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PARAMETERS AFFECTING THE MAINTENANCE OF NEGATIVELY REINFORCED KEY PECKING[1]

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Three negative reinforcement experiments employing a key-peck response are described. In Experiment I, pigeons shocked on the average of twice per minute (imposed condition) could produce, by pecking a key, an alternate condition with correlated stimuli. Delayed shocks were added, across sessions, to the alternate condition until pecking stopped. Two of three pigeons continued to peck despite a 100% increase in shock frequency. In Experiment II, pigeons were shocked in the imposed condition four times per minute. The postresponse delay to shock was held constant by delivering, in the alternate condition, the next shock, or the next two, three, or four shocks from the imposed-condition shock schedule. All three subjects continued to peck with no change in delay to the first two postresponse shocks but with a 75% reduction in shock frequency. In Experiment III, a response produced an immediate shock followed by a shock-free period. Three of four subjects continued to respond despite reduced delay to shock. Delay-to-shock *or* shock-frequency reduction was sufficient to maintain key pecking, but neither was necessary. The conditions that negatively reinforce the pigeon's key peck were similar to conditions that negatively reinforce the rat's bar press.

Key words: aversive control, avoidance, delayed shock, shock frequency, key pecking, pigeons

Response preparedness is an important factor in learning according to several writers (see Seligman and Hager, 1972). The notion is that animals are prepared, unprepared, or contraprepared to learn a relationship between a particular response and a particular consequence. If prepared, subjects learn quickly; if unprepared or contraprepared, subjects learn slowly. Preparedness can be defined by "how degraded the input can be before that output reliably occurs which means that learning has taken place" (Seligman and Hager, 1972, p. 4). An observation consistent with the preparedness notion is that different responses are acquired at different speeds; in avoidance experiments, for example, rats learn a shuttle response faster than a bar press (Bolles, 1971).

Many avoidance experiments, however, deal with the maintenance of behavior under steady-state conditions, not with the initial acquisition of the behavior. The relevance of the concept of preparedness to the understanding of steady-state behavior is unsettled. Seligman and Hager (1972, p. 5) suggest that the laws of behavior might be different for responses prepared, unprepared, or contraprepared for a given consequence, although little evidence is available.

The key-peck response, under negative reinforcement, meets the definition of a contraprepared response—acquisition is very difficult without extensive training. Early attempts to condition key pecking encountered difficulties (Hineline and Rachlin, 1969; Hoffman and Fleshler, 1959; Rachlin and Hineline, 1967). Recently, however, two techniques for successfully training the key peck with negative reinforcement have been reported. The method of successive approximation (Ferrari, Todorov, and Gaeff, 1973; Todorov, Ferrari, and DeSousa, 1974) or a reinforcement-switching procedure may be used (Foree and LoLordo, 1974; Lewis, Lewin, Stoyak, and Muehleisen, 1974). The purpose of the pres-

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ent experiments was to determine whether negatively reinforced key pecks follow the same principles as other negatively reinforced responses. Several observations are consistent with the view that key pecking follows the same principles. One is that key pecking can be maintained by periods of shock-free time (Lewis *et al.,* 1974). More convincing, however, are data that show pecking rates change in a manner similar to other responses with variations in the parameters of the negative reinforcement procedure. Todorov *et al.* (1974) found that key pecking, on a free-operant avoidance schedule, was affected by manipulations in the response-shock interval in a manner similar to the rat's bar press (Sidman, 1953). On the free-operant avoidance schedule, the response-shock interval specifies the delay to shock following a response. Todorov *et al.* found that the longer the response-shock interval, the lower the response rate. This relationship has also been reported for an unprepared lever response with rats (Sidman, 1953) and for an unprepared treadle response with pigeons (Klein and Rilling, 1972).

Determining the necessary and sufficient conditions for negative reinforcement is a problem that has interested students of aversive control. In free-operant avoidance (Sidman, 1953), two response consequences can be identified: (1) increased delay to shock, and (2) reduced shock frequency. Attempts to separate these two consequences have found both important. Hineline (1970) observed bar-press acquisition when a response delayed the onset of a single shock for 10 sec but did not change the overall number of shocks. Gardner and Lewis (1976) shocked rats at variable-time intervals averaging two shocks per minute. A bar press activated a 3-min condition, during which a series of six brief shocks was delivered with a delay of 10, 88, or 165 sec. This procedure held overall shock frequency constant while manipulating delay to shock. The longer the delay from the response to the shocks, the more session time spent in the delayed shock condition. Furthermore, if the shock series was delayed over 150 sec, bar pressing was acquired even when it resulted in shock-frequency increases of 100%. These studies indicate that delay to shock is sufficient negatively to reinforce a bar press, an unprepared avoidance response, and that, given adequate delay, overall shock-frequency reduction is not necessary.

The present first experiment sought to determine if delay to shock is sufficient to maintain key pecking, a contraprepared response, and to determine if key pecking is maintained by delay when it results in decreased, unchanged, or increased shock frequency.

Sidman (1962) suggested that a reduction in shock frequency, defined as the number of shocks per unit time, may be sufficient for negative reinforcement. Several experiments have attempted to test this suggestion by allowing bar presses to decrease shock frequency (Bolles and Popp, 1964; Herrnstein and Hineline, 1966; Lambert, Bersh, Hineline, and Smith, 1973). Herrnstein and Hineline found strong responding when rats could decrease the probability of shock from 0.3 per 2 sec to a probability of 0.1 per 2 sec. In Lambert *et al.* (1973), a response cancelled the delivery of five shocks, but also resulted in delivery of a single immediate shock. Lambert *et al.*'s rats learned to shuttle in a two-compartment box but did not learn to press a bar. In these studies, the contribution of shock-frequency reduction, independent of shock delay, is unclear. Delay to shock was not held constant in either Herrnstein and Hineline or in Lambert *et al.;* a response increased the average delay to shock in Herrnstein and Hineline (see discussion by Hineline, 1970); and decreased the delay to shock in Lambert *et al.* Bolles and Popp (1964) held delay to shock constant, but found no acquisition.

The present Experiment II sought to determine if shock-frequency reduction is sufficient to maintain key pecking, a contraprepared response, in the absence of a change in the postresponse delay to shock.

The third experiment was similar to Lambert *et al.* (1973), except that here a contraprepared response was employed. Lambert *et al.*'s procedure resulted in an 80% reduction in shock frequency, but a reduced delay to shock. Lambert *et al.*'s findings suggested that shock-frequency reduction plus reduced delay to shock, may negatively reinforce a prepared response (shuttle) but may not reinforce an unprepared or contraprepared response. Experiment III sought to determine if shock-frequency reduction would maintain key pecking even with reduced delay to shock.

EXPERIMENT I: DELAYED SHOCK WITH DECREASED, INVARIANT, AND INCREASED SHOCK FREQUENCY

METHOD

Subjects

Three naive White Carneaux pigeons (G-2, G-3, and G-4) from the Palmetto Pigeon farm, Sumter, South Carolina, were maintained at 80% of their free-feeding weights during initial training; thereafter subjects were given free access to food and water in their home cages.

Apparatus

A standard conditioning chamber (BRS-LVE) with translucent response keys, which could be illuminated white or red, was housed in a sound-attenuating box. Two keys (only the left was used) were positioned 25 cm from the floor and 20.3 cm apart. A response of 0.44 N closed a microswitch. The food reinforcer, 4-sec access to mixed grain, was delivered with the houselights out. A variable ac transformer in series with a 10 K-ohm resistor could deliver 0- to 120-V shocks for a duration of 0.3 sec. Shock was carried to stainless-steel electrodes implanted around the pigeon's pubis bone (Azrin, 1959). The electrode wire was routed to the pigeon's back vertically from the pubis bone, posterior to the bird's leg, and was attached to a Nu-way snap. A second Nu-way snap led to a male plug mounted on the pigeon's back, and the male plug was attached to a mercury commutator (Gerbrands, Inc.). White masking noise (80 dB) was present throughout each session. Solid-state scheduling and recording equipment was located in an adjacent room. A 10-cps clicking sound (85 dB) was provided by a BRS-LVE module when required.

Procedure

Initial training. Pigeons were trained to avoid by the reinforcement switching method previously described (Lewis, Lewin, Stoyak, and Muehleisen, 1974). Training sessions lasted for 1 hr or until 50 food reinforcements were presented. Subjects were trained, by reinforcing approximations, to peck the response key when it was either white or red. Next, a two-component chain schedule was introduced. During the first component, the response key was white and the clicker activated; during the second component, the key was red and the clicker was silent. After 10 sec in the presence of the first component (FI 10-sec), a single peck terminated the clicker and changed the key to red for 3 min. While the key was red, pecking produced grain at variable intervals averaging once every 10 sec (VI 10-sec). The parameter of the variable-interval food schedule in the second component was then increased: VI 10-sec, VI 15-sec, VI 30-sec, and VI 60-sec. After responding was maintained on chain FI 10-sec VI 60-sec, 10-V shocks were delivered during the initial link at varying time intervals averaging once every 3 sec (VT 3-sec). Next, the shock intensity was increased from 10 to 120 V in 10-V increments. After shock intensity reached 120 V, the VI food schedule was gradually eliminated by further increasing the VI parameter value (VI 60-sec, VI 2-min, VI 5-min, VI 10-min; after VI 10-min, all food was eliminated). Following food elimination, the size of the initial link was reduced from 10 sec to 1 sec, and the size of the terminal link was reduced from 3 min to 2 min. Finally, the parameter of the variable-time shock schedule in the initial link was gradually increased: VT 3-sec, VT 5-sec, VT 8-sec, VT 12-sec, VT 15-sec, VT 20-sec, VT 24-sec, and VT 30-sec. Initial training required 30, 60, and 54 sessions for G-2, G-3, and G-4, respectively.

Experimental treatments. All subjects were tested for 1 hr every day. In the absence of responding, subjects were shocked on the average every 30 sec (VT 30-sec) with the key white and the clicker on. The variable-time intervals were generated from Fleshler and Hoffman (1967) tables. This is called the imposed condition (Figure 1, frame 1). Key pecks activated a 2-min alternate condition during which no shock was delivered. In the alternate condition, the key was red and the clicker was silent. Responses in the alternate condition were recorded but had no effect. At the end of the 2-min alternate condition, the imposed condition was automatically reinstated (Figure 1, frame 2) and the animal could respond again, reinstating the alternate condition, or not respond and remain in the imposed condition.

After performance stabilized, delayed shocks were gradually introduced. Stability was de-

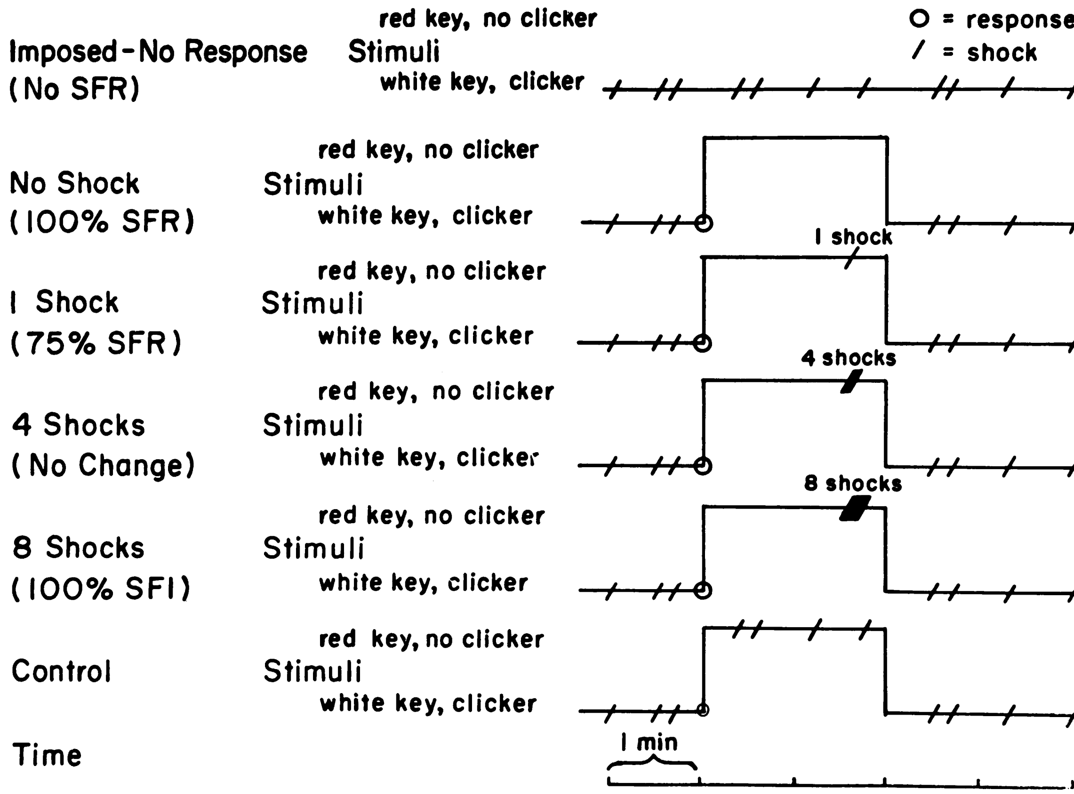

Fig. 1. Schema for the procedure employed in Experiment I. Time is represented from left to right on the bottom line. The remaining six lines represent the sequence of events in the imposed (no response), no shock, one delayed shock, four delayed shocks, eight delayed shocks, and control procedures. The number in parentheses indicates the per cent of shock-frequency reduction (SFR) or shock-frequency increase (SFI) received by responding. Upward displacement of a line marks the onset of the alternate condition with correlated stimuli (red key, no clicking sound). Downward displacement of a line marks return to the imposed, VT 30-sec shock condition (white key, clicking sound). A "/" marks a shock; an "O" marks a response.

termined by inspecting figures showing per cent time in the alternate condition for each session. The performance was considered stable if the trend in per cent time was not increasing or decreasing for five sessions. First, a single shock was introduced 105 sec after the onset of the alternate condition (Figure 1, frame 3). After performance stabilized, a second shock was delivered 1 sec after the first shock. Additional shocks were added in a similar manner until pecking stopped. The delay from a response to the first shock was always 105 sec. Figure 1 depicts two intermediate phases during this procedure. When four delayed shocks were delivered in the alternate condition, overall shock frequency was the same in the imposed condition and alternate conditions (Figure 1, frame 4). When eight delayed shocks were delivered in the alternate condition, overall shock frequency was 100% greater in the alternate condition (Figure 1, frame 5).

After performance declined with increased shocks, responding was reestablishd with either a four-shock delayed condition (Subject G-3) or a six-shock delayed condition (Subject G-2), and a control procedure was introduced (Figure 1, frame 6).

Control. In the control procedure, shocks were delivered on the same VT 30-sec schedule in both the imposed and alternate conditions. A response turned the key from white to red and terminated the clicker, but did not affect the shock schedule. Delay and control procedures were alternated.

Results

Figure 2 shows per cent of the session spent in the alternate condition for each of the three subjects. Under the no-shock procedure, all

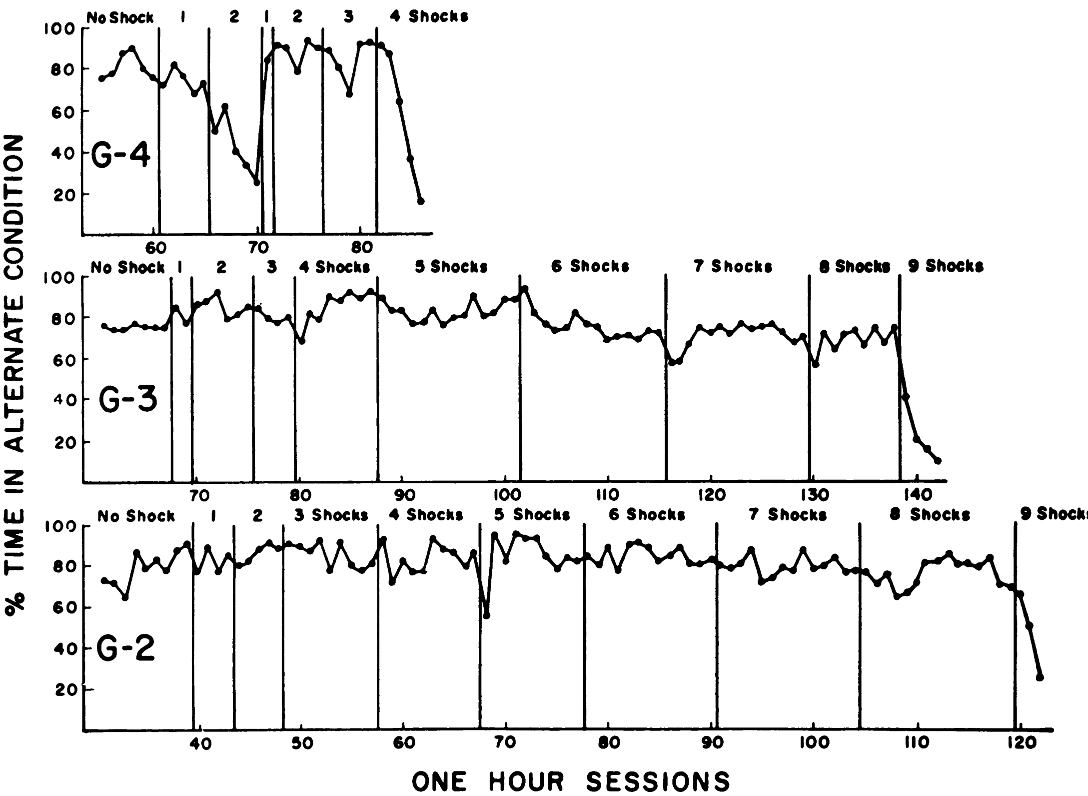

Fig. 2. Per cent of session spent in the alternate condition for Subjects G-2, G-3, and G-4 under no shock, one delayed shock, and two through nine delayed shocks.

three subjects spent approximately 80% of the session in the alternate condition. When a single delayed shock was introduced, G-2 and G-3 continued to allocate 80 to 90% of the session to the alternate condition; G-4's level dropped to approximately 70%. With two delayed shocks, G-2 and G-3 continued responding at steady rates, but G-4's responding deteriorated. When G-4 was returned to one shock, the response recovered, and performance was maintained when a second delayed shock was again introduced. When a third delayed shock was added, all three subjects continued to allocate about 80% of the session to the alternate condition. With the addition of a fourth shock, the performance of G-4 again deteriorated, whereas G-2 and G-3 continued to allocate about 70% of the session to the alternate condition. Subjects G-2 and G-3 continued to perform with up to eight delayed shocks, despite the 100% increase in shock frequency.

Table 1

Mean responses per minute in the imposed condition for the last three days of exposure to each delayed shock treatment in Experiment I. The corresponding figure for the response rate in the alternate condition is shown in parentheses.

	Treatments								
Subject	*No Shock*	*1 Shock*	*2 Shocks*	*3 Shocks*	*4 Shocks*	*5 Shocks*	*6 Shocks*	*7 Shocks*	*8 Shocks*
G-2	3.17 (0.24)	2.99 (0.26)	4.89 (0.31)	2.07 (0.17)	2.75 (0.22)	2.21 (0.17)	2.55 (0.12)	1.93 (0.26)	1.58 (0.17)
G-3	1.62 (0.08)	*2.28 (0.05)	2.36 (0.16)	1.85 (0.04)	3.76 (0.02)	3.20 (0.00)	1.19 (0.05)	1.05 (0.00)	1.24 (0.00)

*Mean for last two days.

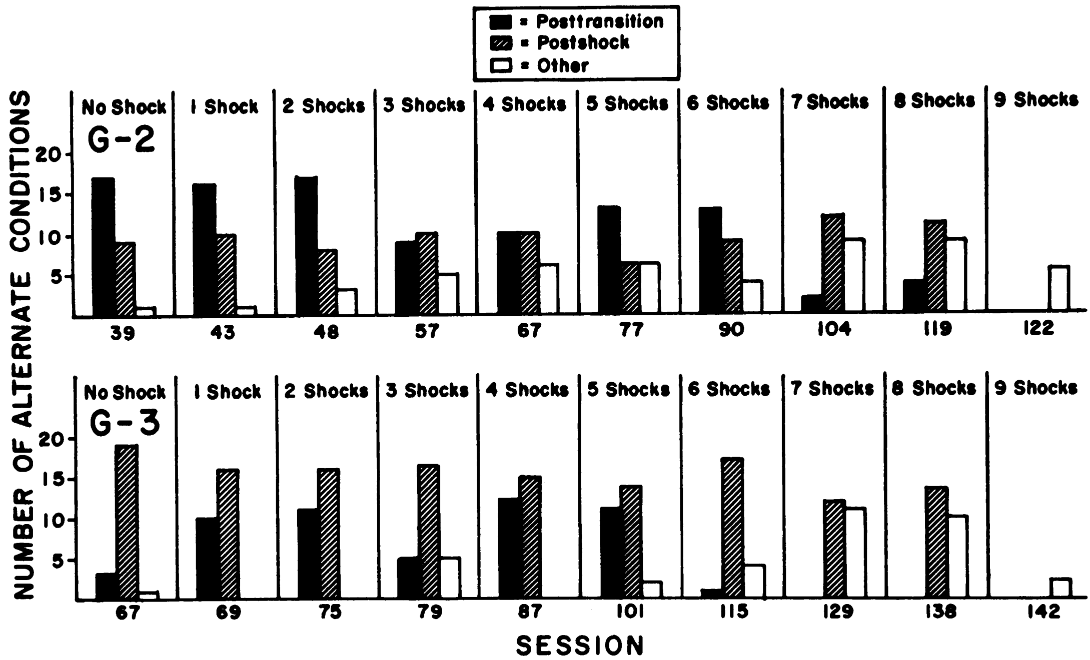

Fig. 3. Number of alternate conditions produced by posttransition (solid bar), postshock (crosshatched bar), and other (open bar) responses on the last day of exposure to each procedure for Subjects G-2 (upper graph) and G-3 (lower graph). Procedures appear in the order administered.

Table 1 shows the mean response rate for the last three days in the imposed (and alternate) condition for Subjects G-2 and G-3. As shocks were added to the alternate condition, response rate in the imposed condition tended to decrease. Subjects rarely responded in the alternate condition.

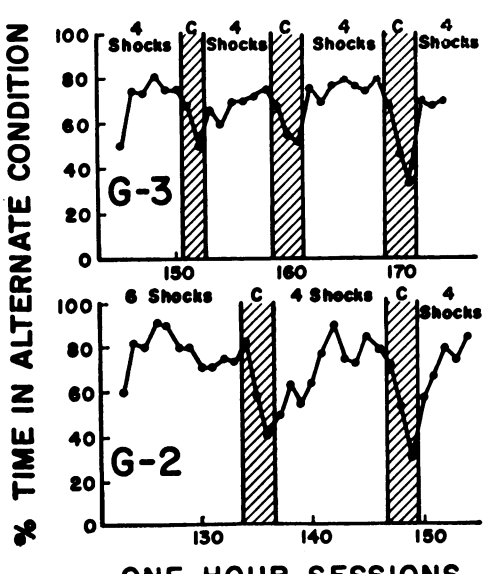

Fig. 4. Per cent of session spent in the alternate condition for Subjects G-2 and G-3 under six delayed shocks, four delayed shocks, and control.

Figure 3 shows the frequency of different types of responses, in the imposed condition, effective in producing the alternate condition. These data were taken from cumulative records of the last session under each procedure. A response was classified as posttransition if no shock had occurred since the previous alternate condition. If, after the previous alternate condition, a single shock had occurred, the response was considered a postshock response. Responses preceded by more than one shock were termed "other" responses. Postshock responses predominated during the first six conditions for G-3; posttransition responses predominated during the first six conditions for G-2. In the seven- and eight-shock delay procedures, both G-2 and G-3 showed predominately postshock responses, and under the nine-shock delay procedure, G-2 and G-3 showed predominately "other" responses.

Figure 4 shows the per cent of the session spent in the alternate condition under delayed shock and control procedures for G-2 and G-3. In the control procedure, the per cent of the session allocated to the alternate condition decreased; in the delayed shock pro-

Table 2

Mean responses per minute in the imposed condition for the last three days of exposure to the delayed shock and control treatments in Experiment I. The corresponding figure for the response rate in the alternate condition is shown in parentheses.

	Treatments								
Subjects	*6 Shocks*	*Control*	*4 Shocks*	*Control*	*4 Shocks*	*Control*	*4 Shocks*	*Control*	*4 Shocks*
G-2	1.33 (0.13)	1.01 (0.36)	1.82 (0.06)	0.62 (0.13)	3.41 (0.11)	—	—	—	—
G-3	—	—	1.76 (0.03)	*0.81 (0.72)	1.44 (0.01)	0.71 (0.08)	1.72 (0.03)	0.54 (0.13)	0.88 (0.02)

*Mean for last two days.

cedure, the per cent increased. Subjects were exposed to the control procedure until performance declined, but not until pecking stopped. If pecking had stopped, subjects would not have made contact with the reinforcer when the procedure was changed.

Table 2 shows the mean response rate for the last three days in the imposed (and alternate) condition under the delay shock and control procedures. For both subjects, the response rate in the imposed condition was higher during the shock delay than during the control procedures. The response rate in the alternate condition was low.

Discussion

These results indicate that delay-to-shock-onset is sufficient to reinforce key pecking. Two of three subjects pecked when it led to a 105-sec delay to shock and to decreased, unchanged, or increased shock frequency.

Gardner and Lewis (1976) reported that posttransition and postshock bar-press patterns predominated, for different rats, under long delay-to-shock procedures. The patterns of pecking maintained by shock delay in the present experiment were similar to the patterns of lever pressing maintained by shock delay, and, as with rats, individual pigeons showed predominately one response pattern.

EXPERIMENT II: SHOCK-FREQUENCY REDUCTION WITH NO CHANGE IN POSTRESPONSE DELAY

Method

Subjects

Of the three White Carneaux pigeons used, G-3 was continued from the previous experiment, G-5 had an extensive history of key pecking on a concurrent, negative-reinforcement schedule, and G-1 was naive. Except for the initial training for G-1, all were given free access to food and water in the home cages.

Apparatus

Same as for Experiment I.

Procedure

Pigeon G-1 was trained to peck by the reinforcement-switching procedure outlined in Experiment I. Shock intensities were 110 V, 120 V, and 80 V for G-1, G-3, and G-5, respectively. All subjects were tested 2 hr daily. In the absence of responding, the key was white, the clicker on, and shock was delivered according to a VT 15-sec schedule (imposed condition). The shortest intershock interval on the VT 15-sec schedule was 5-sec, onset to onset. After 1 sec in the imposed condition (FI 1-sec), a peck initiated a 2-min alternate condition, during which the key was red and the clicker was silent. At the end of the 2-min alternate condition, the imposed condition was automatically reinstated.

In the EXP 0 procedure, no shock was delivered in the alternate condition; in the EXP 1, EXP 2, EXP 3, and EXP 4 procedures, the first, the first two, the first three, or the first four shocks from the imposed-condition VT 15-sec schedule were delivered in the alternate condition, respectively. This resulted, respectively, in an average of 100, 87.5, 75.0, 62.5, and 50% reduction in shock frequency.

The order of procedures was EXP 0, EXP 1, EXP 2, EXP 3, and EXP 4, or until responding stopped; for Subjects G-1 and G-3, the sequence was repeated.

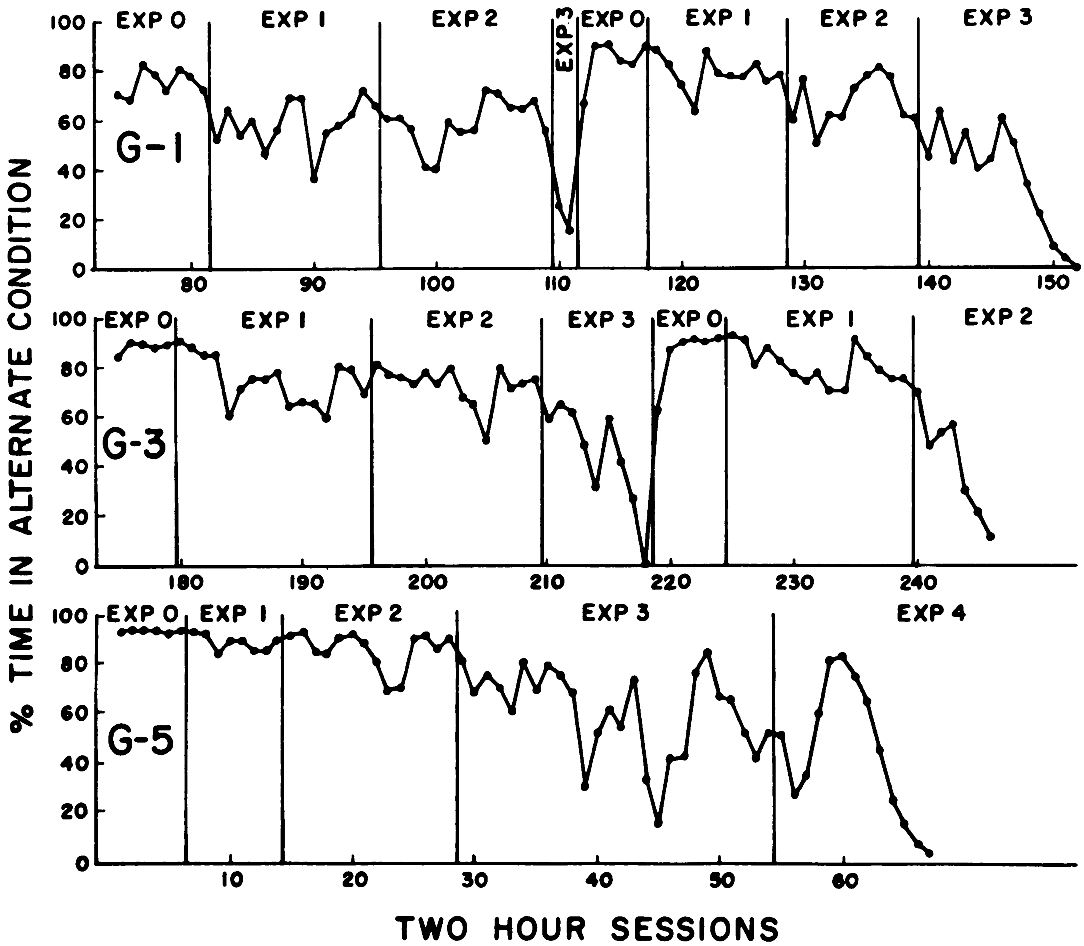

Fig. 5. Per cent of session spent in the alternate condition for Subjects G-1, G-3, and G-5 under EXP 0, EXP 1, EXP 2, EXP 3, and EXP 4.

Results

Figure 5 shows the per cent of the session spent in the alternate condition for all three subjects (G-1, G-3, and G-5) under all experimental procedures. In the initial exposure to EXP 0, EXP 1, and EXP 2 each of the three subjects averaged over 70% of the session in

Table 3

Mean responses per minute in the imposed condition for the last three days of exposure and re-exposure to each treatment in Experiment II. The corresponding figure for the response rate in the alternate condition is shown in parentheses.

	Treatments							
Subjects	*EXP 0*	*EXP 1*	*EXP 2*	*EXP 3*	*EXP 0*	*EXP 1*	*EXP 2*	*EXP 3*
G-1	1.87 (0.00)	1.05 (0.00)	0.91 (0.00)	*0.05 (0.00)	3.23 (0.00)	1.90 (0.00)	1.11 (0.00)	0.02 (0.00)
G-3	4.19 (0.05)	1.76 (0.04)	1.45 (0.02)	0.19 (0.00)	5.31 (0.03)	1.72 (0.09)	0.27 (0.04)	—
G-5	6.97 (0.31)	3.48 (0.25)	3.46 (0.09)	0.50 (0.05)	*Exp 4* 0.03 (0.00)	—	—	—

*Mean for last two days

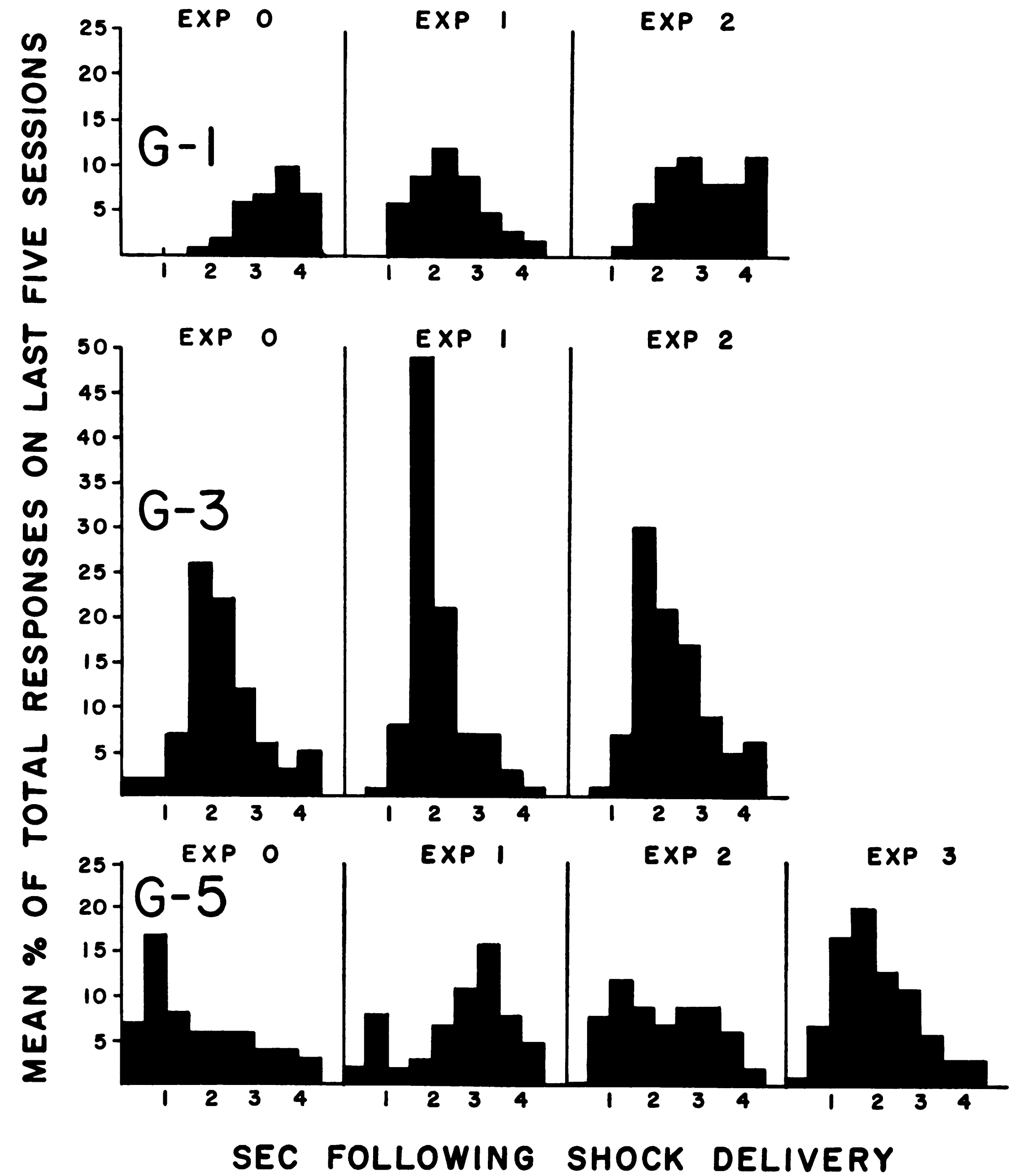

Fig. 6. Postshock responding is shown. Mean per cent of total responses occurring within 4.5 sec after shock in the imposed condition are shown. Data are from the last five sessions of the initial exposure to EXP 0, EXP 1, and EXP 2 for G-1 and G-3, and EXP 0, EXP 1, EXP 2, and EXP 3 for G-5.

the alternate condition. In the initial exposure to EXP 3, G-1 and G-3 showed orderly decreases in the per cent time allocated to the alternate condition. Subject G-5 continued to respond at variable levels for 54 hr in the initial exposure to EXP 3. When re-exposed to EXP 0 and EXP 1, G-1 and G-3 showed maintained performance, spending over 50% of the session in the reduced frequency, alternate condition. On re-exposure to EXP 2, G-1 continued to allocate an average of 66% of the session to the alternate condition, while G-3's performance deteriorated.

Table 3 shows the mean response rate for the last three days in the imposed (and alternate) condition for each subject. The response rate in the imposed condition shows an orderly relationship with the number of shocks delivered in the alternate condition: the more shocks, the lower the response rate. As in Experiment I, the alternate-condition response rate was low for each subject under every procedure.

The distribution of postshock responding is shown in Figure 6. The mean per cent of total pecks in the 4.5 sec following the onset of shock is shown. Data are for the imposed condition during the last five sessions of the initial exposure to each experimental procedure (EXP 0, EXP 1, EXP 2, and EXP 3) for all three subjects (G-1, G-3, and G-5). The percentage of responses increased during the first few seconds after shock, then decreased.

Discussion

The primary finding of Experiment II is that key pecking can be maintained by a reduction in the number of shocks in the absence of any change in delay to the first (or first two) postresponse shocks. Three subjects key pecked for a combined total of 128 hr in the EXP 1 procedure when responding did not affect delivery of the first postresponse shock, but did reduce the shock frequency by 87.5%. Under EXP 2, responding was maintained in four of five exposures when pecking did not affect delivery of the first two postresponse shocks but reduced the frequency of shock by 75%. The distribution of postshock key-peck responses was an inverted U-shaped function that differs from the monotonically decreasing distribution of the rats' postshock bar-press response (Church, Wooten, and Matthews, 1970; Sidman, 1958) and the monkeys' postshock lever-press and tube-biting responses (Hake and Campbell, 1972).

EXPERIMENT III: RESPONSE–DEPENDENT SHOCK WITH SHOCK-FREQUENCY REDUCTION

Method

Subjects

Of the four White Carneaux pigeons used, G-1, G-3, and G-5 were continued from the previous experiment. Subject G-6 had an extensive history of key pecking on negatively-reinforced chain schedules. All subjects had free access to food and water in the home cages.

Apparatus

Same as for Experiment I.

Procedure

All subjects were tested 1 hr daily. The shock intensity for G-6 was set at 70 V. In the absence of responding, subjects were shocked according to a VT 15-sec schedule in the presence of a white key and clicking sound. The shortest intershock interval on the VT 15-sec schedule was 5-sec, measured from onset to onset. The VT 15-sec shock schedule with associated white key and clicking sound is called the imposed condition. After 1 sec in the imposed condition (FI 1-sec), a key peck initiated a 2-min alternate condition, during which the key was red and the clicker was silent. At the end of the alternate condition, the imposed condition was reinstated.

In the no-shock procedure, the alternate condition was 2 min of shock-free time.

In the dependent procedure, a key peck producing the alternate condition also produced an immediate shock. The remainder of the 2-min alternate condition was shock free.

In the control procedure, the same VT 15-sec shock schedule was in effect during both the imposed and alternate conditions. In addition, a response activating the alternate condition produced a single immediate shock.

The order of procedures was no shock, dependent, control, and dependent for all subjects except G-3. Subject G-3 received no shock, dependent, no shock, and dependent.

Results

Figure 7 shows the per cent of the session allocated to the alternate condition for each subject. Under the initial exposure to the no-shock procedure, each subject allocated more than 80% of the session to the alternate condition; under the initial exposure to the dependent procedure, G-1, G-5, and G-6 continued to produce the alternate condition. In the control procedure, the per cent of time allocated to the alternate condition decreased. Subject G-3, the exception, showed gradual decreases in the per cent of time spent in the alternate

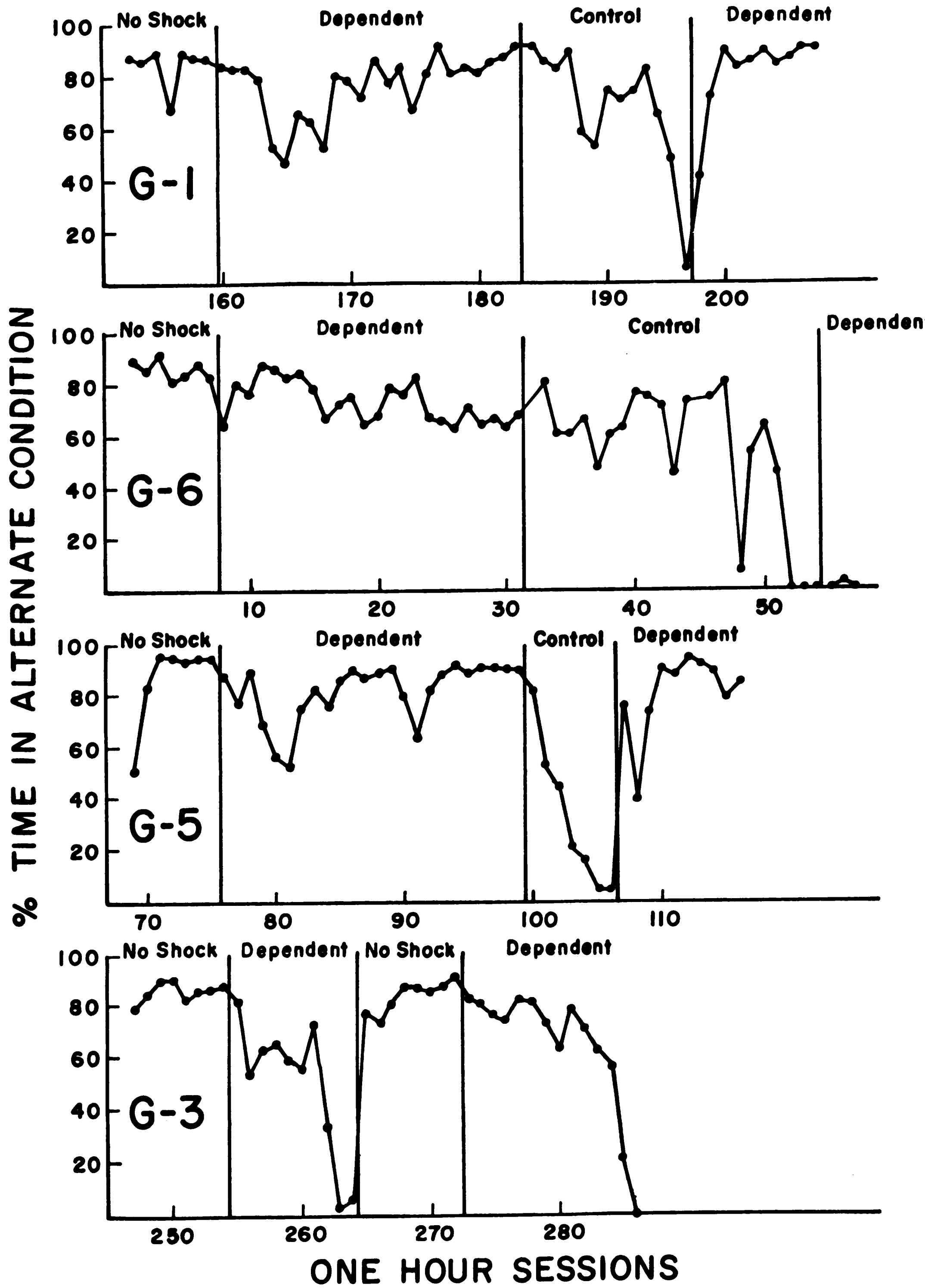

Fig. 7. Per cent of session time spent in the alternate condition for Subjects G-1, G-5, and G-6 under no-shock, dependent, control, and dependent procedures. Subject G-3 received no-shock, dependent, no-shock, and dependent procedures.

Table 4

Mean responses per minute in the imposed condition for the last three days of exposure to each treatment in Experiment III. The corresponding figure for the response rate in the alternate condition is shown in parentheses.

Subjects	*Treatments* No Shock	Dependent	Control	Dependent
G-1	5.51 (0.04)	3.99 (0.00)	0.50 (0.05)	4.20 (0.03)
G-6	3.19 (0.00)	1.05 (0.13)	0.00 (0.00)	0.17 (0.00)
G-5	8.00 (0.00)	4.98 (0.02)	0.10 (0.02)	3.14 (0.04)
			No Shock	
G-3	3.63 (0.06)	0.11 (0.00)	4.42 (0.04)	0.28 (0.01)

condition on both exposures to the dependent procedure. The performance of G-1 and G-5 was replicated, but G-6 stopped responding and did not make contact with the alternate condition in the second dependent procedure.

Table 4 shows the mean response rate for the last three days in the imposed (and alternate) condition for each subject. Subjects G-1, G-5, and G-6 responded at the highest rate under the no-shock procedure, at the lowest rate under the control procedure, and at an intermediate rate on the first exposure under the dependent procedure. As in the first two experiments, the response rate in the alternate condition was low.

GENERAL DISCUSSION

Either increased delay to shock or shock-frequency reduction was sufficient to reinforce a contraprepared, key-pecking response, but neither was necessary. In Experiment I, key-pecking was maintained by shock delay despite increased shock frequency. In Experiment II, key pecking was maintained by shock-frequency reduction despite no change in delay, and in Experiment III despite reduced delay.

A similar conclusion was suggested by Lewis, Gardner, and Hutton (1976). In that report, both the first postresponse shock and overall shock frequency were held constant in a bar-pressing experiment with rats. Shocks were presented at the rate of two per minute whether or not the rat pressed the bar. Each bar press produced a change in illumination for 3 min, during which the distribution of shocks was controlled so that the first shock occurred at the same time as it would have had the bar not been pressed. Other shocks were delivered near the end of the 3-min period. Strong responding was observed, despite no increase in delay to the first postresponse shock and no decrease in shock frequency.

The results of Experiment II are inconsistent with two-factor theories of avoidance (Anger, 1963; Rescorla and Solomon, 1967; Schoenfeld, 1950). For example, Anger's (1963) Conditioned Aversive Temporal Stimuli (CATS) theory postulates that time stimuli acquire aversiveness through pairing with shock, with the degree of aversiveness depending on their proximity to shock—time stimuli just preceding shock are more aversive than time stimuli distant from shock. When a response replaces highly-aversive time stimuli (preresponse time stimuli) with less-aversive time stimuli (postresponse time stimuli), the response is reinforced. In Experiment II, a response did not affect delivery of the first postresponse shock. Accordingly, preresponse and postresponse time stimuli were paired with the same shock. CATS theory predicts no reduction in the aversiveness of time stimuli following a response, yet key pecking was maintained.

In the dependent procedure of Experiment III, and in Lambert *et al.*'s (1973) no-escape procedure, CATS theory predicts postresponse time stimuli to be more aversive than preresponse time stimuli, because of the proximity to the immediate shock. Yet, both the Lambert *et al.* (1973) prepared, shuttle response and the present contraprepared, key-peck response were negatively reinforced in a dependent shock procedure.

Early two-factor theorists (Sidman, 1953; Schoenfeld, 1950) noted that most avoidance procedures punish all behavior, except the avoidance response. In Sidman avoidance, for example, all behaviors are paired with shock, except the avoidance response. Hence, all other behaviors were said to take on the aversive properties of shock through Pavlovian conditioning, and the avoidance response emerged as the only nonaversive behavior. While both Sidman (1962) and Schoenfeld (1960) rejected this explanation, Bolles (1973) argued again that avoidance conditioning is a byproduct of punishment. Bolles (1973) said: "in all common avoidance-learning situations there is no need to invoke the principle of reinforcement except perhaps in the Skinner box, which gives us, ironically, the poorest learning. Most avoidance learning seems to occur because other behavior is punished" (p. 301). In Experiment III, and in the Lambert *et al.* (1973) experiments, behavior was acquired and maintained, respectively, despite the fact that the response produced a shock. These experiments are inconsistent with the notion that avoidance behavior is a byproduct of punishment.

One view of avoidance behavior proposes that responding is reinforced by reductions in the total number of received shocks (Sidman, 1962). Experiment I indicated that, given sufficient delay, shock-frequency reduction is not necessary for negatively reinforcing avoidance behavior (also see Gardner and Lewis, 1976). An adequate analysis of avoidance must take into account both the number of shocks (shock frequency) and the distribution of shocks (shock delay).

In the three experiments reported here, subjects showed a strong tendency to respond immediately following a shock. This is commonly referred to as postshock responding. Several interpretations have been suggested to explain the postshock response phenomenon: shock-elicited aggression, superstitious escape, and discriminative control. Several researchers (Azrin, Hutchinson, and Hake, 1967; Gardner and Lewis, 1976; Hake and Campbell, 1972; Hutchinson, Renfrew, and Young, 1971; Pear, Moody, and Persinger, 1972; and Powell, 1972) have noted that shock often elicits aggression and that postshock avoidance responses may be aggressive attacks. However, although pigeons show aggression under some circumstances (Azrin, Hutchinson, and Hake, 1966; Flory, 1969; and Gentry, 1968) they apparently do not show shock-elicited aggression (Rashotte, Dove, and Looney, 1974). It seems unlikely, therefore, that postshock responding in the present experiments represented aggressive behavior.

Another interpretation of postshock responding focuses on the relationship between a response and the termination of shock. According to this view (Domjan, 1969; Domjan and Rowell, 1969), postshock responding is superstitious escape accidentally reinforced by the offset of shock. This interpretation predicts the probability of a response to be greatest during and immediately following shock, and subsequently to decrease as time elapses. The data reported in Experiments II and III are inconsistent with this interpretation, because the probability of a postshock response increased for several seconds following shock. In addition, Smith, Gustavson, and Gregor (1972) noted that the pigeon's reflexive response to shock, a vertical movement of the head, is incompatible with the key-peck response, which is a horizonal movement toward the key. Hence, the pigeon's reaction to shock may account for the low probability of responding in the first several 0.5-sec periods following shock. Because the reaction to shock is incompatible with the pigeon's peck response, it is highly unlikely that postshock key pecking is fortuitously reinforced by shock offset.

A more likely explanation of postshock key pecking is one based on the shock's discriminative function. Several researchers (Bersh and Lambert, 1975; Sidman, 1966) have noted that shock alone or in compound with other stimuli may serve as a discriminative stimulus and set the occasion for a reinforced response. In the present experiments, shock in the presence of a white key and clicking sound may have served as a compound discriminative stimulus, setting the occasion for a reinforced peck.

Theorists (Bolles, 1970; Seligman, 1970), who emphasize the biological constraints on learning, focus on the acquisition of behavior. The evidence for constraints on acquisition is convincing (see Bolles, 1970; Seligman and Hager, 1972; Shettleworth, 1972). The present experiments, however, examined the maintenance of a previously learned peck response. The present data indicate that the conditions necessary for the maintenance of a contraprepared, key-peck response are similar to the conditions necessary for the maintenance of an unprepared, bar-press response (Gardner and Lewis, 1976; Hineline, 1970; Lambert *et al.*, 1973; Lewis *et al.*, 1976). Accordingly, the present experiments are consistent with the view that certain general laws of behavior are similar for the maintenance of prepared, unprepared, and contraprepared responses.

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