CONDITIONED SUPPRESSION WITH EXTINCTION AS THE SIGNALLED STIMULUS¹

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The key pecking of pigeons that was maintained by a 60-sec random-interval schedule of food reinforcement was suppressed during a variable-duration warning stimulus that signalled a 5-min extinction period. The onset of the extinction period immediately followed the termination of the warning signal and was independent of the subject's responses. All subjects eventually showed nearly complete suppression of responding during the warning stimulus.

Behavior that is maintained by some schedule of reinforcement usually is suppressed in the presence of a stimulus that has been repeatedly followed by shock presentation (see reviews by Davis, 1968; and Lyon, 1968). Less consistent results, however, have been reported when the stimulus signals a period during which reinforcement is not available (an extinction period).

Two procedures have been used to investigate the effects of signalled extinction: in one, the occurrence of the extinction period is dependent upon a response, in the other, it is independent of responding. Ferster (1958) reported that responding by pigeons and chimpanzees increased during a stimulus that signalled a 10-min period of extinction. In Ferster's procedure, the first response that occurred 30 sec after the appearance of the warning signal produced the period of extinction. Similar response enhancement was obtained by Leitenberg (1966) with this procedure. Kaufman (1969), however, found that responding by rats was suppressed when the extinction period was produced by a response. When the occurrence of the extinction period was independent of responding, Kaufman (1969) found

that responding was neither suppressed or enhanced during the 15-sec warning stimulus. Leitenberg (1966), in contrast to this finding, determined that the responding of pigeons increased during the 30-sec pre-extinction signal used in the response-independent procedure. Response-rate enhancement also has been observed during a stimulus that precedes a response-independent change to schedules of lower reinforcement frequency (Pliskoff, 1961, 1963).

These data suggest that in the response-independent procedure a stimulus signalling impending extinction is an ineffective suppressor of responding. The procedures followed, however, may not have been optimal for obtaining suppression. Davis, McIntire, and Cohen (1969) demonstrated greater suppression of bar pressing when shock was signalled by a variable-duration stimulus than by a fixed-duration warning signal. In the present study, a variable-duration stimulus was used as the signal for extinction to determine whether such a procedure might establish reliable suppression.

METHOD

Subjects

Three experimentally naive homing pigeons, 2 to 3 yr old, were individually housed, with water and grit available at all times in the home cage. Supplemental rations of grain were given within 30 min after each experimental session, if required, to keep the subject between 70 to 80% of its free-feeding weight.

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Apparatus

A standard pigeon test chamber (Lehigh Valley Model 1519C) equipped with a two-key response panel was used. One key remained dark and was not functional. The other key, 1 in. (2.54 cm) in diameter, was transilluminated from behind by a single plane rear-projection readout (Industrial Electronics Engineers Series #10-3043-1829-L) and required a force of at least 15 g (0.147N) to register a response. The stimuli used were two hues (555 nm and 606 nm produced by monochromatic filters) and a white line 0.13 in. (3 mm) by 0.88 in. (22 mm) that was tilted clockwise 45° from the vertical. The line was projected onto the response key with a 555-nm hue surround. A houselight and masking noise were presented continuously throughout the session. Stimulus presentations, reinforcement scheduling, and data recording were accomplished by solid-state digital logic, electromechanical counters, and a cumulative recorder, all located in a separate room from that housing the test chamber.

Procedure

Initially, the subjects were maintained at 70% to 75% of their free-feeding weights. Standard magazine training procedures were followed. Throughout the experiment, a subject was placed in the darkened chamber and a delay of at least 30 sec occurred before the houselight, masking noise, and stimulus lights were activated. Subjects had one experimental session per day.

Response training. After magazine training, subjects were maintained at 75% of their free-feeding body weights and trained to peck the key. Two stimulus conditions, S_1 , a yellow-green light of 555 nm, and S_2 , a red light of 606 nm, were alternately displayed on the response key for 5 min each. A trial consisted of the consecutive presentation of the two stimuli. All trials were followed by a timeout period of 10 sec, during which the response-key light was off and key pecking had no scheduled effect. One experimental session (five trials) lasted approximately 50 min.

The reinforcer consisted of a 3-sec access to the grain magazine during which the keylight was off and the hopper was illuminated with a 3-w white light. Initially, key pecking was reinforced on a continuous reinforcement

schedule in S_1 and S_2 ; then, in three or four sessions the schedule of reinforcement was gradually extended until each stimulus condition was associated with a random-interval 60-sec (RI 60-sec) schedule of reinforcement. A random-interval schedule involves brief time intervals in which the probability of reinforcement availability is constant and independent of the number of intervals that have occurred since the last reinforcement availability (Clark and Hull, 1965). With an RI 60-sec schedule the average inter-reinforcement interval is 60 sec. Training continued for 10 sessions, at which time the response rates of each subject in S_1 and S_2 had stabilized and were approximately equal.

Discrimination training. The deprivation schedule was adjusted so that in this and in all following phases, the birds were maintained at 80% of their free-feeding weights (± 10 g). During discrimination training, which lasted for the next 30 to 31 sessions, responses in the 5-min S_1 ($S+$) condition continued to be reinforced on an RI 60-sec schedule, but no responses in the 5-min S_2 ($S-$) condition were reinforced. Every trial (5-min presentations of each stimulus) continued to be followed by a 10-sec period in which the response keylight was off and responses were ineffective.

Adaptation with the warning stimulus. After one or two sessions of discrimination training, a white 45° line was superimposed on the response key for 30 sec once in each $S+ - S-$ period. At the end of the third session, the response rate in neither condition changed when the signalling stimulus was presented.

Pairing the warning stimulus with extinction. The white line appeared during $S+$ and signalled the approaching change to $S-$. The warning stimulus period ranged from 5 to 30 sec (mean duration of 15 sec) and terminated with the onset of $S-$. Extinction periods were signalled in 26 five-trial sessions for a total of 130 pairings.

RESULTS

In the session before discrimination training, the response rates in S_1 and S_2 for each subject had stabilized and were about equal. In the discrimination training phase, response rate in $S+$ increased and response rate in $S-$ decreased. After five discrimination sessions, each subject's response rate in $S-$ (S_2) was less

than 10% of its mean response rate in the 10 sessions completed prior to discrimination training.

Figure 1 shows each subject's suppression ratio for 28 sessions. The suppression ratio was calculated for each session by the formula $A / (A + B)$, where A is the mean rate of responding during the warning signal and B is the mean pre-signal-stimulus rate (Kamin, 1961). The ratio ranges between 0.00 and 1.00. A 0.00 suppression ratio indicates complete response suppression during presentation of the signalling stimulus. Values that are 0.50 show no change in the response rate. Suppression values greater than 0.50 indicate a higher

response rate during the signal periods than in the pre-signal periods.

The first two points (P1 and P2) presented in Figure 1 are the last sessions of adaptation. The suppression ratio was near 0.50, showing that the signalling stimulus had little effect on the baseline S+ rate.

In the first session of signalled extinction, all subjects showed a general trend of reduced responding during the signalling stimulus, although there was some variability in the suppression ratio between sessions and between subjects. Within a few sessions, responding during the signal increased for all subjects. As training continued, however, each of the subjects showed suppressed responding during the warning signal. The suppression ratios for all subjects approached asymptote by Session 26.

DISCUSSION

A variable-duration warning stimulus for extinction effectively suppressed key pecking in pigeons. Before stable suppression occurred, however, other response trends were observed. The warning stimulus reduced responding when it first signalled extinction, then, for the next few sessions the response rate increased during the warning signal. For several sessions, two subjects (A2 and A3) responded with slightly faster rates in the warning stimulus than during the pre-warning stimulus period. These results agree with previous research in which the signalled event was extinction (Pliskoff, 1963; Leitenberg, 1966) or a period in which the frequency of reinforcement was reduced (Pliskoff, 1961, 1963). Other research (Kaufman, 1969) has failed to find any consistent change in responding during stimuli that signal extinction.

With further training, responding suppressed when the warning signal was presented, and marked suppression persisted for the remaining sessions. Such pronounced suppression might be related to the duration of the warning signal. Stein, Sidman, and Brady (1958) demonstrated that short duration stimuli that signalled electric shock produced more suppression of responding in rats than longer-duration stimuli. In those studies reporting response enhancement during stimuli signalling changes to less favorable reinforcement schedules, durations of the warning stimuli

Fig. 1. Suppression ratios for the three subjects during the training of conditioned suppression. P1 and P2, the pretraining sessions, are followed by 26 sessions in which the variable-duration warning stimulus signalled a 5-min period of extinction.

were 3 min (Pliskoff, 1961) or 1 min (Pliskoff, 1963). When extinction was signalled, Pliskoff (1963) employed a 2-min duration signal; and Leitenberg (1966) used a 30-sec duration signal. In the present study, the mean duration was brief (15 sec). These data, then, provide further evidence that suppression is a function of the durations of the warning stimulus, although the exact parametric relationship has yet to be obtained.

The lack of suppression or enhancement reported by Kaufman (1969) may, at first, appear to contradict the effect of a short-duration warning signal. Kaufman's experiment, like the present one, used warning signals with a mean 15-sec duration, but the two experiments differed in other ways. Besides the species difference (rats *vs* pigeons), Kaufman's study used warning signals of fixed duration; in the present study the signals varied from 5 to 30 sec. This procedure with variable-duration warning signals evidently provided a sufficient number of short-duration signals, which may account for the suppression. The variable-duration warning stimulus, furthermore, might make the onset of the extinction period less predictable and thereby enhance the effect.

Finally, another factor may have contributed to the results. Suppression of responding during a signalling stimulus (CS) in conditioned-suppression studies is generally attributed to conditioned competing responses that interfere with the ongoing operant behavior. In the present study, suppression of key pecking could be related to such competing responses. Following discrimination learning with errors, Terrace (1966) observed that pigeons, when presented with a stimulus correlated with non-reinforcement, exhibited various "emotional" behaviors such as turning from the response key and wing flapping. A stimulus that was repeatedly paired with and that signalled the onset of extinction could be expected to gain

control of similar disruptive behavior and this would produce the suppression of key pecking observed during the warning stimulus in the present experiment.

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