Reports

Schedules of Irrelevant Signals and Maintenance of Monitoring Behavior

Abstract. Subjects clearly discriminated between critical and irrelevant signals, yet an intermittent schedule of irrelevant signals produced reliably higher rates of responding than did the continuous presentation of such signals. This is exactly the result obtained with similar variations in reward schedules. It seems that essentially "meaningless" changes in stimulation can reinforce behavior, too.

Engineering progress has increased the number of jobs in which the operator is primarily an observer. The important cues in these monitoring situations are slight changes in stimulation. Often these "critical signals" occur so infrequently that efficiency in detecting them is lowered after prolonged observation. One human engineering problem is to offset such effects.

Holland (*1*) reported that the rate and pattern of monitoring responses vary with the frequency and regularity of critical signals. The signals he used were of little significance to his subjects, which suggests that monitoring might be aided by the proper scheduling of artificially produced signals not crucial to the observer's main task.

For preliminary study of this possibility (*2*), we chose these variations in noncritical stimulation: none, constant, and intermittent. The hypothesis was that no variation (except for critical signals) and continuous variation in stimulation would quickly produce the same reduction in monitoring efficiency, whereas intermittent noncritical stimuli would produce a higher *rate* of observing responses (accuracy of signal detection was not studied).

Six male college students were paid to serve for six sessions; one subject became ill and missed his last two sessions, however. The subject faced an "instrument panel" containing two jewel lights (one not used) and three switches. Above this was a panel with a frosted-glass window in it that had a 1-in. red band at its far right side. In this apparatus, modified from that designed by Premack and Collier (*3*), a movement of switch No. 1 activated a projector shutter for approximately 1/5 sec; depression of either switch No. 2 or No. 3 would move another frame of a 16-mm film reel into position. (Depression of the right-hand button, that is, switch No. 3, both moved the film and lighted a green bulb.) The projector and shutter were inside a long, rectangular box, and threw an image onto the back of the frosted-glass screen.

There were three reels of film, each with some 3000 images of a single vertical line. On all films the line appeared on the far right side of the aperture (in the red band) on every 80th frame. On the "no-variation" film, the line was always projected in the same position—slightly to the left of the mid-line of the screen—except when it appeared in the "critical" (far right, or red) position. On the "constant-variation" film, the line never appeared in the same position on two successive frames; the line's position was determined from a list of random numbers (modified to exclude repetitions). On the "intermittent-variation" film, the position of the line shifted sporadically. Random digits determined the number of frames on which the film would then shift. The indicator remained in one place for an average of 6.50 exposures.

Each subject was told simply that his task was "to score as many points as possible" by reporting whenever the gauge-indicator "moved" into the red band. The impression was created that the indicator was moving continuously; actually, the film was moved by the subjects' working the switches. Subject reported critical signals (line in the red band) by pushing switch No. 3; this turned a green light on (which subject believed to be a confirmation of the accuracy of his report), and moved the film. Usually subject threw switch No. 1, looked at the indicator, then threw switch No. 2; after every 80th observation, however, he threw switch No. 3 instead of No. 2 (because a critical signal had occurred). All activations of switches No. 2 and No. 3 were totaled on a counter that was read every 60 seconds by the experimenter.

The subject viewed one reel per session, and each subject had a different order of presentation of the films over the first 3 days; this order was reversed for the last 3 days.

Table 1 shows the average rates of responding for each subject under each condition. Rates were highly stable within sessions, especially after the first 2 to 4 minutes, so this was not treated as a variable. Analysis of these rates (Table 2) reveals a reliable difference between treatments.

While the original hypothesis was only partially confirmed, the most important prediction was verified: intermittent presentation of irrelevant signals did facilitate observing-response rate. The unpredicted inferiority of the constant-variation schedule probably resulted because this condition required the subject to relocate the indicator position on every trial, so that switch No. 2 movements more often occurred slightly later

Table 1. Summary of mean rate of observing responses (in responses/min). Rates are based on performance during two 45-minute sessions, excepting those for subject F; this subject missed the final two sessions because of illness, so his scores for "no variation" and "intermittent variation" are from only one session each.

Subjects	Treatments		
	No variation	Intermittent variation	Constant variation
A	39.33	43.96	38.97
B	28.42	30.71	27.49
C	29.67	29.81	26.39
D	25.46	26.97	22.98
E	25.39	24.14	22.89
F	29.16	29.60	27.58
Mean	29.58	30.87	27.72
S.D.	5.09	6.80	5.81

Table 2. Analysis of mean rate of observing responses (in responses/min).

df	Mean square	*F*	*p*
	Between treatments		
2	15.025	12.60	.01
	Between subjects		
5	105.602	88.43	.001
	Treatments × subjects		
10	1.192		

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper. (Since this requirement has only recently gone into effect, not all reports that are now being published as yet observe it.)

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors [*Science* **125**, 16 (1957)].

than they did under the treatments that had periods of no indicator movement. The small numerical differences between treatments and the large variability between subjects restrict the practical implications of these findings. Of greater significance is the similarity of these data to the results of certain experiments with other animals (*4*). Taken altogether, these studies suggest that many more conditions can sustain or even form habits than have traditionally been acknowledged by psychologists.

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References and Notes

1. J. G. Holland, *Science* 128, 61 (1958).
2. This research, conducted at the University of Missouri, was supported in part by the U.S. Air Force under contract AF 41 (657)-11 (Melvin H. Marx, principal investigator), monitored by the Operator Laboratory, AFPTRC, Randolph Air Force Base, Tex. Permission is granted for reproduction, translation, publication, use and disposal in whole or in part by or for the U.S. Government.
3. D. Premack and G. Collier, research report submitted to monitor of contract AF41 (657)-11, Feb. 1, 1957.
4. C. L. Roberts, M. H. Marx, G. Collier, *J. Comp. Physiol. Psychol.* 51, 575 (1958); G. B. Kish, *ibid.* 48, 261 (1955); R. Lawson and D. R. Dawson, paper read at Midwestern Psychological Association meetings, 1958.

27 October 1958

Biliary Excretion by the Rat of Bromsulfalein as a Conjugate of Glycine and Glutamic Acid

Abstract. Paper chromatograms of bile collected after the intravenous administration of bromsulfalein to rats reveal four distinct bromsulfalein bands. One migrates with the same R_f as standard bromsulfalein; the other three move less fast. The major band, which accounts for 71.3 percent of the injected bromsulfalein, appears to be a conjugate of bromsulfalein with glycine and glutamic acid.

Bromsulfalein (sodium phenoltetrabromphthalein disulfonate) (BSP) is one of a group of phthalein dyes that is removed from blood predominantly by the liver and excreted into the bile (*1*). Dye removal is impaired in the presence of hepatocellular damage, and BSP retention in blood has proved to be a sensitive index of hepatic dysfunction (*2*). Although this dye has been used extensively in the clinical detection of hepatic disease, the precise mechanisms by which it is handled by the liver are still poorly understood.

A considerable body of evidence (*3, 4*) suggests that hepatic removal of BSP depends upon the simultaneous operation of at least two processes: (i) uptake of dye by liver cells until the cellular space is saturated with respect to a given blood level, and (ii) transfer from blood to bile by a rate-limited transfer mechanism. In order to further examine the process of biliary excretion, an analysis of BSP as it appeared in the bile of the rat was undertaken (*5*).

Fine polyethylene tubing was inserted into the common bile ducts of rats (Long-Evans, Wistar) under ether anesthesia, and bile was allowed to drain into small bottles while the rats were gently restrained in special cages. After collection of a control sample of bile, approximately 5 mg of BSP was injected intravenously, and additional bile samples were obtained. Aliquots of the bile were applied to Whatman No. 1 filter paper, and the chromatograms were developed in a descending system consisting of glacial acetic acid:water:*n*-propyl alcohol (1:5:10 vol./vol.). Usually four and occasionally three chromatographically distinct BSP bands were identified in bile by (i) the development of a purplish color on exposure of the paper to ammonia vapors, and (ii) absorption in the ultraviolet (Fig. 1). One of these bands, band D, migrated with the same R_f (0.75) as standard BSP, while bands A, B, and C moved less far, with average R_f's of 0.44, 0.51, and 0.60, respectively. When BSP was incubated with control bile for as long as 3 hours in vitro and the mixture was chromatographed, only a single band with the same R_f as standard BSP was observed (Fig. 1).

The distribution of BSP between the different bands in bile obtained from two rats is presented in Table 1. Bile was collected in a single tube for 150 and 180 minutes, respectively, after the intravenous administration of BSP, and aliquots were chromatographed; the bands were identified, cut out, and eluted with water; and BSP content was determined colorimetrically after addition of 20-percent KOH to appropriately diluted samples. It is apparent that band A contained most of the excreted BSP, accounting for 71.2 and 71.4 percent, respectively, of the total BSP injected in these two rats. Bands B and D contained smaller amounts of BSP. Band C was identified in one of these specimens, and when observed in bile from other rats it contained only very small quantities of BSP, as judged from the intensity of the purple color which developed on exposure of the paper to ammonia.

Table 1. Distribution of BSP recovered in bile after intravenous injection.

Amt. injected (mg)	Amt. recovered in bile (% of amt. injected)				
	Band				Total
	A	B	C	D	
*Rat No. 6-21** (wt. 312 g)					
5.13	71.2	12.8		11.9	95.9
Rat No. 7-1† (wt. 342 g)					
5.90	71.4	6.0	4.0	10.2	91.6

* Bile collected for 150 minutes.
† Bile collected for 180 minutes.

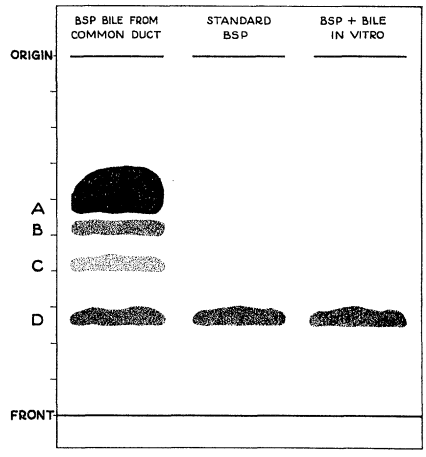

Fig. 1. Descending chromatogram on Whatman No. 1 filter paper in glacial acetic acid:water:*n*-propyl alcohol (1:5:10, vol./vol.).

The compound comprising band A has been subjected to further analysis, which indicates that it is a conjugate of BSP with the amino acids glycine and glutamic acid. Ninhydrin-reacting material which conformed both in shape and position to the ammonia reaction of band A was seen on chromatograms developed in the one-dimensional descending system (acetic acid:water:*n*-propyl alcohol) and a two-dimensional ascending (phenol-NH_3 and 80-percent pyridine) system. When band A was eluted from paper and subjected to acid hydrolysis in 5.9*N* HCl for 3 hours at 15 lb pressure, it yielded bands corresponding to those of free BSP (*6*), and two Ninhydrin spots. The latter were identified as glycine and glutamic acid from the following observations: (i) the Ninhydrin spots assumed the positions of glycine and glutamic acid on two-dimensional chromatography in phenol-NH_3 and 80-percent pyridine; (ii) when the unknown compounds were mixed with known samples of glycine and glutamic acid and chromatographed in the two-dimensional system, only two bands were seen, and these corresponded to the usual location of glycine and glutamic acid standards in this solvent system; (iii) the dinitrophenyl (DNP) derivatives of the unknown amino acids moved with the same R_f's as known DNP-glycine and DNP-glutamic acid in tertiary amyl alcohol-phthalate buffer (*p*H 6.0) (*7*).

The possibility remained that the glycine and glutamic acid were not conjugated with BSP but appeared in bile either as free amino acids or as a dipeptide that migrated to the same position as band A. Indeed, when control bile is chromatographed, Ninhydrin-reacting material with the same R_f as the BSP band may be identified in some speci-