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NOTE

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Temporal uncertainty of reinforcement¹

FRED L. ROYER, *Veterans Administration Hospital, Brecksville, Ohio 44141*

Three CSs had a duration of 5 sec. CS+C was always reinforced with shock 1 sec after termination; CS- was never reinforced; and CS+U was reinforced 75% of the trials with reinforcement occurring randomly 1, 3, or 5 sec after CS offset. Mean heart rate increments were: CS+C, 9.7 bpm; CS-, -2.5 bpm; CS+U, 3.8 bpm. Mean leg flexion latencies for CS+C were 2.9 sec, and for CS+U, 4.2 sec. Cardiac URs for CS+U are diminished. Data suggest more resistance to extinction for CS+U.

In a study of Pavlovian discriminative conditioning of dogs using CSs differing in their reliability as predictors of reinforcement, Royer (1969) found that a CS (CS+C) which was consistently reinforced with shock elicited greater heart-rate change and shorter leg-flexion latencies than one reinforced inconsistently on a temporal basis (CS+U). All CSs were 6 sec in duration. CS+C was reinforced immediately upon termination (delay paradigm). Since reinforcement of CS+U could be immediately after termination or 2 or 4 sec afterward (mixed delay and trace paradigms) there is a possibility that the offset of CS+U was an informative event (Egger & Miller, 1963), which in effect became the CS.

The purpose of this study was to replicate

the previous one using the trace paradigm for each CS+.

SUBJECTS

Four experimentally naive female Beagle dogs were used as Ss. They were 11 months old at the beginning of conditioning.

APPARATUS

Heart rate, flexion response, and intensity of shock current were recorded by means of a Grass Model 7P polygraph. A digital logic system provided the programming of both CSs and USs.

PROCEDURE

The acquisition data used in the analyses are for the 15 days beginning with the 8th and continuing through the 22nd day of conditioning. Extinction trials were carried out over a 4-day period.

Each CS was 5 sec in duration and was presented eight times daily in a fixed order with a 2-min interstimulus interval. In order of occurrence, the CSs were (1) CS+C, a 61-dB tone of 4500 Hz, followed, 1 sec after termination, by an electric shock of 1 sec duration; (2) CS-, a flashing light never reinforced; (3) CS+U, a 61-dB tone of 2500 Hz followed by one of four reinforcement consequences—no shock for 25% of the trials, and shock either 1 sec, 3 sec, or 5 sec after CS termination on remaining trials.

The US was presented to the shaved left foreleg. Electrode gel was used to ensure minimal resistance. US intensity was

adjusted to produce a vigorous flexion without at the same time producing generalized motor excitement. Alternating current and voltage were monitored and the power was computed; the intensity varied from 12 to 20 mW.

RESULTS

An analysis of variance was made of the daily change in heart rate (heart rate during CS minus heart rate pre-CS) for the 15-day conditioning period. Mean heart rate changes were: CS+C, 9.7 beats per minute (bpm); CS-, -2.5 bpm; CS+U, 3.8 bpm. These means are significantly different ($F = 47.83$, $df = 2/6$, $p < .01$). The appropriate t tests (McNemar, 1962, p. 345) showed that the means of each possible pair differed significantly.

The percentage of trials in which leg flexion responses occurred were: CS+C, 85.6%; CS-, 5.0%; CS+U, 81.2%. A probability distribution of the latencies of flexion responses is shown in Fig. 1. The differences in latencies are clear; flexion during the CS+C is more probable during the first half of the CS, while flexion during the CS+U is more probable late in the CS. Mean latencies for CS+C were 2.9 sec, for CS+U were 4.2 sec.

Figure 2 shows the unconditional heart rate levels for the various reinforcement alternatives. Because of the time intervals elapsing between termination of the CS and onset of US, levels were used rather than change scores. The UR for CS+C is greater than that for CS+U (1), the condition under which the US was presented in the same temporal relation as for the CS+C ($F = 282.00$, $df = 1/3$, $p < .01$). The heart rate during the period immediately following the CS+U when no reinforcement was presented (Condition 0) is also significantly greater than that for the CS- during the post-CS period. Furthermore, it will be seen that the UR may be different, depending upon the time interval after the CS in which the US occurred ($F = 6.88$, $df = 3/9$, $p < .05$). The following pairs of means were significantly different: 0,1; 0,2; 2,3. It is clear from these data that even the unconditional response is affected by the temporal uncertainty of the US.

The results of the extinction procedure were evaluated by an analysis of daily mean changes in heart rate. There were no significant differences ($F = 2.94$, $df = 2/6$, $p > .05$) among the means for changes in the stimulus periods (CS period minus pre-CS period). There were, however, significant differences among the means ($F = 6.88$, $df = 2/6$, $p < .06$) for the post-CS periods (post-CS minus CS). The mean changes in beats per minute were: CS+C, 1.8; CS+U, 8.8; CS-, -3.4. The t tests for individual comparisons indicate that CS+U and CS- are significantly different but CS+C is not

Fig. 1. Probability distribution of latency of leg flexion CR.

significantly different from either of the other two. Since there are overlapping subsets of nonsignificant means, these results must be interpreted cautiously. It would appear that although there were no differences in response to the various signals when reinforcement had been terminated, there is on the other hand more arousal during the post-CS period for that stimulus which had been an unreliable predictor of reinforcement.

DISCUSSION

The results of the present experiment make it clear that the informative aspect of CS+U offset in Royer (1969) was not the critical variable in the finding that there was less cardiac response to CS+U than to the CS+C. The results reported here show that when both positive CSs terminate before the

US is presented, the results are not essentially different. An unreliable signal for reinforcement produces less arousal than a reliable signal.

Conceptually, partial reinforcement is also a member of the class of experimental conditions producing unreliable signals. In Pavlovian conditioning such studies (e.g., Fitzgerald et al, 1966) repeatedly have shown lower levels of response for partial reinforcement than continuous reinforcement during acquisition. The results here are consistent.

Partial reinforcement is ordinarily expected to produce a greater resistance to extinction than continuous reinforcement. Although changes in heart rate to the signals during extinction were not significantly different, heart rate changes in the post-CS

(US) period did show significant differences. While these results must be interpreted cautiously, they suggest a partial reinforcement effect during the period when the unconditional stimulus is ordinarily presented.

While the present experiment shows that increased arousal is not produced by this type of unreliable signal for reinforcement, there is a possibility that other conditions could produce different results. Zill (1967) reports an unpublished study of his with dogs in which he used a CS of long duration and in which the time of reinforcement was fixed or variable during the CS. He reports that flexion responses had a very short latency and that flexions were maintained for the duration of the CS. He also states that heart-rate data were equivocal; but since the method of analysis is unclear, no conclusions can realistically be made on this particular question.

The contrast of Zill's results with those reported here with respect to flexion support what might be called a "cognitive" interpretation of conditioning where temporal uncertainty of reinforcement is involved: that probabilistic learning occurs where experimental conditions pose such a problem to the animal and that the results of such experiments will be affected by the type of "predictive" behavior demanded of the organism.

In the present experiment and in Royer (1969), the differences in heart rate would be due to changes in the temporal expectancies of the organism. When such changes over 6-sec time periods are averaged, they should inevitably result in lower levels of mean autonomic response since the onset of acceleration would be later in the stimulus period on some trials than on others.

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NOTE

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Fig. 2. Cardiac URs for each reinforcement alternative. (Alternatives: 0, no reinforcement; 1, shock 1 sec after CS offset; 2, shock 3 sec after; 3, shock 5 sec after.)