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NEGATIVELY REINFORCED KEY PECKING[1]

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A reinforcement-switching procedure was used to produce negatively reinforced key pecking in pigeons. First, key pecking on a chain schedule (fixed-interval 10-sec variable-interval 60-sec) was conditioned using grain reinforcement. Second, intermittent shock in the initial link was introduced at a low intensity and gradually increased. Third, food reinforcement in the terminal link was eliminated. With shock at 90 V occurring on the average every 3 sec, initial-link pecking was maintained with no terminal-link food. Three of four pigeons responded consistently at shock intensities of 90, 70, and 50 V but not at 30 V. A fourth pigeon responded at but not below 90 V. Rate of response was directly related to shock frequency. Eliminating food deprivation did not affect the negatively reinforced performance.

Key pecking in pigeons can be conditioned using negative reinforcement, but only with considerable difficulty. Hoffman and Fleshler (1959) found it impossible to shape key pecking using the method of successive approximation. When the required response was changed to head lifting, some avoidance responding was observed, although several thousand trials were required. Smith and Keller (1970) mentioned briefly an attempt to train pigeons to avoid shock by key pecking that failed completely. These authors did describe a procedure that successfully conditioned treadle pressing in pigeons.

Hineline and Rachlin (1969) and Rachlin and Hineline (1967) reported greater success. These authors conditioned and maintained stable key pecking by removing a series of shock pulses that slowly increased in intensity. Two shock pulses per second were delivered. Each response reset the shock intensity to zero for 5 sec. Although the procedure produced negatively reinforced pecking in five of seven birds, four of the five required several hours of shaping. The rationale for the gradually increasing shock intensity was that pigeons, in some cases, seem to adapt to shock.

Ferrari, Todorov, and Graeff (1973) also shaped key pecking with negative reinforcement. Subjects placed in a chamber illuminated only by a red keylight received 35-msec shocks at 0.5-sec intervals. A movement away from the key resulted in an increase in shock intensity, and a movement towards the key decreased shock intensity. Shaping time to the *first* key peck varied from 0.5 to 5.5 hr. After conditioning, key pecking was maintained on free-operant avoidance schedules.

A technique that would ensure conditioning in 100% of the subjects and that would not require tedious manual shaping procedures would be desirable. Rachlin (1969) attempted to use an "autoshaping" procedure to condition negatively reinforced key pecking automatically. A standard experimental chamber, with a hemispherical extension attached to the key, was employed so that wing-flap responses as well as key pecks could be recorded. The basic procedure involved shocking naive pigeons once per second at progressively increasing intensities from 0 to 6 mA. Visual stimuli were paired with the elimination of the shock. A key response immediately eliminated the shock pulses and their associated stimulus. The procedures employed in two of Rachlin's six experiments were partially successful in conditioning pecking behavior. In one experiment, four of six birds learned to peck, in another three of five. The other birds learned to escape, but with a wing-flapping response.

The present report describes a procedure, referred to as reinforcement switching, that reliably produces negatively reinforced key pecking. The procedure consists of condition-

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ing pecking with positive reinforcement, adding negative reinforcement to the situation, then eliminating the positive reinforcement.

METHOD

Subjects

Four naive White Carneaux pigeons, from the Palmetto Pigeon farm, Sumter, North Carolina, were maintained at 80% of their free-feeding body weights except where noted.

Apparatus

A standard conditioning chamber (BRS-LVE) with translucent keys illuminated by a white or red 24-V bulb was housed in a sound attenuating box. Two pigeon keys (only the left one was used in this experiment) were centered 25 cm from the floor and 20.3 cm apart. A response of 0.44 N closed a microswitch. The food reinforcer, with houselights out, consisted of 4-sec access to mixed grain. Solid-state scheduling and recording equipment was located in an adjacent room. A variable ac transformer in series with a 10 K-ohm resistor could deliver 0- to 120-V shocks. Shock was carried to stainless steel electrodes implanted around the pigeon's pubis bone (Azrin, 1959) via a mercury commutator (Gerbrands, Inc.) mounted in the ceiling of the

Table 1

Sequence of Conditions Used to Switch from Positive to Negative Reinforcement Schedule

Bird Number	*Number of Sessions*	*Initial-Link FI Schedule (sec)*	*Terminal-Link VI Food Schedule (sec)*	*Initial-Link VT Shock Schedule (sec)*	*Shock Intensity (volts)*
B-30	1	1	15		
	1	1	30		
	1	1	45		
	1	1	60		
	1	5	60		
	4	10	60		
	2	10	60	3	10
	2	10	60	3	20
	1	10	60	3	30
	1	10	60	3	40
	2	10	60	3	50
	1	10	60	3	60
	3	10	60	3	70
	1	10	60	3	80
	3	10	60	3	90
	3	10	240	3	90
	2	10	600	3	90
	Total = 30		No Food		
B-40	2	1	15		
	1	1	30		
	1	1	45		
	1	1	60		
	5	5	60		
	9	10	60		
	1	10	60	3	10
	1	10	60	3	20
	1	10	60	3	30
	1	10	60	3	40
	2	10	60	3	50
	1	10	60	3	60
	1	10	60	3	70
	1	10	60	3	80
	2	10	60	3	90
	8	10	240	3	90
	1	10	600	3	90
	Total = 39		No Food		

Table 1 *continued*

Bird Number	*Number of Sessions*	*Initial-Link FI Schedule (sec)*	*Terminal-Link VI Food Schedule (sec)*	*Initial-Link VT Shock Schedule (sec)*	*Shock Intensity (volts)*
B-50	4	1	15		
	1	1	30		
	1	1	45		
	2	1	60		
	3	5	60		
	11	10	60		
	1	10	60	3	10
	1	10	60	3	20
	1	10	60	3	30
	1	10	60	3	40
	3	10	60	3	50
	1	10	60	3	60
	1	10	60	3	70
	1	10	60	3	80
	6	10	60	3	90
	2	10	240	3	90
	Total = 40		No Food		
B-60	2	1	15		
	1	1	30		
	1	1	45		
	1	1	60		
	2	5	60		
	15	10	60		
	1	10	60	3	10
	1	10	60	3	20
	1	10	60	3	30
	2	10	60	3	40
	1	10	60	3	50
	1	10	60	3	60
	1	10	60	3	70
	2	10	60	3	90
	2	10	240	3	90
	2	10	600	3	90
	Total = 36		No Food		

chamber. White masking noise (80 dB) was present throughout each session.

Procedure

Pigeons were shaped to peck a key illuminated white or red. A two-component chain schedule was introduced gradually. After 1 sec in the presence of a white key a single peck (fixed-interval 1-sec) changed the key to red for 3 min. While the key was red, pecking produced grain at variable intervals averaging 15 sec (VI 15-sec). If responding was well maintained, either the length of the initial-link fixed-interval schedule (FI) or the size of the VI schedule, or both were increased. After pecking was consistently maintained on chain FI 10-sec VI 60-sec, brief shocks 0.3-sec duration and 10-V intensity were delivered during the initial link only. Shocks occurred after varying time intervals averaging 3 sec (VT 3-sec). As long as responding was not disrupted by the shock the intensity was increased in the next session. After shock intensity reached 90 V, food reinforcement was gradually eliminated. This was accomplished by changing the food schedule in the terminal link to VI 2-min, VI 4-min, and VI 10-min; after VI 10-min all food was eliminated. After food was eliminated, the schedule was more properly described as FI escape with an FI stimulus and a stimulus for the period of negative reinforcement. On this schedule, the first response after 10 sec in the presence of a white key changed the key to red for 3 min. Intermittent shock at

90 V occurred on a VT 3-sec schedule only in white. Responding was maintained on the negative reinforcement schedule alone for 11 to 14 sessions after food was removed. The resulting negative reinforcement schedule is similar to schedules of escape from conditioned aversive stimuli studied by Azrin, Holz, and Hake (1962) and Dinsmoor (1962). The sequence of conditions and number of sessions of each are shown in Table 1.

All VI and VT schedules were determined by Fleshler and Hoffman (1962) tables. Sessions, conducted at the same time daily, ended after 18 terminal links.

Shock intensity. After responding was maintained by the negative reinforcement contingency, the effect of shock intensity was investigated. Shock intensity was decreased in 20-V steps after every five to six sessions until pecking was no longer maintained.

Shock frequency. Shock intensity was returned to 70 V (Birds 40 and 50) or 90 V (Birds 30 and 60) to recover the escape performance. Next, the VT shock schedule was increased every five or six sessions. Mean VT schedules of 3, 4, 8, 12, 16, 24, 32, and 56 sec were employed. After the VT 56-sec schedule, the initial-link shock schedule was changed to VT 3-sec with a shock intensity of 90 V.

Free feeding. Responding was maintained on the 90-V, VT 3-sec schedule for 13 to 17 sessions. After three to seven sessions, increased home-cage feeding was introduced to determine whether food deprivation influenced negatively reinforced pecking. All subjects were given 40 g per day for three days and then placed on free feeding.

Noncontingent-negative reinforcement. Birds 30 and 40 were studied further to determine if pecking was due to the response-contingent entry into the negative reinforcement period or simply the result of shock delivery. First, pecking was recovered on the FI 10-sec escape schedule with the 3-min stimulus correlated with the negative reinforcement period. Shock occurred at 90 V on a VT 3-sec schedule. On this schedule, entry into the negative reinforcement period was contingent upon the first response after 10 sec. Next, a noncontingent condition was introduced such that entry into the negative reinforcement period occurred automatically after 10 sec, independent of responding.

RESULTS

The reinforcement for key pecking was successfully switched from the presentation of a stimulus associated with food reinforcement to the termination of a stimulus associated with shock. Pecking continued after food was eliminated. Pecking occurred primarily during and just after the initial link. Table 2 shows that rate of responding was variable and that there was a small drop in rate as a result of eliminating terminal-link food presentations.

Figure 1 shows the effect of shock intensity on escape responding. Three of the four pigeons pecked at between five and 25 responses per minute at shock intensities of 90, 70, and 50 V. All three birds stopped pecking when shock intensity was lowered to 30 V. The fourth pigeon (Bird 60) responded at 90 V, but consistently stopped responding at 70 V.

After the shock-intensity data were collected, shock was returned to 70 V for Birds 40 and 50, and to 90 V for Birds 30 and 60. Bird 60 was tested at 90 V, the only intensity at which responding was maintained; Bird 30 was tested at 90 V for comparison purposes.

Table 2

Initial-link key pecks per minute for five sessions before elimination of food from the terminal link and five sessions after elimination of food.

Bird Number	Sessions: Terminal-Link Food 1	2	3	4	5	$\bar{x}$	No Terminal-Link Food 6	7	8	9	10	$\bar{x}$
B-30	11.4	11.7	9.7	11.9	11.9	11.3	10.4	9.2	13.5	7.5	8.8	9.9
B-40	7.7	9.4	2.6	5.8	8.1	6.7	2.9	2.6	4.9	15.0	5.0	6.1
B-50	3.7	6.8	17.0	4.4	1.6	6.7	2.1	1.8	5.0	2.6	4.4	3.2
B-50	3.7	6.8	17.0	4.4	1.6	6.7	2.1	1.8	5.0	2.6	4.4	3.2
B-60	7.9	6.8	10.3	8.2	7.7	8.2	7.0	8.3	8.1	4.3	8.2	7.2

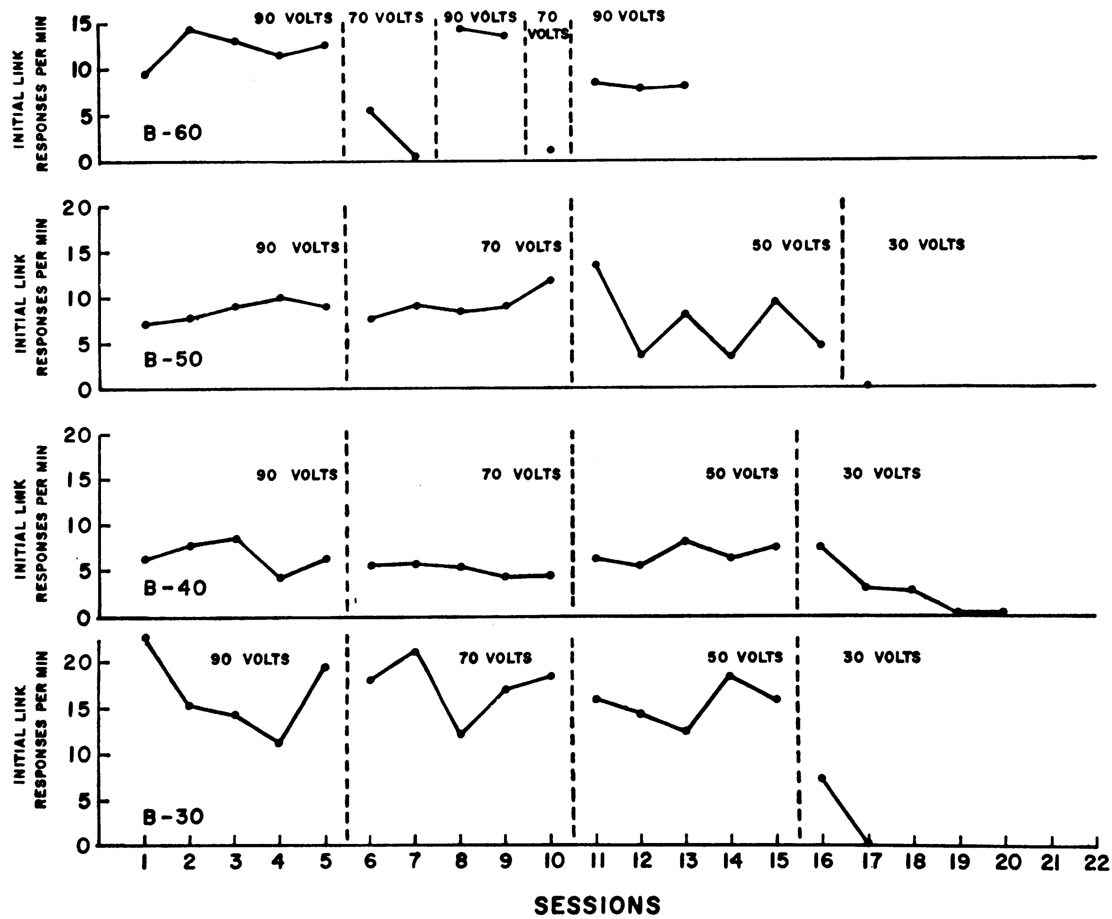

Fig. 1. Escape pecks per minute as a function of shock intensity for each pigeon. Pecks on FI 10-sec escape schedule were reinforced with a 3-min shock-free period. Sessions are numbered from the beginning of the shock-intensity manipulation phase.

Rate of responding in the initial link generally decreased as shock frequency decreased (Figure 2). There were several exceptions to this, however. For example, the highest response rate was on VT 4-sec shock for two birds and on VT 8-sec shock for a third. Initial-link responding was maintained in three of the four birds when shock was presented as infrequently as VT 56-sec. It may be noted that on VT 56-sec and on other intermittent shock schedules, no shocks occurred during many of the FI escape periods. The fourth bird (Bird 30) essentially stopped responding on the VT 56-sec shock schedule. After shock frequency had been reduced to a VT 56-sec schedule, responding was recovered for all subjects on a VT 3-sec 90-V shock schedule.

All subjects were given 10 sessions after increased home cage feeding was begun. Increased feeding and subsequent weight gain had no systematic effect on escape responding. Two birds showed minor decreases in pecking rate and two birds showed slight increases.

Figure 3 shows the effect presenting the 3-min negative-reinforcement period contingent upon responding and noncontingently after 10 sec. Responding was maintained only when the escape period was contingent upon responding. Bird 40 required one or two sessions to reach a zero rate of responding, while Bird 30 required 10 to 14 sessions to reach a low rate of pecking.

DISCUSSION

The reinforcement-switching procedure led to consistent key pecking in pigeons without tedious manual shaping. It seems certain that

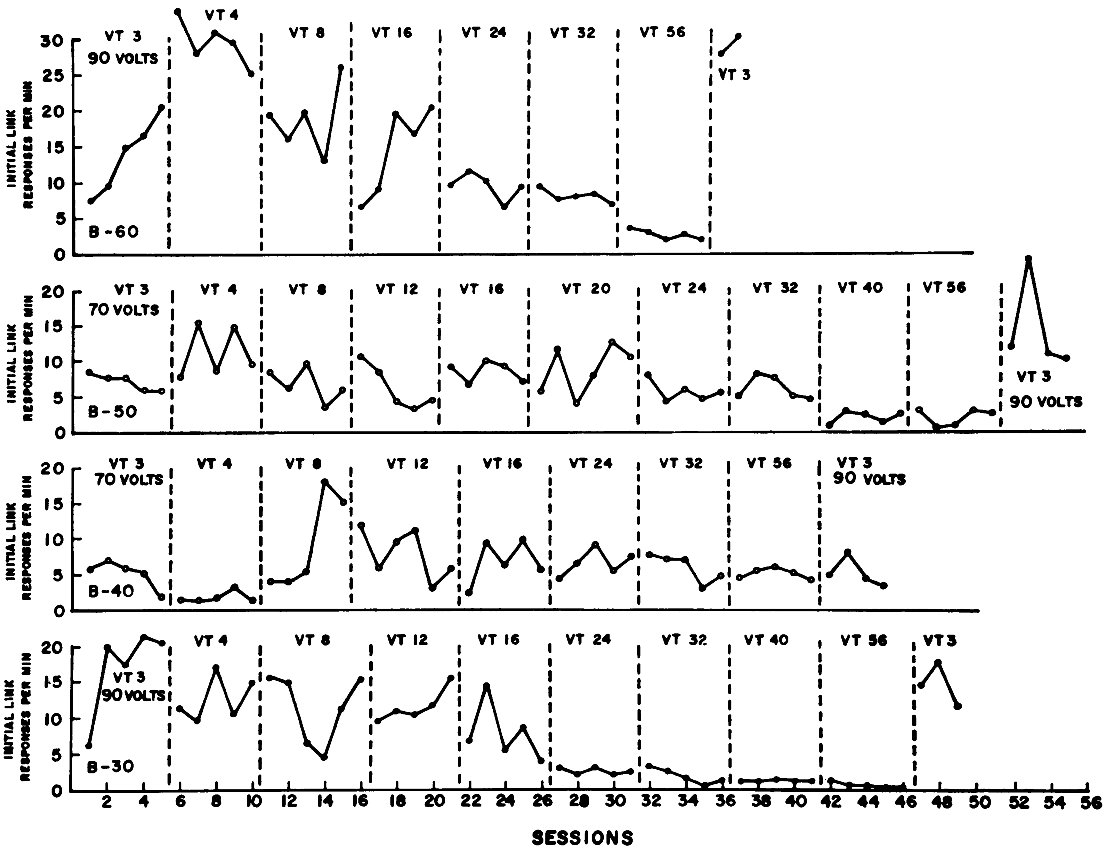

Fig. 2. Escape pecks per minute as a function of VT shock schedule for each pigeon. Pecks on FI 10-sec escape schedule were reinforced with a 3-min shock-free period. Sessions are numbered from the beginning of the shock-frequency manipulation phase. Open circles indicate 70-V schedules and closed circles indicate 90-V shock schedules. Final condition for all subjects was VT 3-sec, 90 V.

the successive experimental conditions employed to obtain the negatively reinforced performance were introduced too slowly. At the time the data were being collected, evidence suggesting the maintenance of pecking was scarce, and conditions were changed cautiously. Future experiments should determine minimum exposure periods to the early phases of the reinforcement-switching procedure.

The present findings support and extend the findings of Ferrari *et al.* (1973). Under appropriate conditions, key pecking in pigeons can be conditioned and maintained using shock as an aversive stimulus. A response need not be part of an organism's species-specific reactions to be controlled by negative reinforcement. Several factors suggested by earlier investigators as critical to controlling negatively reinforced pecking seem unnecessary. Hineline and Rachlin (1969) raised shock intensity on each trial because data from previous researchers (Azrin, 1959; Hoffman and Fleshler, 1959) suggested that pigeons' sensitivity fluctuated. Performance was maintained in the present experiments and in Ferrari *et al.* (1973) for many hours without providing increasing intensity shocks. Ferrari *et al.* (1973) believed it was important to reduce environmental stimuli to a minimum by making the keylight the only source of illumination in the chamber. A standard houselight was on during the present experiments and pecking was well maintained, indicating that specific illumination conditions are not critical, at least, not critical after acquisition of the response. Furthermore, food deprivation probably has little effect on negatively reinforced pecking.

The concept of preparedness, as discussed by Seligman (1970), suggests that organisms are

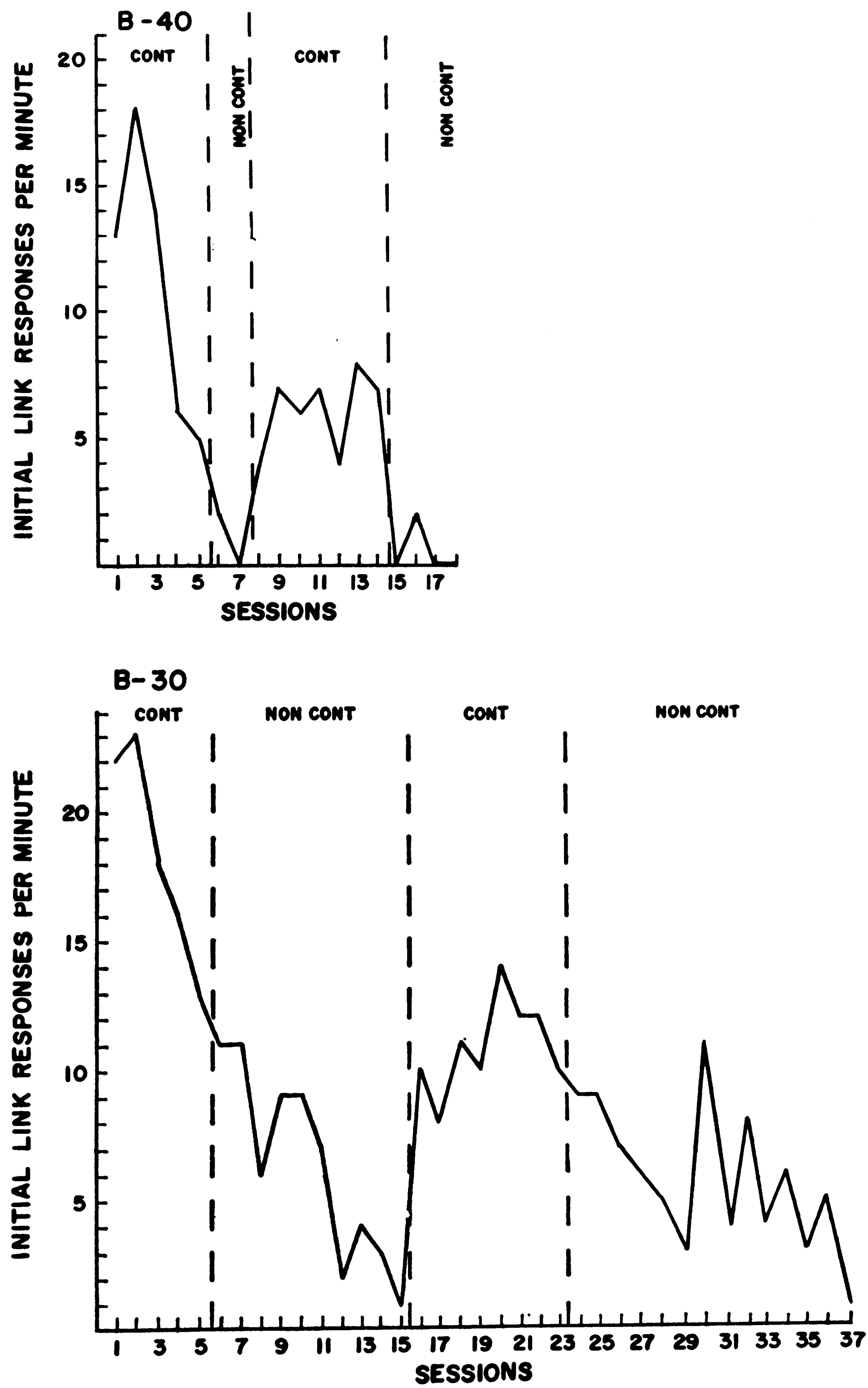

Fig. 3. Escape responding under contingent and noncontingent reinforcement. Panels labelled contingent show pecking on FI 10-sec escape schedule reinforced by 3-min shock-free period. During noncontingent sessions, 3-min shock-free period in red began immediately after 10-sec in white, regardless of responding. Sessions are numbered from the beginning of the contingent-noncontingent phase.

more or less prepared to associate certain responses with a certain consequence. The difficulty typically encountered (Hineline and Rachlin, 1969; Hoffman and Fleshler, 1959) in attempting to shape key-peck avoidance is consistent with Seligman's hypothesis that pigeons are contraprepared to associate pecking with shock avoidance. These present data in no way contradict this hypothesis. Seligman goes on to suggest that the laws of behavior may be different for responses prepared, unprepared, or contraprepared for a given consequence. The evidence with respect to negatively reinforced key pecking, while minimal to date, suggests otherwise. Both Ferrari *et al.* (1973) and the present experiments found negatively reinforced key-pecking performances comparable to previously reported results for other responses and other organisms (Azrin *et al.*, 1962; Dinsmoor, 1962; Sidman, 1953). The reinforcement-switching procedure described in the present report provides a procedure for the study of unprepared and contraprepared responses.

Bolles (1970) argued that a response must be a species-specific-defense-reaction (SSDR) in the avoidance situation to be acquired rapidly as an avoidance response. To allow for those occasions when non SSDRs avoid shocks, Bolles suggested that a safety signal following each response plays a critical role in reinforcing the response. In all of the present experiments, an exteroceptive stimulus followed a successful escape response and this stimulus may have facilitated reinforcement of responding.

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