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LICK-SHOCK CONTINGENCIES IN THE RAT[1]

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Hungry rats were allowed to lick an 8% sucrose solution and then one of four lick-shock contingency conditions was superimposed on the licking baseline. These conditions were: free-operant avoidance, free shock, punishment, and no shock. From highest to lowest response rates, the groups fell in the order—avoidance, no shock, free shock, and punishment. Lick rates adjusted rapidly to introduction and removal of the contingencies. Post-shock responding was lowest in the punishment condition and highest in the free shock condition. No method was found simultaneously to equate shock frequency and separate response rates for the three shock contingency conditions. Only small, or no, reductions in shock rate occurred over sessions under the free-operant avoidance schedule when the shock-shock interval was 10 sec but large reductions occurred when the shock-shock interval was reduced to either 1 or 2 sec.

Although there is much information about response-shock dependencies, positive, zero, and negative contingencies have not been compared within a single paradigm. This comparison is more difficult than the analogous comparison of different conditional stimulus-shock contingencies in respondent conditioning (Davis and McIntire, 1969), but it can be effected by superimposing the aversive contingencies on an appetitive baseline. The appetitive schedule insures that responses will occur under all three response-shock conditions. This superimposition arrangement is known as a conjoint schedule, since two independent schedules are arranged simultaneously for the same response (Catania, Deegan, and Cook, 1966; Kelleher and Cook, 1959). Conjoint schedules appear promising for use in transfer designs. For example, in comparing the influence of punishment, free shock, and avoidance histories on resistance to punishment, a conjoint schedule offers the opportunity, via a yoking procedure, of having the number and temporal pattern of shocks the same in the three conditions. It is difficult to control for these variables, however, because both punishment and avoidance contingencies are included. The experimental parameters, therefore, must be carefully adjusted so that a similar number and pattern of shocks occur in the two conditions. If this were possible, shock frequency and pattern effects could be separated from contingency effects, an important consideration in this type of experiment (Quinsey, 1970).

The effects of aversive contingencies are less well understood where the criterion response is species-typical and topographically defined than when functionally defined. The case of licking in the rat is of particular interest. Licking is not a species-typical defensive response and, therefore, according to Bolles' (1970) theory of avoidance should not be easily acquirable as an avoidance response. There is, however, evidence that the rat easily adjusts to free-operant avoidance licking schedules (Crawford, 1970; Teitelbaum and Derks, 1958). In addition, changes in the bursting lick pattern and intrasession slowing of lick rate were thought to be potentially useful in identifying the degree of control over licking exerted by the aversive schedules. Licking has been employed as a baseline in experiments on conditional stimulus-shock contingencies in conditioned suppression (Quinsey, 1971*a*).

The purposes of the first experiment were (a) to examine the effects of positive, negative, and zero lick-shock contingencies, and (b) to attempt to develop a procedure whereby these

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different contingencies can be studied with shock frequency equated.

EXPERIMENT 1

Method

Subjects

Four albino and 12 hooded male rats from Sprague-Dawley Inc. and Les Elevages Medico Inc., Ville de Laval, Quebec, respectively, were maintained at 80% of their free-feeding body weights by restricted feeding throughout the experiment. They ranged from 331 to 517 g before deprivation; all were experimentally naive and housed individually.

Apparatus

Four chambers, 9 in. long by 8 in. wide by 6 in. high (23 by 20 by 15 cm) with grid floors, were housed in sound-attenuating shells equipped with ventilating fans. The ends and one side of each box were wood while the other was Plexiglas. Light was provided by a 7.5-w bulb located above the opaque plastic ceiling. There was a hole of 0.5 in. (1.3 cm) diameter approximately 1.75 in. (4 cm) above the grid at one end of the box. An 8% weight/weight sucrose and tap water solution was available from a spout with an opening of approximately 3 mm in diameter, 5 to 9 mm outside of the hole. In licking the spout, a subject made a connection between it and the metal rim of the 0.5-in. (1.3-cm) hole, activating one of four Grason-Stadler drinkometers (model E4690A-1). Licks were recorded on event and cumulative recorders and counters. No scheduled feedback accompanied a response. It was extremely unlikely that a subject could hear the clicks of the recording equipment produced by responses, which were in any event usually masked by clicks produced by the other three rats. Shocks were provided by four E1064GS Grason-Stadler shock sources. Scheduling apparatus, home cages, and experimental chambers were each in separate rooms.

Procedure

Hourly sessions of unrestricted access to the 8% sucrose solution were given five days a week. The 8% concentration was chosen because it was low enough to avoid early satiation and high enough to produce persistent responding in the face of free shock (Ayres and Quinsey, 1970) and punishment (Quinsey, 1971*b*).

After a pre-experimental session of exposure to the sucrose solution, subjects received four shock-free sessions and then five to 14 sessions with shock. Several shock-free sessions completed the experiment.

Subjects were arbitrarily assigned to squads of four and were labelled by the numbers of their squad (1 to 4) and the box in which they were run (a to d). During shock sessions, one rat of each squad was exposed to a free-operant avoidance schedule with an intershock (SS) interval of 10 sec in the absence of lick responses and a response-shock (RS) interval of 23 sec. Yoked to the avoidance rat was a noncontingent or free shock animal which was shocked each time the avoidance rat was. Each shock delivery to the avoidance rat set up a shock to follow the next response emitted by the punishment rat. A 9-sec limited-hold contingency was introduced on this punishment schedule after the behavior of the punishment rats in Squads 1 and 2 had been completely suppressed for several sessions. Punishment subjects in Squads 3 and 4 had the limited-hold feature from the outset. All shocks were of 0.25-mA nominal intensity and 0.5-sec duration. A no-shock rat was included in each squad except the first (albino) squad where the no-shock animal died. Contingency conditions were varied among the boxes over squads.

Results and Discussion

Absolute Lick Rates

As shown in Table 1, the mean number of responses per shock session in each squad was in the descending order: avoidance, no shock, free shock, and punishment. The avoidance contingency superimposed on sucrose reinforced licking held the response rate at the level of the no-shock animals. Lick rates in the yoked free shock and punishment conditions were lower than the preshock and no shock baselines. Representative data are shown from Squad 3 in Figure 1. The fast decline in response rate and the slow but incomplete recovery seen in the punishment and free shock subjects of Squad 3 occurred in all squads.

Pattern of Licking

Figure 2 shows the characteristic slowing of overall rate throughout each session and the

Table 1

Response and Shock Rates in Experiment 1[1,2]

Squad	Condition	Licks Per Session in Last Two Nonshock Sessions	Licks Per Shock Session	Shocks Per Session in First Two Shock Sessions	Shocks Per Session in Last Two Shock Sessions
1	Avoid	5062	5862	239	203
	Free Shock	4583	3136	239 (11)	203 (26)
	Punishment	4151	260	4	0
2	Avoid	6424	9234	161	99
	Free Shock	5568	3667	161 (12)	99 (7)
	Punishment	5707	1664	5	11
	No Shock	6567	6600	0	0
3	Avoid	7513	7854	123	74
	Free Shock	6320	2260	123 (24)	74 (27)
	Punishment	6162	1381	8	4
	No Shock	7555	7747	0	0
4	Avoid	7005	8199	100	66
	Free Shock	7738	4776	100 (19)	66 (7)
	Punishment	7842	4651	22	6
	No Shock	5335	7334	0	0

[1]Numbers in parentheses represent response-shock pairings.
[2]The number of shock sessions in Squads 1 through 4 were 14, 10, 10, and 5 respectively.

discontinuous nature of licking before shock was introduced. The free-operant avoidance schedule did not change this pattern. The satiation-like slowing and bursting pattern remained, as illustrated in Figure 3. Since avoidance subjects took shocks in bursts, response rate was very low in the 6-sec period following shocks as compared to response rate otherwise. The pattern illustrated in Figure 4 was found in all avoidance subjects. Shocks were nearly always followed by periods of nonresponding in the punishment condition. Typically, post-punishment pauses increased in length throughout a session until the subject ceased to respond.

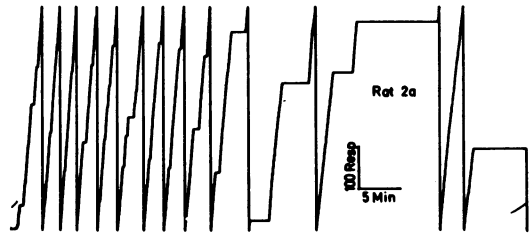

Fig. 2. Cumulative record of Session 3 for Rat 2a. There are 5795 licks in this record.

There was considerable between- and within-subject variability in post-shock response rate in the noncontingent shock condition. Three of the four free shock animals, however, showed post-shock bursting in long trains

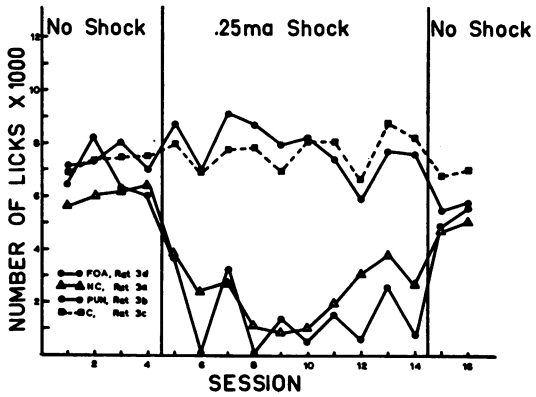

Fig. 1. Responses per session for each subject in Squad 3. FOA = free-operant avoidance. NC = noncontingent shock. PUN = punishment. C = no shock.

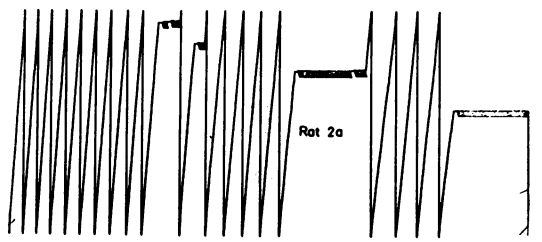

Fig. 3. Cumulative record of Rat 2a's seventh avoidance session. There are 108 shocks and 10,343 licks in this record.

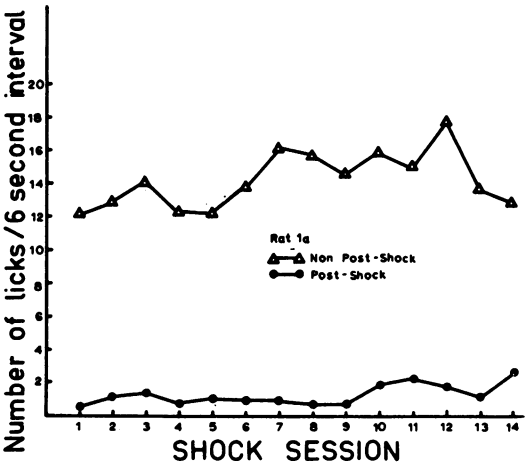

Fig. 4. Average number of licks per 6-sec interval after shocks and not right after shocks for Rat 1a.

of shock. In this pattern, licking stopped during the second or two immediately preceding each shock. An illustration of the post-shock bursting pattern is shown in Figure 5. The post-shock increase in rate resembled the disinhibition phenomenon described by Quinsey and Ayres (1969) for the licking response and Brimer (1971) for bar pressing because it occurred when response rate was low. It is difficult to account for this post-shock bursting because it did not occur in the avoidance group, even though the avoidance schedule insured that shocks always occurred when response rates were depressed.

Rate of Shocks

The reduction in shock rate for the avoidance animals shown in Table 1 was small. No reduction in shock rate occurred after the second session in any of the avoidance rats and they all continued to take large numbers of shocks. Whether avoidance learning actually occurred in these subjects is doubtful because the reduction reported in Table 1 was small relative to intrasubject variability. Data from four rats exposed to the same free-operant avoidance schedule in a replication of this study indicate that shock rate is almost as likely to drift up as down under this condition.

The punishment rats passively avoided a large number of the shocks potentially available to them, as shown in Table 1. They not only received fewer shocks than their free shock partners but also typically received fewer response-shock pairings. The minimum number of response-shock pairings in the noncontingent shock condition was determined from the cumulative and event pen records. A response and shock had to appear to be simultaneous in the record to be judged as a response-shock pairing—*i.e.*, response-shock occurrences that were judged pairings in the free shock records appeared identical to the pairings in the punishment records. Since any delay between a response and a shock in the free shock records precluded that response and shock occurrence from being judged as a pair-

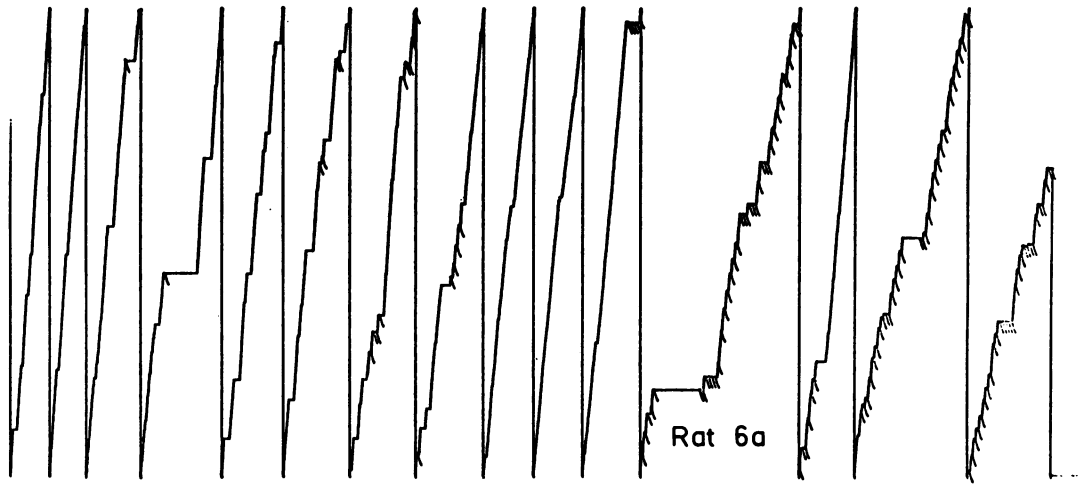

Fig. 5. Cumulative record of nineteenth shock session for Rat 6a. Although taken from a replication of the experiments reported in this paper, these data are typical of rats exposed to non-contingent shock. There are 8277 responses and 128 shocks of 0.4-mA intensity in this record.

ing, this procedure resulted in a very conservative estimate of the number of pairings. The number of pairings in the free shock group is shown in Table 1. Since the behavior of the punishment rats was more suppressed than the free shock subjects in every squad, but usually received fewer response-shock pairings, response-shock contingencies were involved. Therefore, when response-shock pairings occurred, shocks temporally removed from licks partially prevented suppression from occurring.

Shock rates were not held constant over the three contingency conditions because the punishment subjects passively avoided too many shocks. A further study was conducted in which avoidance and free shock groups were yoked to an intermittently punished group but the frequency of delivered shock, although equal in the three conditions, was so low as to leave licking unaffected in the two yoked groups. Because it appears very difficult to equate number and pattern of shocks across contingency conditions and still have the contingencies affect responding, some modifications in procedure are necessary if the effects of positive, negative, and zero lick-shock contingency histories are to be compared on subsequent learning. A partial solution to the problem would be to have punishment and free shock rats yoked to an avoidance rat as before but, in addition, to have another rat yoked to the punishment rat. The avoidance rat and its free shock yoke could later be exposed to a punishment condition and the punishment rat and its free shock yoke could later be exposed to an avoidance schedule. In both cases, it could be determined whether experience with the contingency opposite to the new schedule had effects other than those attributable to noncontingent shock.

EXPERIMENT 2

Despite the fact that avoidance animals averaged 139 shocks a session, the avoidance schedule did not appear to change their licking behavior from what it had been before shock was introduced. Unequivocal evidence of avoidance responding was not seen in any of the avoidance rats. But avoidance drinking in nondeprived animals was obtained by Teitelbaum and Derks (1958) with an S-S interval of 1 sec. Perhaps the S-S interval of 10 sec was too long to produce efficient avoidance. Experiment 2 tested this hypothesis by exposing some rats to briefer S-S intervals as well as by varying the S-S interval within subjects.

Subjects and Apparatus

Four hooded rats, 9b, 9d, 10b, and 11b, were similar to those in Experiment 1, except that Subject 9d was maintained at 85% of free feeding weight. The apparatus was unchanged.

Procedure

All rats received five hourly sessions with no shocks. Subjects 9b and 9d were then exposed to avoidance schedules that had an R-S interval of 23 sec and an S-S interval of either 1 or 10 sec. The sequence of conditions for Rat 9b is shown in Figure 6. Rat 9d received the same treatment but had one less session with S-S = 1 sec. Rats 10b and 11b received eight sessions of avoidance; the S-S and R-S intervals of the schedule they were exposed to were 2 and 23 sec, respectively.

RESULTS

Neither rat 9b nor 9d reduced shock frequency during exposure to the avoidance schedule with the 10-sec S-S interval. All subjects, however, greatly reduced shock frequency over sessions when exposed to the brief S-S avoidance schedule, as shown in Figure 6 and Table 2. The reduction in shock rate that was associated with the brief S-S intervals appears to represent actual avoidance. The subjects apparently avoided by distributing their responses more effectively in time because, as shown in Table 2 and Figure 6, the number of shocks was reduced without a concomitant increase in lick rate.

GENERAL DISCUSSION

It was much easier, in the sense of requiring fewer shocks, to get rats to avoid shocks by not licking (as in punishment) than to avoid by licking (as in free-operant avoidance). Several obvious explanations of this discrepancy can be discarded at the outset. The lack of active avoidance behavior when the S-S interval was 10 sec cannot be attributed to a ceiling effect because rats are capable of making 15,000 licks in an hour in this situation. More compelling, however, is the fact that when rats avoid they

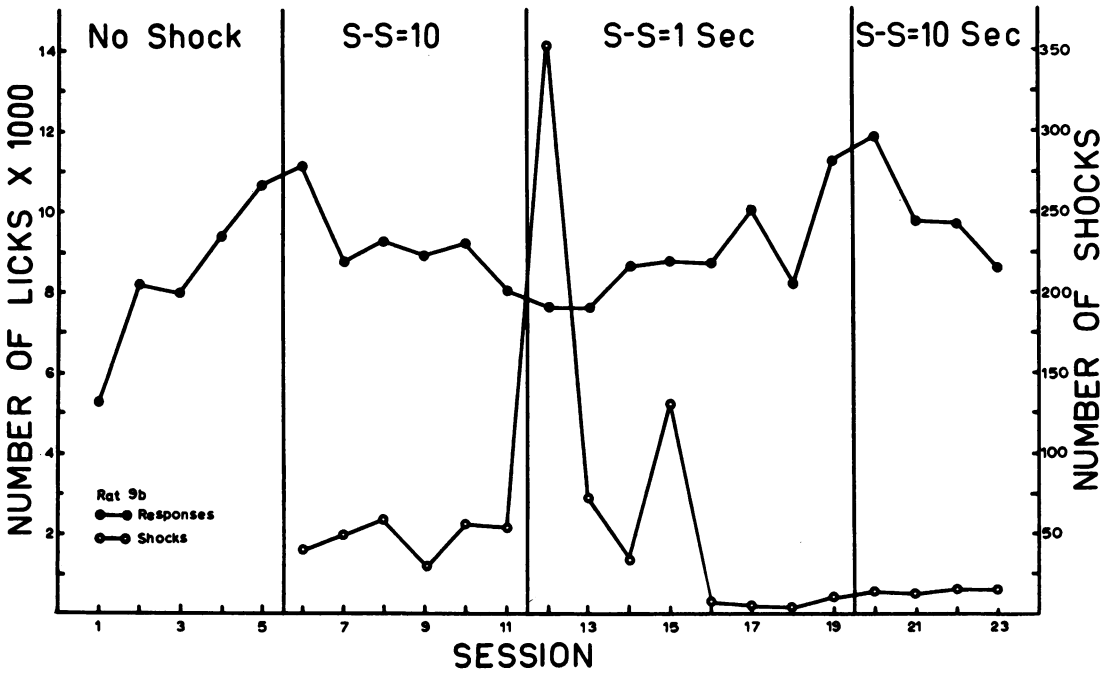

Fig. 6. Responses and shocks per session for Rat 9b.

can do it by changing the temporal distribution of their responses, as seen in Experiment 2. This difference between punishment and avoidance schedules cannot be explained by invoking any innate suppressive property of shock, since shock elicited licking or suppression of licking depending on the schedule the rat was exposed to and how long it had been in effect.

Perhaps the free-operant avoidance contingency may have failed with the 10-sec S-S interval simply because responses are not easily controlled by consequences that are not temporally contiguous with them. In the punishment condition, the consequence of failing to avoid was available immediately following a response, whereas in the avoidance condition a failure to avoid could not be detected until at least 10 or 23 sec (depending upon whether an S-S or R-S interval was involved) after it occurred. This idea is supported by the finding of Camp, Raymond, and Church (1967) that a

Table 2

Number of licks and shocks per session in Experiment 2 starting with first session of avoidance with brief S-S interval.

		Session						
		1	*2*	*3*	*4*	*5*	*6*	*7*
9b	Licks	7654	7683	8620	8786	8728	10,005	8228
	Shocks	352	74	33	131	9	6	5
9d	Licks	9423	8388	10,759	9985	9334	9922	9938
	Shocks	609	119	124	94	160	159	145
10b	Licks	3885	4496	4761	4201	4896	4619	3942
	Shocks	795	488	138	20	40	155	106
11b	Licks	8844	9888	9083	10,994	9101	9677	7807
	Shocks	519	199	247	56	150	211	262

30-sec delay in punishment removed the effect of the contingency. The acquisition of avoidance behavior with brief but not long S-S intervals in Experiment 2 could be because a failure to avoid with a brief S-S interval is frequently signalled almost immediately.

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