.983	.960	.955	.979	.940 .900 .938
	σ	.111	.151	.041	.055	.114	.070	.107 .119 .056
16	$\bar{x}$	.876	.939	.910	.952	.952	.931	.926 .921 .934
	σ	.087	.087	.120	.068	.062	.079	.092 .079 .054
32	$\bar{x}$	.943	.899	.949	.982	.974	.976	.954 .936 .963
	σ	.030	.100	.060	.020	.022	.026	.061 .076 .044

probabilities of these outcomes are 1/4 and 3/4 the expected informational outcome is $.75(.415) + .25(.20) = .811$ (which may be obtained directly from tabled values of $-p \log_2 p$). A strategy score of 1 indicated an information-maximizing strategy whereas a score of less than 1 indicates either that S is gambling on getting a lot of information from one move, or making redundant moves, or both. It will be noted that gambling was never reinforced in this situation.

Group mean and σ for number of moves to solution on each problem are summarized in Table 1. There is a slight decrease in number of moves over the first 6 problems but trials as a main effect are not statistically significant, nor is trials $\times$ groups interaction. Overall differences among groups, on the other hand, are highly significant ($F, 56.5$; $df, 2/27$). There are no significant differences among groups on the last 2 problems (which were the same for all groups). A plot of total group mean moves (N) against $\log_2 n$ yields a straight line slightly above the value to be expected from $N = \log_2 n$.

Table 3. Mean and standard deviation of total time to solution (in minutes) for each group.

	Group		
	8	16	32
$\bar{x}$	22.67	35.08	42.04
σ	6.55	13.35	13.49

For strategy scores, on the other hand, (Table 2) there is a significant improvement over the first 6 problems ($F, 4.77$; $df, 5/135$). Although slopes of group learning curves differ significantly ($F, 2.09$; $df, 10/135$) overall differences among groups are not significant. Once again, on the last 2 problems there are no significant differences among groups. Thus, number of alternatives may affect the rate of improvement in quality of information gathering; it does not affect the average level.

Finally, total time scores (Table 3) seem to be an increasing function of number of possible solutions ($F, 11.38$; $df, 2/27$).

Discussion

All of the obvious expectations appear to be confirmed: (a) number of information getting moves is an increasing linear function of $\log_2 n$ (n = no. of possible answers); (b) a similar relation obtains for time to solution; (c) the nature of information gathering behavior, as reflected in strategy scores, is relatively unaffected by number of possible solutions with the exception that the 32 alternative group starts out with a slightly greater tendency toward information maximizing whereas the 8 group starts lower and shows somewhat more rapid improvement. Additional findings that the 32 group has (a) slightly fewer incorrect solutions, (b) fewer 0-information moves (3 as against 12 for the 8 and 16 groups), and (c) less variability in strategy scores, suggest that where a problem superficially appears more complex S may initially show more caution and thought in solution. However, after 6 problems all groups are sufficiently familiar with the general strategy that there are no significant differences among groups on the last two transfer problems (which have 32 possible answers) on any response measure.

Reference

NEIMARK, E. D. Information-gathering in Diagnostic problem-solving: A preliminary report. *Psychol. Rec.*, 1961, 11, 243-248.

Notes

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2. Now at Rutgers (Douglass College).