Partial Reinforcement and Conditioned Heart Rate Response in Human Subjects

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IN A RECENT REVIEW of the experimental literature concerned with partial reinforcement, Jenkins and Stanley (*1*) state that "Most of the research in this area has involved responses of the skeletal musculature rather than behavior innervated by the autonomic nervous system." The present note deals with the latter case, in particular with the use of a partial reinforcement schedule for conditioning changes in the human heart rate. It has been shown that changes in heart rate are successfully conditioned by means of a regular reinforcement schedule (*2*). In the latter study, it was reported that a previously neutral stimulus acquires the power of exercising a depressant effect upon the heart rate, following the regular pairing by the trace conditioning technique of that stimulus with electric shock to the hand. Curves of conditioned response strength were obtained for successive trials during conditioning, extinction, spontaneous recovery, reconditioning, and further extinction.

A survey of the literature reveals that several other researchers, beginning with Sherrington (*3*), have observed conditioned changes in heart rate when some noxious agent was used as the unconditioned stimulus. Some of these investigators report conditioned cardiac decelerations (*3, 4*), others report accelerations (*5–7*), and still others report both (*8, 9*). Although these cases all involve the use of an aversive stimulus as the reinforcing agent, it is difficult to determine whether there is anything else in common among them, or, on the other hand, if there are any systematic operational differences that might account for the disparate results. This difficulty exists principally for two reasons: (*a*) Some of the publications are in the form of abstracts and so contain few procedural details (e.g., intensity of noxious stimulus; temporal relations between CS and US; use of simultaneous, trace, or delay techniques; number of trials, etc.). (*b*) None of the human studies available contains any readily quantifiable data bearing upon the actual acquisition, extinction, spontaneous recovery, and reconditioning processes.

Complete details of the apparatus used in the present experiment are available in (*2*). In the main, the apparatus consisted of a cardiograph, shock circuit, and tone-oscillator circuit. The shock was 30 v a-c and was administered by means of two electrodes strapped to the palmar and dorsal sides of the left hand. The subject received a 750-cps tone, approximately 20 db, through a headset. The tone was of one second and the shock of six seconds' duration. On trials during which shock followed tone, a six-second interval separated the paired stimuli. There were six phases to the experiment, occurring in the following order: (1) determination of basal (preconditioning) heart rate response to the tone; (2) conditioning; (3) Extinction I; (4) spontaneous recovery; (5) reconditioning; and (6) Extinction II. The first three phases were administered in one session of approximately 1¾ hours' total duration; the remaining three phases, in one session of about 1¼ hours, some 24 hours later. The basal, Extinction I, spontaneous recovery, and Extinction II phases consisted of 20, 11, 10, and 11 tone-alone presentations, respectively, and were identical with similar phases for the previously reported regular reinforcement group (*2*). The conditioning phase consisted of 18 trials, of which 11 were tone-shock pairings, and seven were tone-alone trials. The reinforcement schedule of these 18 trials was as follows: the first five in the series were tone-shock, the remaining 13 were randomly presented tone-shock trials (six) and tone-alone trials (seven). The randomization of reinforced and unreinforced trials was not begun with the first trial, because it has been found that responses become conditioned more readily under partial reinforcement schedules if some response strength is built up initially with regular reinforcement (*1*). The reconditioning phase likewise consisted of 11 tone-shock and seven tone-alone trials, but randomization of reinforcement was begun after a single tone-shock presentation. The number of tone-shock combinations given during conditioning and reconditioning in the present experiment was precisely the same as that given the subjects of the regularly reinforced group reported in (*2*). Hence, the sole difference in experimental conditions between the partial and regular groups lay in the presence of the seven randomized tone-alone trials during conditioning and during reconditioning.

All trials were separated by one to two minutes, and each subject's cardiogram was taken continuously from about 30 seconds before the tone to about 30 seconds after the shock, or normal time for shock, on each trial. Heart rate measures were taken by determining the period of the last two cycles immediately preceding onset of tone, and the period of the last two cycles in the six-second interval following tone (and, therefore, immediately preceding shock on

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TABLE 1

MEAN PRE-TONE AND MEAN POST-TONE HEART RATE (IN BEATS PER MINUTE) DURING SUCCESSIVE PHASES OF THE EXPERIMENT*

Subjects	Basal		Conditioning		Extinction I		Spontaneous Recovery		Recondioning		Extinction II	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post.	Pre	Post
1	73.2	73.3	77.0	70.3	78.5	63.2	88.3	73.3	81.6	71.6	84.7	72.4
2	87.1	87.3	87.9	85.2	88.8	83.9	80.7	78.5	82.1	79.7	85.8	79.5
3	67.2	67.5	67.2	65.0	70.6	68.1	61.5	60.4	61.7	58.2	63.3	60.9
4	92.7	87.2	92.6	86.5	88.9	84.5	99.1	92.8	92.9	86.6	90.2	84.4
5	90.2	88.4	84.4	78.7	82.9	74.7	95.0	80.4	89.0	77.6	88.1	75.4
6	90.4	92.2	88.7	82.1	86.0	80.4	83.1	82.1	81.3	78.4	81.7	78.2
7	54.0	52.7	54.6	47.7	53.9	46.5	54.0	50.3	52.5	48.1	49.2	44.6
8	74.2	71.8	70.5	66.0	68.7	65.3	69.4	64.1	67.1	65.2	67.4	64.9
9	74.3	76.9	74.8	68.0	68.4	65.1	78.7	76.1	71.1	65.6	65.1	62.0
10	66.6	70.1	72.2	66.0	69.2	62.6	76.7	67.6	73.6	70.3	76.3	69.4
Group mean	77.0	76.7	77.0	71.6	75.6	69.4	78.7	72.5	75.3	70.1	75.2	69.1
Level of confidence	$P > .05$		$P < .001$		$P < .001$		$P < .001$		$P < .001$		$P < .001$	

* The levels of confidence shown are for group mean pre-tone minus group mean post-tone differences within each phase. The basal means are for basal trials 11–20; the means for the other phases are for all trials within each phase.

the tone-shock trials). These measures, called the "pre-tone" and "post-tone" heart rate, respectively, were then converted to beats per minute.

The data of this experiment are concerned with two principal questions: Does an originally ineffective stimulus come to initiate a characteristic heart rate response as a result of irregular pairing of that stimulus with shock? If so, how does the response strength acquired under these conditions compare with that acquired under regular reinforcement?

The data in Table 1 relate to the first question. These data are the mean pre-tone and mean post-tone heart rate values in beats per minute for the ten subjects used, over each phase of the experiment. The table shows, for example, that subject No. 1 had a mean pre-tone heart rate during conditioning of 77.0 beats per minute (b/m), this figure being based on 18 trials. The mean post-tone heart rate for the same individual was 70.3 b/m. The *group* mean pre-tone value for all subjects during conditioning, 77.0, was obtained from the individual means shown in the pre-tone subcolumn. In all phases except basal, the individual means shown are for the total number of trials given during each phase. For basal, the individual means are for the last 11 of the 20 trials given, these latter trials being used because they are a more stable estimate of preconditioning heart rate (*2*).

Pitman's variation (*10*) of a nonparametric test by Fisher was used to determine whether the distributions of the individual mean pre-tone minus mean post-tone differences for each phase are significantly different from chance. (Nonparametric tests were used throughout the treatment of these data, because in some comparisons variance was heterogeneous, and distributions did not appear to be normal.) This test shows that the basal changes in heart rate are not different from those to be expected on the basis of random variation, whereas for each of the other phases the probability that chance variation accounts for the heart rate changes is slight ($P < .001$). It is thus apparent that a schedule of irregular or partial reinforcement can be used to establish a characteristic conditioned depression in heart rate.

Regarding the second question, several trends are indicated in the data:

1) *Acquisition*: The difference in conditioned response strength produced by regular vs. irregular schedules of reinforcement is slight. Table 1 shows

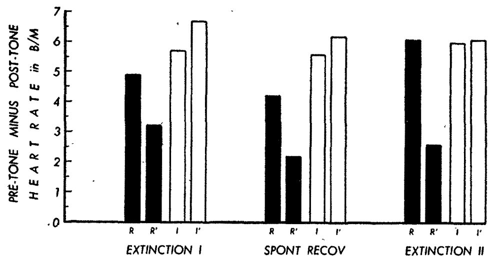

FIG. 1. Resistance to extinction of regularly and irregularly reinforced groups. Response strength of the first five trials (labeled *R* or *I*) is compared with response strength of the last five trials (*R'* or *I'*) for the indicated phases.

that, for conditioning (acquisition), the magnitude of the acquired heart rate depression in the present instance is 5.4 b/m (group mean pre-tone minus group mean post-tone heart rates). This value is quite similar to the 5.6 b/m drop reported in (*2*) for a regularly reinforced group. It may be noted parenthetically that, in view of reports by some previous investigators of conditioned cardiac acceleration under aversive stimulation, the present authors were interested in determining whether the *immediate* effect of the tone was to induce a heart rate speed-up, whereas the deceleration was simply a later effect. For this reason, heart rate measurements based on the first two cycles immediately following the tone were also taken during acquisition in the case of the regularly reinforced group. The data indicate a nonsignificant drop of 0.2 b/m compared to the pre-tone heart rate. Moreover, the heart rate appears to drop progressively throughout the six-second interval separating tone and shock.

2) *Reconditioning*: Here, too, the difference in con-

ditioned response strength produced by the two separate methods of reinforcement is only minor. Table 1 indicates that the reconditioning drop for irregular subjects is 5.2 b/m; for the previously reported regular group, the drop was 6.8 b/m. The difference between these drops is not significant ($P > .05$ by Pitman's spread test, based on rank-ordered data [*10*]).

3) *Extinction*: The most striking effect is found in terms of resistance to extinction; the irregularly reinforced subjects show a significantly greater perseveration of the conditioned response than do regularly reinforced subjects. Fig. 1 compares the resistance to extinction of the regularly and irregularly reinforced groups during Extinction I, spontaneous recovery, and Extinction II. Two pairs of columns are shown for each phase; the first pair (solid columns) depicts data of the regular group; the second pair, data of the irregular group. The first member of each pair of columns (marked *R* for regular, or *I* for irregular) gives the group mean pre-tone minus group mean post-tone heart rate for the first five trials of each respective phase. The second member of each pair (marked *R′* or *I′*) gives the corresponding change in heart rate for the last five trials of each phase. By comparing each group's level of conditioned heart rate response for the first five and the last five trials of each phase, differences in the perseverative tendency of the response may be noted. Thus, for Extinction I, there is a marked drop in the conditioned heart rate effect for the regular group, but a slight rise for the irregular group. In general, a diminution of conditioned response strength during the tone-alone trials is characteristic for the regular group; the irregular groups show either a slight rise, or no difference.

Table 2 gives a summary of the results of statistical comparisons made for the data illustrated in Fig. 1 (Pitman's nonparametric tests for correlated or uncorrelated items were used throughout, as appropriate). The probability values shown here, together with the data of Table 1, provide the basis for the following conclusions: (1) Heart rate changes may be conditioned in human beings by means of a schedule of irregular reinforcement. The fact that this autonomic response can be conditioned by such a technique meets a research need indicated by others (*1*). (2) The most conspicuous difference between the irregularly and regularly reinforced groups in the present research is in terms of the former's much greater resistance to extinction. It is noteworthy that this difference is obtained with an autonomically mediated response, inasmuch as the same effect has been almost universally observed with respect to motor responses (*1*).

TABLE 2

PROBABILITY VALUES FOR TESTS OF SIGNIFICANCE BASED UPON COMPARISONS OF EXTINCTION EFFECTS FOLLOWING SCHEDULES OF REGULAR AND IRREGULAR REINFORCEMENT

	R vs I	R' vs I'	R vs R'	I vs I'
Extinction I	$P > .05$	$.05 > P > .02$	$.02 > P > .01$	$P > .05$
Spontaneous recovery	$P > .05$	$P > .05$	$P > .05$	$P > .05$
Extinction II	$P > .05$	$.05 > P > .02$	$.03 > P > .02$	$P > .05$

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News and Notes

Scientists in the News

M. H. Arveson, technical director of the Indoil Chemical Co., has been elected director-at-large of the American Chemical Society. Originally named a director last April to fill the unexpired term of Edgar C. Britton, of the Dow Chemical Company, Mr. Arveson will now serve a full, four-year term.

Manuel Villafano Barajas, manager of the Comision de Fomento Minero, Mexico, is in this country to study and observe coal and iron mining techniques. His itinerary includes several mining operations, as well as visits in the Denver office of the Geological Survey and Bureau of Mines.

Albert F. Blakeslee, a past president of the AAAS and now director of the Smith College Genetics Experiment Station, has received an honorary doctor's degree from the Sorbonne. The degree was conferred at the annual meeting of the American Members of the Institut de France, of which Dr. Blakeslee is president.

Fred M. Bullard, professor of geology at the University of Texas, will be on leave from the university