EFFECTS OF OPERANT REINFORCEMENT ON THE GSR¹

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Each of nine Ss was run for 11 daily sessions. Except for the first (operant level) and last two (extinction) sessions, 500-ohm drops in skin resistance were followed by reinforcement (light). These reinforcement periods lasted 20 min and were preceded by 10-min control periods during which no reinforcement was administered. Although the results showed no evidence for operant conditioning of the GSR, they did indicate that increased emission of GSR's occurred during the reinforcement period. This effect was shown to hold for Ss with low operant levels of GSR's but not for Ss with high operant levels.

The galvanic skin response (GSR) is usually considered a classic example of respondent behavior. Although some respondents have been subjected to operant conditioning (*cf.*, Keller & Schoenfeld, 1950) in order to investigate the borderline between operants and respondents, relatively little attempt has been made to study the response of the GSR to operant reinforcement. The only study available appears to be a recent one by Kimmel and Hill (1960), which showed that pleasant and unpleasant odors presented contingently and noncontingently with GSR responses produced no changes in rate of emission, except for an increase in GSR rate following the cessation of reinforcement (start of extinction).

In this study, we investigated the rate of GSR emissions when each response was followed by a reinforcing event. In a pilot study with three subjects, we used the verbal reinforcer "Good" after GSR responses of 500 ohms or more. The Ss were run in daily 1-hr sessions, and the GSR rate of two of the three subjects increased after 10 and 4 sessions, respectively. However, the variability of the reinforcing event and other procedural problems suggested the use of a nonverbal reinforcer and the addition of a control period. In this study, we used nonreinforcement rather than a noncontingent reinforcement control, because we were primarily interested in the effect of the reinforcer on GSR emission and because of the difficulty of using noncontingent reinforcement with the GSR. The

response has a latency of 1.5 to 2 sec, and noncontingent reinforcement occurring during the latency period might convert a noncontingent procedure into a partial reinforcement one.

METHOD

Subjects

The Ss were nine Harvard freshmen. None of them had previously participated in any psychological experiments. All Ss volunteered for a project that ostensibly was to last for 7 to 15 1-hr sessions; they were paid \$1.25 per session, with additional money available through bonuses. The only other criterion was that each S had to give at least five 500-ohm responses during the first session.

Procedure

The S was seated in a 6-by-10-ft experimental room about 3 ft from a wall on which there was a red light bulb at approximately the S's eye level. The E was seated behind S at the write-out table of a Grass six-channel polygraph. Skin resistance was measured with a Yellow Springs Dermohmmeter, with electrodes placed on the wrist and palm of S's right hand. Respiration was monitored with a pneumograph to check unusual or abnormal breathing. Because the GSR and breathing did not appear to be correlated, no further reference will be made to the respiration measures. Temperature in the experimental room was controlled at $72 \pm 2^\circ\text{F}$.

The Ss were told that E was interested in measuring several physiological processes for

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about 40 min. They were reassured that nothing unpleasant was going to happen to them, and they were required to sit quietly and comfortably during the whole period, preferably without moving or falling asleep. They were informed that after about 20 min they would be told to begin (start of experimental period), and that after the first session the red light would go on periodically during the last 20 min. Then *E* said: "Your job will be to make the red light go on as many times as possible." Finally, each *S* was told that a bonus would be paid in proportion to the number of times the light went on. The bonus ranged from 10 to 60 cents per session, and was related to *S*'s improvement over the previous session. At the end of each session, *S* was asked what he was thinking about during the session, what he felt and thought when the light went on, and whether he did something that made the light go on. At no time did *E* answer any questions about the function of the polygraph or the purpose of the experiment.

Each *S* participated in 11 daily sessions. Each session consisted of a warmup and control period, varying from 20 to 30 min, and an experimental period of 20 min. The last

10 min of the warmup period were designated as the control period. In order to find an operant level, no reinforcement was used in the first session. During the second to ninth sessions, no reinforcement was administered during the 10-min control period; then, after every GSR showing a drop of 500 ohms within 2 sec, *E* briefly turned on the red light (reinforcement). Responses of lesser magnitude or more gradual responses were neither reinforced nor scored. During Sessions 10 and 11, no reinforcement was administered and extinction records were obtained. Because *S*s were told that the total number of sessions would be between 7 and 15, they had little reason to expect Sessions 10 and 11 to be the last ones.

RESULTS AND DISCUSSION

The main dependent measure was the frequency of GSR's (500-ohm drops within 2 sec) per min. Figure 1 shows this mean frequency measure for each of the nine *S*s across 11 sessions for both control and reinforcement periods. As a statistical test for the difference between reinforcement and control periods,

Fig. 1. Mean number of GSR's emitted per minute during the 10 min of the control period and the 20 min of the reinforcement period. The data show mean rates per session for each of the nine *S*s across 11 sessions: Operant (0), Reinforcement (1-8), and Extinction (E1, E2).

Table 1
Individual Conditioning Scores and Operant Levels

Subject	Conditioning		Number of GSR's per minute			
	T-test	Rank	Control Sessions 1-10	Rank	Session 1	Rank
1	40	3	2.04	5	2.97	4
2	42	4	.77	2	1.60	2
3	36	1.5	.75	1	1.73	3
4	53	6	3.28	8	3.17	6
5	52	5	1.98	4	3.93	9
6	62	7	2.77	6	1.23	1
7	36	1.5	1.62	3	3.03	5
8	69	8	4.79	9	3.40	7
9	76	9	2.99	7	3.90	8

we used White's (1952) ranked T-test on the eight reinforcement sessions. We ranked the mean rates for 16 periods (the eight reinforcement periods and their controls), and then summed the ranks for the reinforcement periods. The column labelled T-test in Table 1 shows these sums of ranks. This method has the advantage of comparing each reinforcement with every control period, and thus reduces the effect of day-to-day variation in rate. In addition, the T-scores not only allow statistical evaluation but also permit us to rank the Ss in order of relative difference between reinforcement and control periods. Statistical evaluation indicates that reinforcement and control periods differ at the .01 level or better for Ss 1, 2, 3, and 7, and are not significant ($p > .05$) for all other Ss. The stringency of this measure is illustrated for S4, who showed higher reinforcement than control rates in every session, but does not show significant effects by our test.

Figure 1 shows that the four Ss who show significant effects due to reinforcement have lower GSR emission rates during the control periods than do the other Ss. These data are presented in Table 1, which shows the mean number of GSR's per minute during the first 10 control sessions. Subjects S1, S2, S3, and S7 have four of the five lowest control rates, and the other S (S5) with a low rate ranks next highest on the conditioning variable. This relation between the low operant rate of GSR emission and large differences between reinforcement and control periods is illustrated by a rank correlation of .827 between these

two variables. The mean rate during Session 1 only (before any reinforcement) also indicates that the "conditioning" effect is associated with operant rates. As Table 1 shows, the four highest Ss on the conditioning variable rank 3, 5, 4, and 2 on rate. Figure 2 shows the data from Fig. 1 combined for all nine Ss. These data show consistent differences between reinforcement and control rates, but with both rates declining fairly consistently across the eight reinforcement sessions.

Lacey and Lacey (1958) have explored individual differences in resting or operant-

Fig. 2. Mean number of GSR's emitted per minute by nine Ss across 11 sessions.

level autonomic activity, and have used the terms "labiles" and "stabiles" for Ss who show much or little spontaneous autonomic discharge. Our limited sample shows that although stabiles show the "conditioning" effect, labiles do not. However, how Lacey and Lacey's demonstration of greater motor impulsivity for the labiles fits our findings is not immediately apparent. What might be the case is that labiles are at or near their limit of GSR emission, so that the appearance of the reinforcer does not produce any appreciable increase. On the other hand, stabiles are well below their individual limit of GSR emission, and the reinforcing event can drive their rate higher.

In the absence of a noncontingent control group, two pieces of evidence concern the effect of the reinforcer (the red light) on the emission of the GSR. During Session 6, all Ss, except one whose rate was too high to permit this procedure, were given three reinforcements in the absence of a GSR. Of these 24 occasions, 8 were followed by a GSR, suggesting that in the middle of the experiment the red light had by no means become a reliable conditioned stimulus for the GSR. More important, 12 of the 18 extinction periods show higher rates for the reinforcement than for the control periods, and five Ss had higher reinforcement period rates during the first extinction session than during the last reinforcement session. Thus, GSR emissions are not likely to be accounted for in terms of respondent behavior to the reinforcer.

Even for the successful Ss, has anything like operant conditioning been demonstrated? Quite clearly not. None of the Ss shows any

regular acquisition curves, although all Ss show an increase in GSR's during the first reinforcement session. Moreover, within-session analysis of the data shows typically a flat record during the control period followed by a large increase in GSR's during the first 2 min of the reinforcement period. The remaining reinforcement records during Sessions 2 to 5 show a decrease in GSR's levelling out to a fairly stable level after about 8 min. For the conditioned Ss, that level is usually above the level of the control period. During Sessions 6 to 9, the increase following the control period is less pronounced, and the general level of emission during the 20 min of the reinforcement period is more stable.

These findings and an inspection of Fig. 2 make it quite clear that no simple operant-reinforcing effect was obtained. What does seem to be the case is that the reinforcement period as such is the occasion for increased GSR rates, with the onset of that period having the most marked effects. Furthermore, in view of our previous discussion, the increased rate is probably not a response to the reinforcer. In other words, the reinforcement period as a whole apparently serves as a controlling stimulus for a state of the organism characterized by increased GSR rates. One possibility is that this state may be one of activation or arousal. Woodworth and Schlosberg (1954), among others, have suggested that activation or arousal may be diagnosed by the general level of skin resistance.

Figure 3 shows conductance levels in successive 2-min periods for all 11 control and reinforcement periods. Mean data are used because the behavior of individual Ss is

Fig. 3. Changes in conductance (in log micromhos) within each of the 11 sessions. Each point represents the mean conductance for nine Ss measured at 2-min intervals.

typically presented here. The data are quite consistent. Except for the first (operant) session, conductance level rises consistently in all control periods. Following the instructions to S that the reinforcement period is about to begin, the conductance level increases greatly from the end of the control period to the beginning of the reinforcement period. This rise in conductance is followed by a significant drop in conductance in Sessions 0 to 6, which does not reach the control period level except in Session 1. Even in Sessions 7 and 8, in which the level of conductance does not drop during the reinforcement periods, it is maintained well above the control periods. Finally, during the two extinction sessions, conductance rises during the "reinforcement" period, particularly during E2.

If we interpret conductance as an index of activation or arousal, the data show increasing activation up to and including the beginning of the reinforcement period, followed by some adaptation, but a maintenance of a high activation level throughout the period that the reinforcer is administered. The absence of the reinforcer during the extinction sessions produces further activation. The increase during control and extinction periods might be interpreted as arousal anticipatory to the appearance of the reinforcer. During the reinforcement periods, the reinforcer maintains activation at a high level.

Although we have demonstrated an increase in GSR emission as a function of operant reinforcement in some (stable) Ss, the main

effect of the reinforcer appears to be a conditioning of high levels of conductance or activation to the reinforcement periods. This possibility of producing high arousal or activation levels is substantiated by the otherwise not particularly fruitful interview data. Eight of nine Ss reported that the light apparently came on most frequently when they were concentrating, excited, tense, somatically active, or in conflict. Also, S1 reported that a state of complete relaxation was necessary to produce the lights, and S2 and S4 mentioned that in addition to concentration and tenseness, relaxation and calmness seemed to be effective. We can only conjecture that these reports of relaxation may be the verbal correlates of stability, which is one condition for high conditioned GSR rates.

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