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LEVER ATTACKING AND PRESSING AS A FUNCTION OF CONDITIONING AND EXTINGUISHING A LEVER-PRESS AVOIDANCE RESPONSE IN RATS[1]

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Six experimental rats were conditioned to press one of two available levers to avoid shock. The levers registered bites as well as presses. For four of these rats, shock was contingent on lever bites when a specified time period had elapsed after the previous shock. An extinction period, in which only periodic noncontingent shocks were presented, followed avoidance training. Six yoked-control rats received the same sequence of shocks as did the corresponding experimental rats in both the conditioning and extinction phases. All six experimental rats repeatedly bit the avoidance lever. Four bit it more than the nonavoidance lever during conditioning, and five bit it more during extinction. Five of the six experimental rats consistently bit the levers many more times during each session than did their respective control rats, suggesting that avoidance conditioning facilitated lever biting. Rates of lever biting and pressing by all of the experimental rats and by some of the control rats were highest immediately following shock throughout both phases. During later portions of the intervals following shock, characteristic effects of conditioning and extinction were observed. This finding suggests that extinction of avoidance behavior by unavoidable shock presentations can be demonstrated more readily when shock-elicited responding is extricated from the data.

Key words: elicited aggression, lever attacking, response bursting, free-operant avoidance, extinction of avoidance, elective shock, rats

The role that shock-elicited attack behavior (*e.g.*, Azrin, Rubin, and Hutchinson, 1968; Hutchinson, Azrin, and Hake, 1966; Ulrich and Azrin, 1962) may play in operant conditioning experiments involving shock is a matter of some interest. Azrin, Hutchinson, and Hake (1967) demonstrated interactions between shock-elicited attack behavior and escape and avoidance conditioning in rats. Hake and Campbell (1972) observed high rates of postshock responding on the operandum by monkeys exposed to a fixed-interval negative reinforcement schedule for key pressing. The fact that this postshock responding was attenuated when the animals had access to a rubber tube that they could bite suggested that the behavior was at least partly aggressive.

The operandum can also be an object of shock-elicited attack by rats with a history of free-operant avoidance conditioning (Sidman, 1953). Powell (1972) found that following free-operant avoidance conditioning of lever pressing, rats typically continued to respond immediately after shock when only response-independent shocks were presented. He inferred that this postshock responding was due to shock-elicited lever attacking. Pear, Moody, and Persinger (1972) used a lever that recorded biting attacks as well as presses. Rats frequently bit the lever during free-operant avoidance conditioning and maintenance of lever pressing, and also during extinction in which shocks were delivered irrespective of responding. The data suggested that lever attacking might account, at least in part, for postshock response bursting (*e.g.*, Sidman, 1958). They also tended to confirm Powell's (1972) explanation for the persistence of responding he observed during extinction of avoidance behavior.

The present study was undertaken to determine whether the tendency for rats to attack a lever is affected by a history of avoidance conditioning. A second purpose was to assess

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the extinction of avoidance behavior by examining lever presses that were isolated from lever attacks.

METHOD

Subjects

Twelve experimentally naive, male Long Evans hooded rats, obtained from Canadian Breeding Farm and Laboratories Ltd., served. E-1, E-2, E-3, E-4, E-5, and E-6, were designated "experimental" rats and C-1, C-2, C-3, C-4, C-5, and C-6 were their respective "yoke-control" rats. Experimental and control rats were matched according to ages and weights. E-1 and C-1 were 163 days old; E-2 and C-2 were 159 days old; E-3, C-3, E-4, and C-4 were 105 days old; and E-5, C-5, E-6, and C-6 were 144 days old at the beginning of the study.

Apparatus

Two similar operant conditioning chambers were used. Rats E-1, C-1, E-2, and C-2 received sessions in one chamber and Rats E-3, C-3, E-4, C-4, E-5, C-5, E-6, and C-6 received sessions in the other. The chambers were each approximately 29 cm wide by 23 cm long by 20 cm high. Each chamber contained two levers of the type described by Pear *et al.* (1972). Each lever was constructed in such a way that a sufficiently large force applied between its upper and lower surfaces caused a "bite" to be recorded by a microswitch located at the back of the lever. Lever presses were recorded in the usual manner, in that a downward press activated another microswitch located outside of the chamber. Thus, bites and presses were recorded separately: a response defined as a bite could not activate the microswitch for pressing unless the rat also made a downward motion on the lever; a press response that the rat made with its paws could not activate the microswitch for biting.

The levers protruded 2.0 cm into the chamber from the same front wall. They were located 8.4 cm above a grid floor, and were separated by a distance of 4.1 cm measured from their inner edges. The levers were each 5.1 cm wide, 1.3 cm thick, and located 7.4 cm from the closer side wall, as measured from the outer edge of the lever. Each lever recorded presses having a force above 0.2 N and bites having a force above 2.45 N.

Electric shocks with a duration of 0.5 sec and an intensity of 3.0 mA were delivered to the grid floor by a Grason-Stadler shock generator and scrambler. (These shock paramenters were used because previous data in our laboratory indicated that they reliably resulted in lever biting.) A tape recorder and relay attachment programmed for each control rat the same temporal sequence of shocks received by the corresponding experimental rat in the same chamber immediately preceding the control rat's session (*cf.* Masterson, 1965).

Illumination throughout all sessions was provided by a 7.5-W jewel lamp located above and between the two levers in each chamber. Ventilation and a partial masking noise were provided by fans in sound-insulated cubicles housing the experimental chambers. An additional masking noise was provided by BRS/Foringer audio-generators (Model AU-901). All programming and recording equipment was located in a room adjoining the one containing the experimental chambers.

Procedure

Each rat received one 2-hr session per day, six or seven days per week. During conditioning (Phase I), the experimental rats received sessions on a free-operant avoidance schedule (Sidman, 1953). The response-shock interval on one lever, the avoidance lever, was 20 sec (RS = 20 sec) and the shock-shock interval was 10 sec (SS = 10 sec); *i.e.*, shock occurred 20 sec after the last lever press on the avoidance lever following the previous shock, or 10 sec after the previous shock if there was no press on the avoidance lever during that period. Presses during shock presentations were recorded but had no other scheduled consequence. Presses on the second lever, the nonavoidance lever, were recorded separately and also had no other scheduled consequence. The left lever was the avoidance lever for E-1, E-4, and E-6; the right lever was the avoidance lever for E-2, E-3, and E-5.

For E-3, E-4, E-5, and E-6, shock was contingent on any lever bite that occurred at least 6 sec after the previous shock, and a new shock-shock interval was then initiated. This punishment contingency was used to help ensure that lever bites on the avoidance lever would not be conditioned as part of the avoidance behavior, and to compensate for the fact that lever bites by the control rats might be punished if they occurred just before shock. The punishment contingency was applied to the nonavoidance

lever as well as the avoidance lever to equalize its effects across levers. It was not used with E-1 and E-2, so that any large effects it might have could be assessed.

Immediately following an experimental rat's session, the corresponding control rat was given the same temporal sequence of shocks that the experimental rat had just received in the same apparatus. For the control rats, lever presses and bites on either lever had no scheduled consequences, other than being recorded.

During extinction (Phase II), all rats received shock approximately every 30 sec. Lever presses and bites had no scheduled consequences, other than being recorded. E-1 received 41 and 21 sessions in Phases I and II, respectively; E-2 received 31 and 21 sessions; E-3 received 23 and nine sessions; E-4 received 10 and 11 sessions; E-5 received 23 and 15 sessions; and E-6 received 22 and 15 sessions.

RESULTS

Observations revealed that during the first few sessions, the rats sometimes activated the bite switches by jumping up under the levers when shock was delivered. The frequency with which this occurred decreased rapidly, and, after the first three or four sessions, the number of these spurious "bites" was negligible, relative to the number of actual bites recorded.

The overall results, averaged over the last five sessions of each phase for each rat, are summarized in Table 1. These data supplement the data presented in the following figures and may best be viewed in conjunction with them.

Figure 1 shows ratios over sessions of total recorded lever bites of each experimental rat to total recorded lever bites of that rat plus total recorded lever bites of the corresponding control rat. Totals include responses on both levers. A ratio above 0.5 indicates that in a particular session a particular experimental rat registered more bites than did the corresponding control rat. After the fourth session of Phase I, five rats—E-1, E-2, E-4, E-5, and E-6—had biting ratios well above 0.5 and remained there throughout the remainder of Phase I and all of Phase II. Thus, Figure 1 shows clearly that avoidance conditioning facilitates lever biting.

A more detailed analysis of the animals' behavior follows. To conserve space, only data for three representative pairs of rats—E-1 and C-1, E-3 and C-3, and E-6 and C-6—are presented in the remaining figures.

Figure 2 shows presses and bites on both levers across sessions for the three representative experimental rats (E-1, E-3, and E-6). During Phase I, all of the experimental rats pressed predominantly on the avoidance lever. This, and the gradual decrease in shock frequencies, indicates that they acquired avoidance behavior. E-1, E-3, E-4, and E-5 concentrated their biting on the avoidance lever. E-2 and E-6 bit mainly on the nonavoidance lever.

During Phase II, all experimental rats continued to engage in substantial amounts of

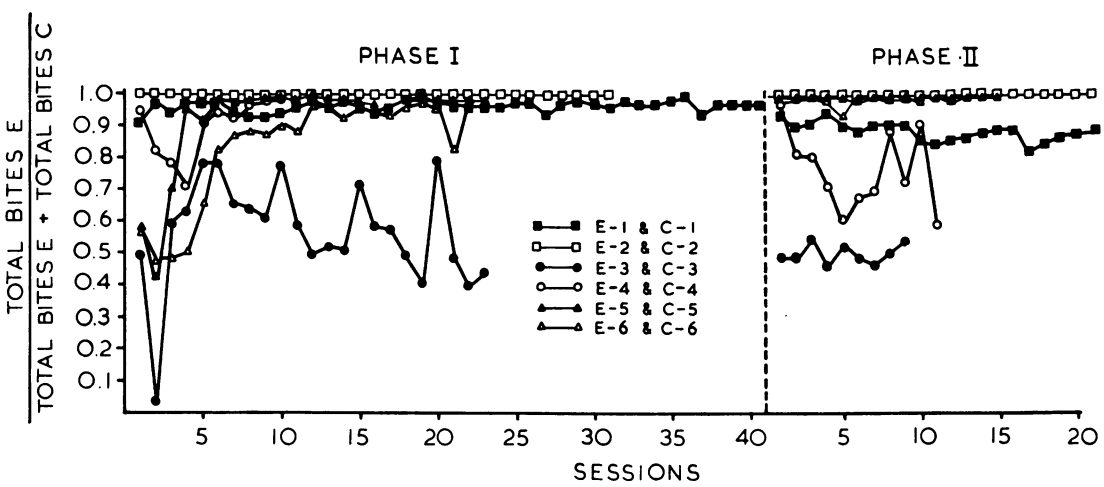

Fig. 1. Ratios of number of lever bites made by each experimental rat to the combined number of lever bites by that experimental rat and its respective control rat.

Table 1

Mean numbers of presses on each lever and on both levers combined, mean numbers of bites on each lever and on both levers combined, and mean number of shocks (excluding bite-contingent shocks) for each rat over the last five sessions of each phase.

	PHASE I						
Exp'l	Avoid Lever		Nonavoid Lever		Total		
Rats	Presses	Bites	Presses	Bites	Presses	Bites	Shocks
E-1	9288.8	406.0	13.4	0.2	9302.2	406.2	8.6
E-2	612.4	6.6	46.8	94.6	659.2	101.2	18.8
E-3	1544.0	755.8	39.6	2.0	1583.6	757.8	128.0
E-4	1164.0	1088.4	1.8	0.4	1165.8	1088.8	313.6
E-5	1449.0	156.0	85.4	7.6	1534.4	163.6	68.4
E-6	1560.6	52.2	320.8	306.6	1181.4	358.8	71.6
Control	Left Lever		Right Lever		Total		
Rats	Presses	Bites	Presses	Bites	Presses	Bites	Shocks
C-1	54.8	10.2	40.6	1.2	95.4	11.4	8.6
C-2	0.4	0.0	0.0	0.0	0.4	0.0	19.6
C-3	685.2	758.6	2.0	0.0	687.2	758.6	128.0
C-4	3.8	0.6	867.4	13.0	871.2	13.6	313.6
C-5	0.0	0.0	0.8	0.0	0.8	0.0	68.4
C-6	105.6	8.4	7.2	2.2	112.8	10.6	71.6

	PHASE II						
Exp'l	Avoid Lever		Nonavoid Lever		Total		
Rats	Presses	Bites	Presses	Bites	Presses	Bites	Shocks
E-1	1981.6	2703.6	27.6	4.0	2009.2	2707.6	199.6*
E-2	892.6	710.4	173.0	560.0	1065.6	1270.4	234.0
E-3	2000.0	1599.8	1.2	0.0	2001.2	1599.8	237.4
E-4	534.6	726.8	15.4	2.6	550.0	729.4	237.2
E-5	1318.4	718.8	68.0	15.0	1386.4	733.8	238.2
E-6	123.6	12.0	1635.8	1415.0	1759.4	1427.0	236.4
Control	Left Lever		Right Lever		Total		
Rats	Presses	Bites	Presses	Bites	Presses	Bites	Shocks
C-1	225.8	343.4	139.6	84.0	365.4	427.4	199.8*
C-2	1.4	2.8	0.6	0.0	2.0	2.8	234.0
C-3	1446.8	1512.0	1.0	0.0	1447.8	1521.0	237.4
C-4	1.4	1.4	683.4	264.8	684.8	266.2	236.8
C-5	4.0	0.0	1.8	0.6	5.8	0.6	238.6
C-6	435.8	1.6	3.2	0.2	439.0	1.8	237.6

*Shocks during Phase II were delivered approximately once every 36 sec for Rats E-1 and C-1, rather than every 30 seconds for the other pairs of rats.

lever biting. E-1, E-3, E-4, and E-5 continued to bite predominantly on the avoidance lever. E-6 increased its biting on the nonavoidance lever. E-2's biting on the nonavoidance lever, which had received most of this rat's biting during Phase I, increased and then decreased, while bites on the avoidance lever gradually increased until they were occurring more frequently than bites on the nonavoidance lever.

None of the experimental rats showed the gradual decrease to near-zero responding that typically occurs when positively reinforced behavior is extinguished (Skinner, 1938, p. 75), or when free-operant avoidance behavior is extinguished in the absence of shocks (Sidman, 1966, pp. 484-486). E-1, E-2, and E-3 increased their avoidance-lever pressing above that occurring in Phase I, while E-5 continued to press at about the same rate on the avoidance lever. Although E-6 showed a sudden and substantial decrease in avoidance-lever pressing at the start of Phase II, its pressing on the nonavoidance lever—which this rat bit more often during both phases—just as suddenly increased to and stayed at about the level at which pressing on the avoidance lever was maintained during

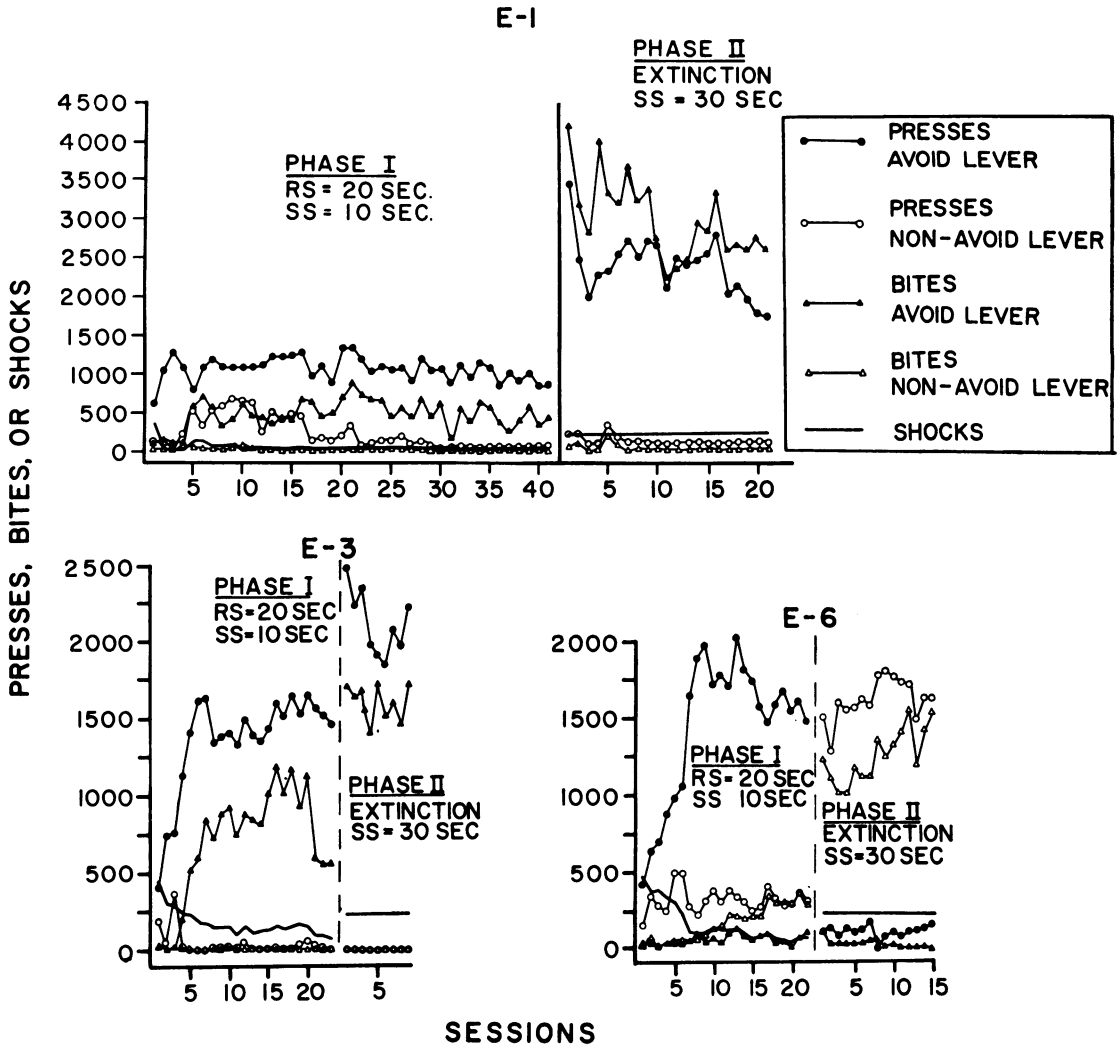

Fig. 2. Number of lever presses, lever bites, and shocks for three representative experimental rats (E-1, E-3, and E-6).

Phase I. E-4, whose shock frequency decreased from Phase I to Phase II, concomitantly decreased its avoidance-lever responding, which then still remained high and showed little or no further decreasing trend. It appears that the persistence of extinction responding in the experimental rats was at least partly due to lever attacking, which resulted in lever-press responses. Further support for this conclusion is given below.

Figure 3 shows the number of presses and bites across sessions for three representative control rats (C-1, C-3, and C-6) corresponding to the experimental rats, whose data are presented in Figure 1. C-1 and C-2 pressed very little on either lever during Phase I, but increased their lever pressing during Phase II when their shock frequencies increased. C-3, C-4, and C-6 pressed a substantial amount on one of the two levers during both phases, while C-5 showed virtually no lever pressing during either phase. The fact that during Phase I the lever-pressing curves for C-3, C-4, and C-6 seem similar to acquisition curves, even though lever presses did not result in the avoidance of shock, reveals a potential artifact in experiments on avoidance conditioning. Some responding that has been classified as "avoidance" might actually be elicited aggression directed toward the operandum.

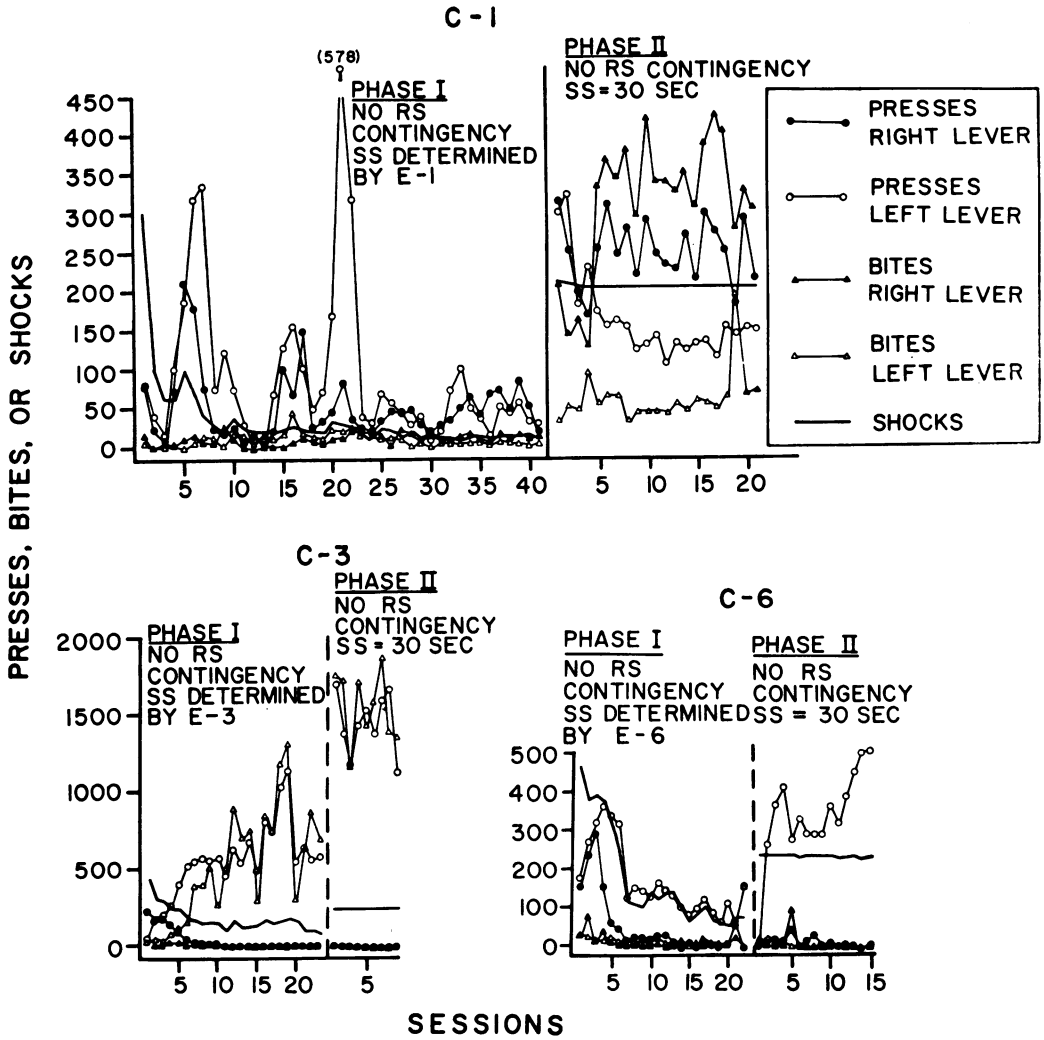

Fig. 3. Number of lever presses, lever bites, and shocks for the control rats corresponding to the experimental rats whose data are presented in Figure 2.

The large amount of lever pressing by some of the control rats appears to have been at least partly due to lever attacking. C-3 certainly registered a large number of bites during both phases, as did C-1 during Phase II. C-5, which pressed very little during either phase, showed little lever biting. However, C-4 registered little biting during Phase I and C-6 registered little during both phases, even though these rats showed substantial amounts of lever pressing. One possible reason for this apparent discrepancy is that C-4 and C-6 frequently bit around the tops of the levers on which they concentrated their presses. While these bites should be considered in accounting for the presses made by these control rats, they lacked the force or topography necessary to activate the bite switch, and therefore clearly differed quantitatively and/or qualitatively from the responses that were operationally measured as "bites" in this study.

The main conclusion to be drawn from the data in the first three figures is that the control rats tended to make fewer and/or less-forceful lever bites than did the experimental rats. Nevertheless, while an avoidance contingency seems to facilitate lever biting (if only, perhaps, by keeping the rat closer to the lever), Figure 3 indicates clearly that an avoidance contingency is not necessary for shocks to cause rats to attack or press a lever. Consider now the temporal properties of the behavior.

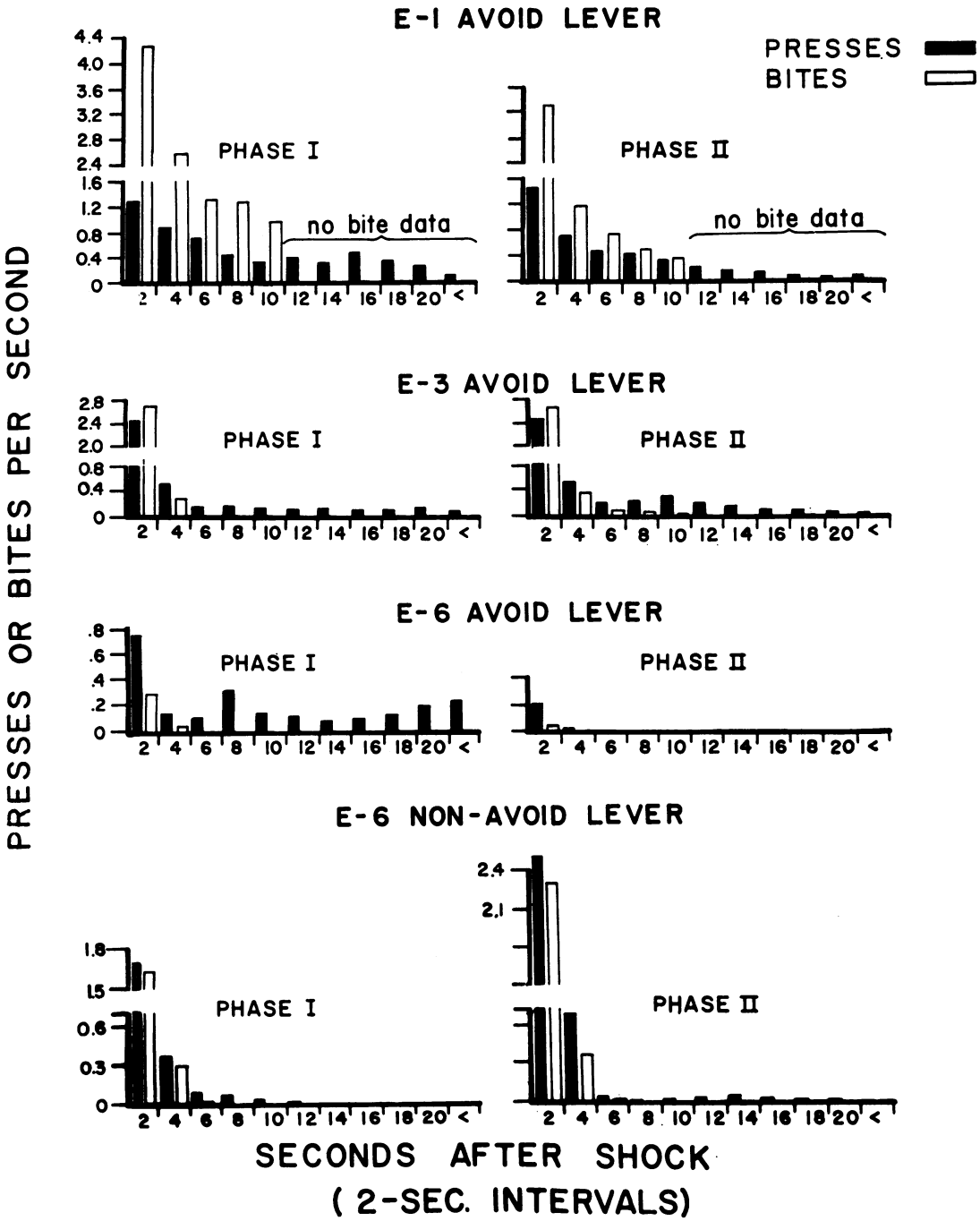

Fig. 4. Rates of lever pressing and lever biting in discrete time intervals following shock for the three representative experimental rats (E-1, E-3, and E-6). The data are for the last five sessions of each phase.

Figure 4 shows rates of pressing and biting during 2-sec intervals (up to 20 sec) following shock during both phases for the three representative experimental rats. Each bar was constructed by determining the total number of presses or bites that a particular rat made in the corresponding 2-sec interval during the last five sessions of a particular phase, and dividing

that number by the total amount of time that the rat spent in that 2-sec interval during those five sessions.

Note that in both phases, the biting rates of the experimental rats were much higher during the first 2 sec after shock than during later intervals. Correspondingly, so were rates of pressing. These graphs thus depict correlated bursts of postshock lever biting and pressing (*cf.* Pear *et al.*, 1972, Figure 4). As biting rates decreased with time following shock, so did pressing rates.

Unlike the other experimental rats, E-1 bit the avoidance lever up to and more than 10 sec after shock (the distribution for bites was not recorded past 10 sec). This indicates that biting might have been conditioned as part of this rat's avoidance behavior. However, the fact that E-1 bit at substantially higher rates during early intervals following shock than did the other experimental rats during Phase I, suggests that adventitious reinforcement probably did not account for all of E-1's lever biting.

The decreases in E-6's biting and pressing rates in the early 2-sec postshock intervals during Phase II were more than compensated for by the corresponding increases on the nonavoidance lever. Similarly, E-2 decreased its postshock biting and pressing rates on the nonavoidance lever during Phase II and correspondingly increased them on the avoidance lever. Of all the experimental rats, an overall decrease in rates of postshock biting from Phase I to Phase II occurred only for E-1; however, this rat continued to bite at a rate well above the rates for the other rats.

For all experimental rats, pressing rates on the avoidance lever during the last few postshock intervals, well after shock-elicited biting had ceased, were lower at the end of Phase II than at the end of Phase I. This indicates that the avoidance behavior evidenced the characteristic effect of extinction, despite the high rates of pressing in the earlier intervals. It is not clear, at present, why these decreases were so small.

Figure 5 shows rates of pressing and biting during 2-sec intervals (up to 20 sec) following shock during both phases for the three representative control rats. The bars in this figure were constructed in the same manner as those in the previous figure.

During both phases, these control rats pressed mainly in the first few postshock intervals and, relative to the experimental rats, they pressed very little in the later intervals following shock. Similar patterns of postshock responding were shown by C-4 during Phase I and C-2 during Phase II, while C-5 made virtually no lever presses during either phase. It seems reasonable to attribute, at least partly, the postshock lever pressing by the control rats to shock-elicited lever attacking. Although C-4 and C-6 registered very little lever biting, they were often observed, as mentioned above, to make lever bites whose force or topography was not sufficient to activate the bite switch.

Comparing the data in Figure 5 with those in the previous figure indicates the major differences between the control rats and the experimental rats. Both groups exhibited postshock lever biting and pressing during both phases, but the experimental rats bit more than did the control rats. Moreover, the experimental rats also exhibited characteristic evidence of conditioning and extinction in the later postshock intervals when avoidance responding presumably was less confounded with the effects of shock-elicited lever attacking.

DISCUSSION

Since five of the six experimental rats consistently made many more lever bites than did their corresponding control rats, it appears that a history of shock-avoidance conditioning of lever pressing facilitates shock-elicited lever attacking. This result is similar to Weiss and Strongman's (1969) finding that rats with a history of positive reinforcement for lever pressing showed postshock bursts of responding when shocks were presented during a "warning signal", whereas control rats with no history of reinforced lever pressing failed to show these bursts. The experimenters attributed these postshock responses to attack behavior. It appears that rats may have a strong tendency to attack an operandum that has been associated with a positive or negative reinforcement contingency. Possibly the simplest explanation for this, on the basis of available data, is that such reinforcement contingencies ensure the animal's proximity to the operandum. It is interesting to note, however, that the experimental rats in the present study typically continued to bite the levers more than

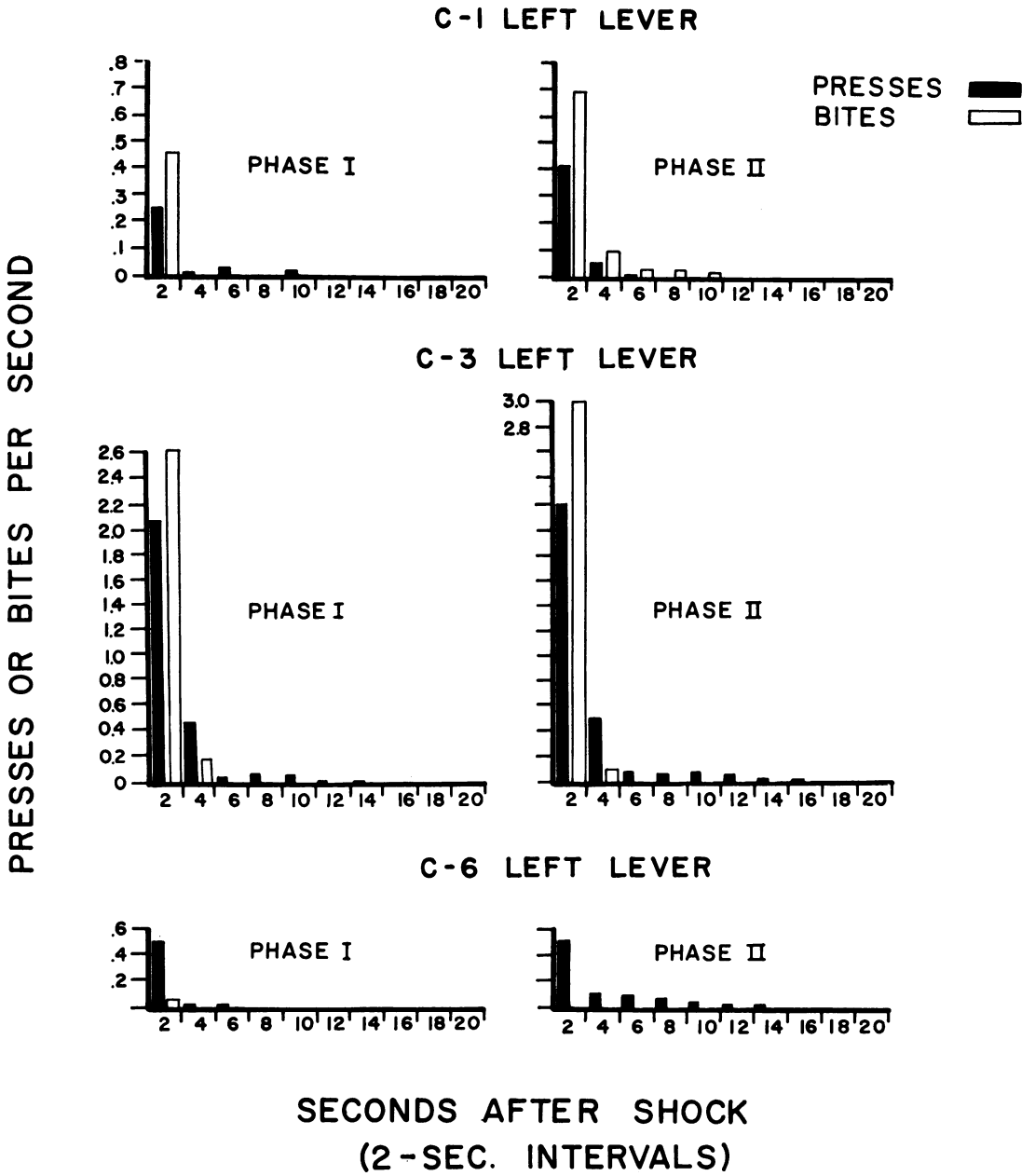

Fig. 5. Rates of lever pressing and lever biting in discrete time intervals following shock for the representative control rats. The data are based on the last five sessions of each phase.

did the control rats long after the avoidance contingency was removed.

It is not likely that the lever biting of at least five of the experimental rats was an adventitiously conditioned part of their avoidance behavior. For four experimental rats during Phase I, any lever bite that occurred more than 6 sec after the previous shock was punished, and these rats almost never bit during that time period. Moreover, one of the other two experimental rats never registered lever bites more than 4 sec after shock. Only one experimental rat registered lever bites an appreciable amount of time after shock delivery. Some of this rat's lever biting, therefore, may have been adventitiously conditioned by shock

avoidance when the rat made concomitant bites and presses.

Two of the six experimental rats in the present study bit the nonavoidance lever more than the avoidance lever during Phase I, and one consistently continued to bite more on the nonavoidance lever during Phase II. This seems somewhat inconsistent with Powell's (1972) finding that rats with a history of pressing a lever to avoid shock responded relatively little on a second lever when response-independent shocks were delivered. This discrepancy may be accounted for by the fact that the levers were much closer together in the present study than in Powell's study. Indeed, it was possible for the rats in the present study to bite one lever while pressing the other. Visual observations of E-2 during Phase I revealed, however, that this rat was typically facing away from the levers when shock occurred, whereupon it would then turn and attack the nonavoidance lever. Variables other than the distance between the levers may therefore have affected the tendency to attack a particular lever.

Nevertheless, the present results support Powell's (1972) explanation for the persistent responding he observed when response-independent shocks were delivered to rats with a history of avoidance conditioning. The substantial pressing by the experimental rats in Phase II, and by some of the control rats in both phases, evidently was due to shock-elicited lever attacking. Pressing rates of both groups tended to remain high in Phase II during the periods shortly following shock, whereas pressing in the later postshock intervals tended to decrease for the experimental rats.

The above analysis indicates that there may be at least two types of lever pressing by rats during conditioning and extinction of a lever-press avoidance response: (1) responding due to shock-elicited aggression; and, (2) responding due to avoidance behavior. Although development of the former can be facilitated by the avoidance conditioning procedure, it can also occur independent of such conditioning. It typically does not decrease as a result of an extinction procedure in which noncontingent shocks are delivered. The latter, on the other hand, increases and decreases as a function of the avoidance conditioning and extinction procedures.

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