FACILITATION OF FOOD-REINFORCED RESPONDING BY A SIGNAL FOR RESPONSE-INDEPENDENT FOOD[1]

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Five pigeons whose key pecking was maintained by 4-sec access to grain on a variable-interval 2-min schedule received Pavlovian differential conditioning trials superimposed upon the instrumental baseline. The conditioned stimuli were changes in the stimulus on the key from white to red, or to a white horizontal line against a dark background. The positive conditioned stimulus was 20 sec long, and was followed immediately by 8-sec access to grain. The negative conditioned stimulus, also 20 sec long, was never paired with response-independent food. All pigeons responded more rapidly in the presence of the positive conditioned stimulus than in the presence of the negative one. The positive conditioned stimulus produced an increase in response rate over the pre-conditioned stimulus period. The negative conditioned stimulus had no marked effect upon response rate. When the roles of the positive and negative stimuli were reversed, and the duration of the response-independent reinforcement was reduced to 4 sec, the new positive conditioned stimulus came to facilitate responding, and the new negative conditioned stimulus no longer produced facilitation. A second discrimination reversal produced similar outcomes. When a third reversal was initiated, and the duration of response-independent reinforcement was reduced to 2 sec, the difference between the effects of the positive and negative stimuli diminished.

Recently, there has been considerable interest in the interaction of Pavlovian and instrumental conditioning procedures (e.g., Rescorla and Solomon, 1967). One can study this interaction by training an organism to make some instrumental response, determining the effects of a to-be-conditioned stimulus upon the stable baseline, and then presenting response-independent pairings of the conditioned stimulus (CS) and an unconditioned stimulus (UCS) while the instrumental response is being performed. The conditioned suppression or conditioned emotional response (CER) procedure (Estes and Skinner, 1941), in which presentations of a CS followed by some aversive event occur while an organism is performing a positively reinforced instrumental response, is the best known pro-

cedure of this kind. It produces suppression of the instrumental response during the CS under nearly all conditions that have been studied (Davis, 1968; Lyon, 1968).

When response-independent pairings of a CS and a positive reinforcer are superimposed on a schedule of response-dependent positive reinforcement, the outcome is less clear. Herrnstein and Morse (1957) trained pigeons on a differential-reinforcement-of-low-rate (DRL) 5-min schedule of food reinforcement, which was in effect throughout sessions in which a CS consisting of a stimulus change on the response key was presented repeatedly independent of responding. Food was presented 1 min after the onset of each CS. After a few response-independent reinforcements had been presented, there was a large increase in response rate during both the CS and the intertrial period. Four of the six birds maintained higher response rates during the CS than in the periods between CSs; but the response rates of the other two birds were lower during CS than between CSs. Brady (1961) obtained an increase in the rate of water-reinforced operant behavior of a rat during a 5-min CS immediately followed by electrical stimulation of the septal region of the brain.

Azrin and Hake (1969) studied the effect of response-independent presentations of a brief CS followed by food, water, or positively reinforcing brain stimulation upon a variable interval 1-min (VI 1-min) schedule of food or water reinforcement. Fifteen of the 18 rats in the various groups quickly acquired suppression to the CS. When the response-independent reinforcement was omitted, the suppression extinguished.

Meltzer and Brahlek (1970) presented pairings of a CS and 6-sec access to 0.5 cc of sucrose to rats pressing a lever on a VI 2-min schedule of dry food reinforcement. When CS duration was 12 sec, responding was suppressed, but when the CS was 120 sec, response rate increased in the presence of the CS, although it never exceeded the baseline rate obtained before the CS and response-independent reinforcement were introduced.

The present experiment is similar to those of Brady (1961), Azrin and Hake (1969), and Meltzer and Brahlek (1970) insofar as it involved presentation of response-independent pairings of a CS (CS+) and a positive reinforcer to animals performing on a variable-interval schedule of positive reinforcement. In addition, a second CS (CS−), which was never followed by a response-independent reinforcement, was presented occasionally to the same animals. The procedure can be described as the superimposition of a Pavlovian differential conditioning procedure upon an instrumental baseline. The CS− in differential conditioning was called a differential inhibitor by Pavlov (1927), who observed that it elicited a conditioned response opposite in direction to that elicited by CS+, *e.g.*, when the CS− from a differential salivary conditioning procedure was compounded with the CS+, the magnitude of the salivary conditioned response to CS+ was reduced substantially. Recently, it has been demonstrated that Pavlovian CS+s and CS−s from aversive conditioning procedures have opposite effects upon instrumental baselines. Rescorla and LoLordo (1965) presented CSs that had been used in differential aversive conditioning to dogs performing on an unsignalled, free-operant avoidance schedule. The positive conditioned stimulus (CS+) produced a marked increase in the rate of avoidance, but CS− produced a virtual cessation of responding. Hammond (1966) observed that in a differential CER experiment, CS+

suppressed responding, but CS− produced an increase in response rate, though the increase disappeared after nine sessions. The present experiment examined the effects upon an instrumental baseline of CS+ and CS− from differential appetitive conditioning.

METHOD

Subjects

Five male White Carneaux pigeons that had been run in a successful replication of an experiment by Morse and Skinner (1958), which demonstrated more generalized key pecking during a stimulus in which response-independent food reinforcement had previously been presented than during a stimulus in which no food had been presented, were used. The stimuli used in the replication were white, green, and red houselights, with the function of red and green counterbalanced across birds. The birds were maintained at 80% of their free-feeding weights throughout the present experiment.

Apparatus

The apparatus consisted of five identical pigeon chambers, each 10 by 11 by 15.75 in. (25 by 28 by 40 cm). The response key was illuminated with white or red light, or with a white horizontal line on a dark background. No houselight was illuminated. During reinforcement the grain magazine, located below the key, was illuminated. White noise and the noise of the ventilating fan masked extraneous sounds. Scheduling and recording equipment were located in an adjacent room.

Procedure

All birds were given several days key-peck training on a VI 2-min schedule of reinforcement (Fleshler and Hoffman, 1962) in the presence of a white key. The key remained illuminated during reinforcement, which consisted of 4-sec access to mixed grain.

The conditioned stimuli (CSs) were a red light and a white horizontal line on a dark background. Each CS replaced the white inter-trial stimulus on the key for 20 sec on each of 12 occasions during every 2-hr session. Conditioned stimuli were presented on a variable-time 5-min schedule (range = 3 to 7 min). Presentations of the two CSs alternated randomly. The variable-interval schedule of food rein-

forcement was in effect throughout all sessions, regardless of the stimulus present on the key.

Responses were counted during each CS presentation and the 20-sec period immediately preceding it. Data from trials on which a dependent reinforcement occurred during either the CS or pre-CS periods were excluded from the analysis. The remaining data were used to compute a suppression ratio = total number of responses during CS/ (total number of responses during CS + total number of responses during pre-CS). The value of this suppression ratio (Annau and Kamin, 1961) is 0.50 when response rate is unaffected by presentation of the CS. When suppression occurs, the value of the ratio is <0.50, while values >0.50 indicate facilitation.

Sessions in which neither CS was followed by response-independent reinforcement were continued until the daily suppression ratios for individual birds had remained stable over several consecutive sessions. This procedure required from 30 to 72 sessions.

When the suppression ratios had stabilized, response-independent reinforcement was introduced. The CSs were presented as before, but the termination of CS+ was accompanied by access to response-independent food reinforcement. The horizontal line was CS+ for three birds, while red light was CS+ for the others. The duration of the response-independent reinforcement was 8 sec, during which time the key was dark. After 20 sessions the discrimination was reversed, the duration of response-independent reinforcement reduced to 4 sec, and 20 additional sessions were run. A second discrimination reversal followed, and 20 sessions were run. Finally, a third discrimination reversal occurred, the duration of response-independent reinforcement was reduced to 2 sec, and 20 sessions were run.

RESULTS

Figure 1 illustrates the suppression ratios for individual pigeons over two-session blocks during the period before response-independent reinforcement was introduced, the first conditioning phase, and the first reversal. Two-session blocks were used because response-dependent reinforcements sometimes occurred during nearly all trials within a single session, leaving only a few trials contributing data to the analysis.

During the first conditioning treatment (HL+8 or R+8), when response-independent reinforcement consisted of 8-sec access to grain, all pigeons had higher suppression ratios to CS+ than to CS−. Furthermore, during nearly all sessions for all pigeons, CS+ produced absolute facilitation, *i.e.*, a suppression ratio >0.50, as well as facilitation relative to its effect during the last four sessions before response-independent reinforcement was introduced. The suppression ratio for CS− was not markedly affected by the introduction of response-independent reinforcement.

Suppression ratios for CS+ began to exceed those for CS− within the first few sessions of the first discrimination reversal (Fig. 1), and this effect persisted until the end of the treatment. The positive conditioned stimulus (CS+) produced absolute facilitation for all birds. Suppression ratios for CS− declined across sessions within the first reversal, reaching the levels that prevailed before response-independent reinforcement was introduced. The facilitation that developed when a given stimulus was CS+ during the first conditioning treatment extinguished when this stimulus became CS− during the first reversal.

Figure 2 illustrates the suppression ratios for individual pigeons over two-session blocks during the second and third reversals. The positive CS came to produce larger suppression ratios than CS− for all pigeons within the first few sessions of the second discrimination reversal. The CS+ consistently produced absolute facilitation of responding for all pigeons. Suppression ratios for CS− declined across sessions within this treatment, reaching approximately the levels that prevailed before response-independent reinforcement was introduced.

When the amount of response-independent reinforcement was reduced to 2-sec access to grain, and a third discrimination reversal was instituted, only Birds MS2 and MS6 consistently responded more rapidly during CS+ than during CS−. The behavior of the other pigeons was less consistent; during some sessions there was no difference between the suppression ratios for CS+ and CS−. The positive CS produced facilitation relative to its effect in the previous treatment (when it was CS−) for all pigeons, and produced absolute facilitation for all but MS3. The suppression ratio for CS− declined across sessions
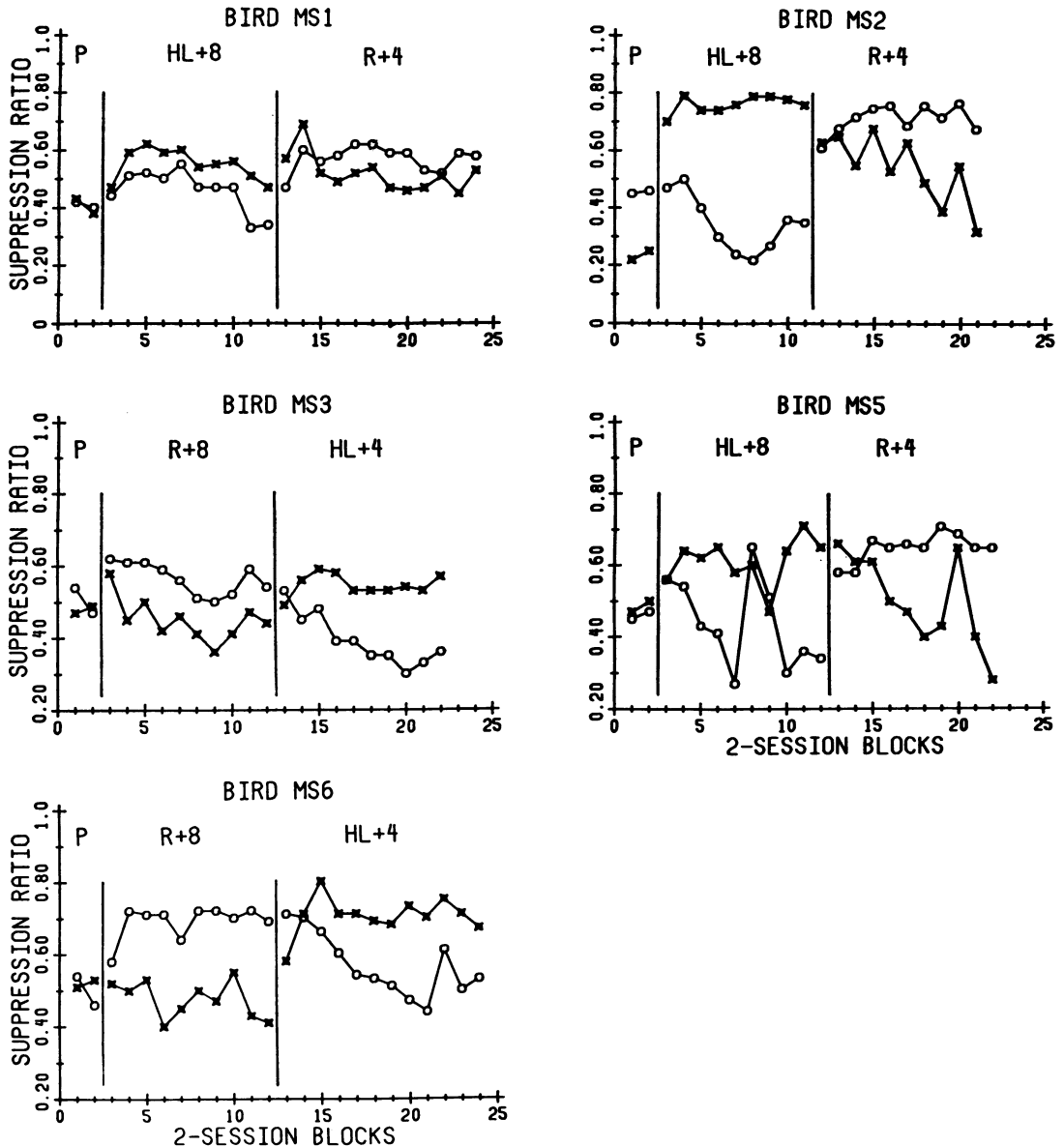
Fig. 1. Suppression ratios for individual pigeons over two-session blocks before the introduction of response-independent reinforcement, during acquisition, and during the first reversal. Open circles represent the red light (R); stars represent the horizontal line (HL). "P" designates sessions before the introduction of response-independent reinforcement, "R+" designates sessions in which red was CS+, "HL+" designates sessions in which horizontal line was CS+, and "8" and "4" indicate the duration of response-independent reinforcement.

within the third reversal for all pigeons except MS1; the ratio did not change systematically for this bird.

There were no large differences between pre-CS+ and pre-CS− response rates for any pigeon, nor did the pre-CS rates change systematically for any pigeon during the course of the experiment.

DISCUSSION

A stimulus paired with response-independent food reinforcement produced an increase in the rate of food-reinforced pecking. The negative conditioned stimulus, which was never paired with response-independent food, had no marked effect upon response rate.
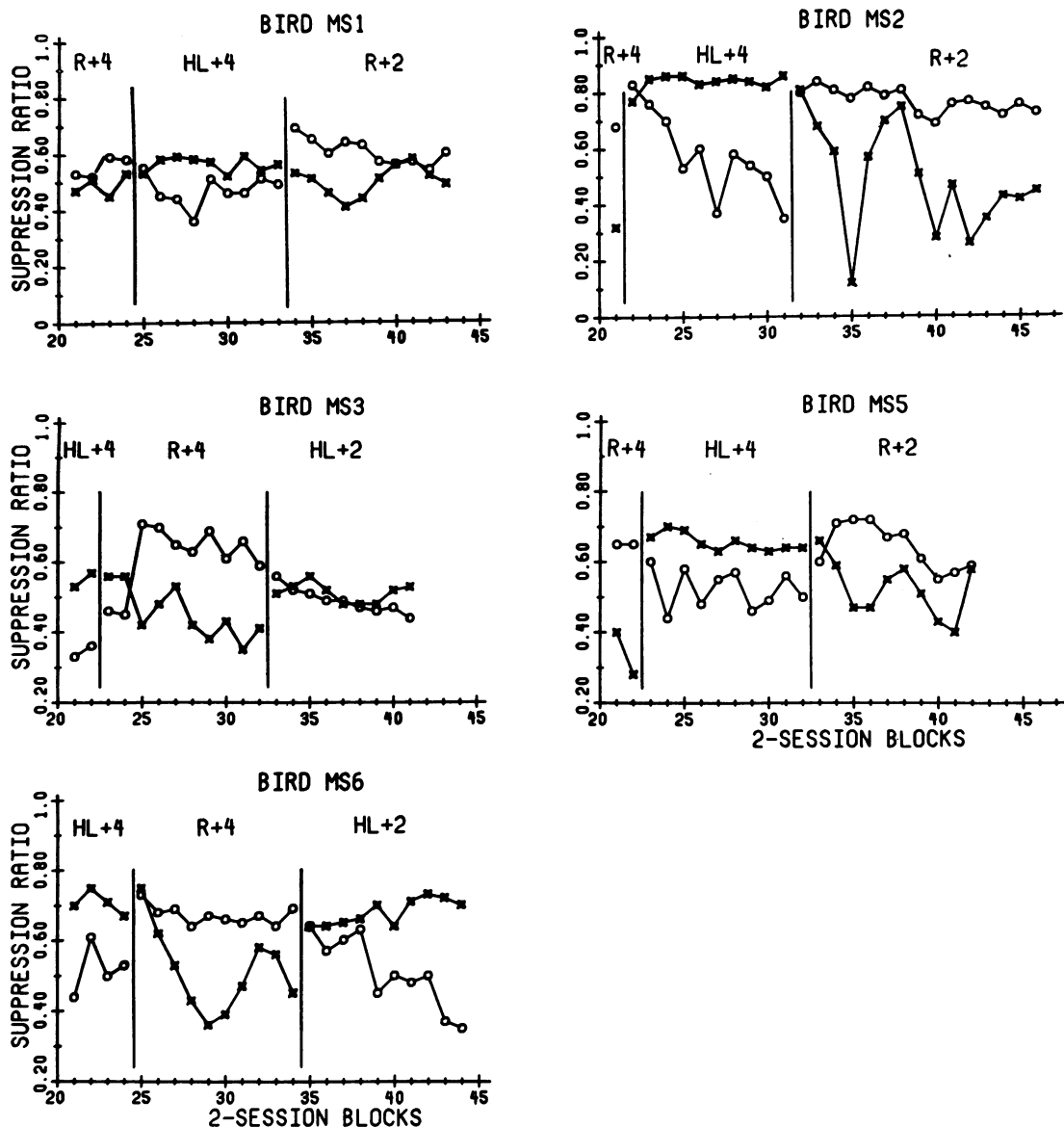
Fig. 2. Suppression ratios for individual pigeons over two-session blocks during the last few sessions of the first reversal, and during the second and third reversals. Open circles represent the red light (R); stars represent the horizontal line (HL). "R+" designates sessions in which red was CS+, "HL+" designates sessions in which horizontal line was CS+, and "4" and "2" indicate the duration of response-independent reinforcement.

These outcomes were replicated in several reversals of the discrimination, and occurred when the response-dependent and response-independent reinforcers differed in magnitude, as well as when they were the same size (see Azrin and Hake, 1969).

The effect of CS+ in the present experiment was opposite that obtained by Azrin and Hake (1969), and Meltzer and Brahlek (1970),

who superimposed CS+s, but not CS−s, upon a variable-interval schedule baseline. In order to assess the importance of this procedural difference, several weeks after completion of the third reversal, Birds MS2 and MS6 were presented with pairings of CS+ and 8-sec access to food as before; but CS− was omitted. CS+ consistently facilitated responding of both pigeons. Over 10 sessions, daily suppres-

sion ratios ranged from 0.75 to 0.83 for MS2, and from 0.62 to 0.70 for MS6. Thus, the facilitatory effect of CS+ in the present experiment did not depend upon the presentation of CS– during the same sessions.

Meltzer and Brahlek (1970) argue that the likelihood of response suppression in the presence of a CS is inversely related to the number of response-dependent reinforcements that would be missed if suppression occurred. The 20-sec CS+, which facilitated responding in the present experiment, should have produced suppression, according to their argument. It may be the case, however, that a very short CS-UCS interval, say 5 sec, would produce suppression even with pigeons. In any case, Meltzer and Brahlek (1970) recognized that their argument failed to predict the facilitation of responding in the presence of CS+ that occurs when long CS-UCS intervals were used. Recently, Henton and Brady (1970) observed that the rate of occurrence of a response maintained by a DRL 30-sec schedule of food reinforcement increased in the presence of a CS that preceded response-independent food by 80 sec, but was unchanged when the CS-UCS interval was 20 or 40 sec. Thus, facilitation occurred only in the condition where it would have produced the greatest loss of response-dependent reinforcement.

It is difficult to estimate the contribution of species and response differences to the aforementioned divergent outcomes, but it is known that repeated response-independent presentations of illumination of a key followed by food reinforcement will condition pecking in naive pigeons (auto-shaping, see Brown and Jenkins, 1968; Williams and Williams, 1969), while a comparable outcome has not been reported for rats pressing a lever for positive reinforcement. Perhaps facilitation to a brief CS+ and autoshaping are related phenomena, and the former will occur only with stimulus-response-reinforcer combinations that would produce autoshaping in naive subjects. Williams and Williams (1969) showed that persistent, directed key pecking occurs under an autoshaping procedure in which each illumination of the key was followed by food only if the pigeon failed to peck the key on that trial. Adventitious reinforcement thus does not seem to be responsible for the maintenance of pecking in the autoshaping procedure. Facilitation of responding in the presence of a brief CS+ preceding food may be equally independent of the consequences of responding. On the other hand, the facilitation during CS+ could have been due to adventitious reinforcement of key pecking; the present experiment does not decide the question.

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