BEHAVIORAL CONTRAST AND THE AUTOMAINED KEY PECK

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In two experiments behavioral contrast was demonstrated during discrimination training in a positive automaintenance procedure. During the baseline condition in each experiment, a key was transilluminated for eight seconds by one of two colors (CS) following a variable intertrial interval signaled by a dark key. Keylight transillumination terminated with a response-independent food presentation. In the first experiment, food was eliminated during one CS for up to fifty sessions. After reinstatement of food following each CS, the discrimination was reversed. Six of the eight subjects showed positive behavioral contrast, i.e., response rates increased during the CS associated with food as they decreased during the CS associated with no food. The effect was replicated in Experiment II, but it did not occur when both the food and its associated CS were eliminated. These results were comparable to those obtained with operant discrimination training procedures (behavioral contrast) and with Pavlovian discrimination training. The results suggest that additivity theories of behavioral contrast may be insufficient to account for these data.

Key words: autoshaping, behavioral contrast, multiple schedule, Pavlovian induction, pigeons

Behavioral contrast is a reliable widely studied effect of operant discrimination training. In a typical situation, removal of reinforcement from one component of a multiple schedule reduces response rates in that component and simultaneously results in an increase in responding in the other, unchanged, component. Reinstatement of reinforcement in the component associated with extinction has the opposite effect, i.e., response rates increase there and decrease in the unchanged component. These effects are respectively labeled positive and negative behavioral contrast.

Most studies of behavioral contrast have used a free-operant response under the control of one or more schedules of reinforcement (e.g., Marcucella & MacDonall, 1977; Reynolds, 1961). However, similar effects also have been reported in discrete trial procedures. For example, in a study by Jenkins (1961), a pigeon's first peck on a response key that was lighted following a variable intertrial interval was

immediately reinforced (S+). After stable responding was observed, a second keylight color that was never associated with food (S-) was introduced for 5-sec periods on a variable schedule. The mean latency of the occurrence of the response during S+ decreased significantly after discrimination training. Since the first response during the S+ was reinforced on each trial, no measure of response rate could be derived. The excitatory effect (shortened latency), however, is analogous to behavioral contrast (increased rate) obtained using free-operant procedures.

Induction during Pavlovian discrimination training parallels the operant behavioral contrast effect. Kogan is cited by Pavlov (1927) as first defining induction, although he did not go on to systematically study it. Foursikov, also cited by Pavlov (1927), conditioned an alimentary response to tactile stimulation of a dog's front paw (CS+); similar stimulation of the hind paw (CS-) signaled reinforcement was not forthcoming. Following the acquisition of the discrimination, the CS+ elicited as much as a 50% larger salivary response if it followed a CS- trial than if it followed another CS+ trial. Pavlov (1927) also reported similar induction effects in alimentary conditioning to auditory (rates of clicks) and visual

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(bright vs. dim light) conditional stimuli. Hearst and Jenkins (1974) suggested that induction effects are not common in the standard Pavlovian discrimination training procedure. Their conclusion was based upon studies of eyelid conditioning in which an aversive unconditional stimulus was used. Since studies of operant discrimination learning based on aversive stimuli have provided mixed evidence of behavioral contrast (e.g., Brethower & Reynolds, 1962; Dinsmoor, 1952; Rachlin, 1966), their conclusion may have limited generality.

The experiments presented here examined behavioral contrast during discrimination training of automaintained responses. Since the autoshaped key-peck response is widely regarded as a Pavlovian conditional response, positive results would provide additional generality of the behavioral contrast effect in non-operant procedures. Such a demonstration also would question the nature of positive behavioral contrast during operant discrimination learning.

EXPERIMENT I

This study examined the effects of extinguishing autoshaped responding in the presence of one stimulus (CS) on autoshaped responding in the presence of a second CS.

METHOD

Subjects

Seven experimentally naive White King pigeons, obtained from a local breeder, and one experimentally naive Japanese quail (Q2), obtained from the colony maintained by the Biology Department at West Virginia University, served. All were maintained at 75% of their free-feeding weights throughout the experiment.

Apparatus

A 30.5 by 21.5 by 21.5-cm operant conditioning chamber was used. A grain hopper was located behind a 5.0 by 5.0-cm opening centered horizontally on the work panel 6 cm from the floor. A 3-sec presentation of the grain hopper, accompanied by illumination of the magazine opening by a white light, was the reinforcer. A single translucent plastic response key, 2 cm in diameter and fitted with a clear plastic extension that protruded 8 mm from the work panel, was mounted on the

work panel 14 cm from the chamber floor and to the right of the feeder opening. Key operation required approximately .06 N. Key illumination was provided by white, yellow, red, and green chamber lights mounted behind the key.

All lights were adjusted to register a reading of 13 on a Gossen (Luna-Pro) light meter by adjusting the voltage to each light. Light readings were taken at the surface of the key extension in the experimental chamber while the houselight was off. The chamber was illuminated by a 110-V ac, 15-W bulb mounted behind a glass shield in the top of the chamber. Standard electromechanical scheduling and recording equipment was used. White noise was continuously supplied during each experimental session.

Procedure

During the first session, each subject was trained to approach and eat from the grain hopper, which was presented for 20 sec according to a variable-time 35-sec schedule. After the bird ate from the hopper on at least 8 of 10 of these response-independent hopper presentations, the duration of the hopper presentation was reduced to 10 sec and then to 3 sec for 20 and 40 presentations, respectively.

In the baseline condition, a fixed-trial autoshaping (positive automaintenance) procedure similar to that described by Brown and Jenkins (1968, Experiment IV) was in effect. The response key was dark during a variable intertrial interval (mean = 35 sec; range = 10 to 60 sec) and then transilluminated by either a white or yellow or a red or green light for an 8-sec trial interval. At the light offset the hopper was raised and illuminated for 3 sec independently of the subjects' behavior. Thirty white or red and thirty yellow or green stimulus presentations per daily session were scheduled. The order of stimulus presentation was random with the constraint that no more than four consecutive presentations of either stimulus occurred. Key-peck responses in the presence of each conditional stimulus (CS) were recorded separately. Responses to the darkened key were also recorded initially, but were so infrequent that recording was discontinued.

For three birds and the quail, food delivery was discontinued (extinction) following one of the CSs (yellow light; CS-) after stable re-

Fig. 1. Schematic representation of the conditions studied in the two experiments. Vertical inflections represent the "on" condition for the two conditioned stimuli (CSs) and food hopper.

sponding was observed in the baseline condition. The baseline and extinction conditions can be seen in the top 2 panels in Figure 1.

This condition was in effect for different numbers of sessions for each subject to assess the effects of prolonged maintenance of the extinction condition on induction effects. After these sessions, the baseline condition (food following both CSs) was reinstated. Next, the discrimination was reversed, so that extinction was associated with the previously unchanged component. This condition remained in effect as indicated in Figure 2, which shows the sequence and number of sessions at each condition. Finally, baseline condition was reinstated for several sessions. Each condition remained in effect at least until three consecutive sessions occurred in which visual inspection indicated no systematic directional trends in responding in the two components.

Two birds (A1 and C3) were trained initially using a yellow and a white stimulus light and a final two (Birds A3 and B3) were trained using a red and green stimulus light to examine possible effects of different key colors. Figure 3 shows the order and number of sessions of each condition for each of these subjects. Subjects were maintained on the baseline and extinction conditions as defined above. All conditions were continued until stable responding was observed. Following the initial baseline

Fig. 2. Mean responses per trial emitted by each of the four subjects in Experiment I. AUTO refers to the 8-sec presentation of a CS followed by the delivery of food. EXT refers to the 8-sec presentation alone.

sessions, extinction was introduced by discontinuing food delivery following one of the CSs. Baseline was reintroduced for all birds following this extinction condition. For Birds B3 and C3 extinction was introduced for a second time and associated with the previously unchanged component. This condition was followed by a return to baseline. Trial stimuli for all birds were then changed. Keylights for birds exposed initially to red and green were changed to yellow and white; keylights for birds exposed initially to yellow and white were changed to red and green. After stable responding was re-established, extinction was associated with one CS. This condition was then followed by a return to the baseline auto-maintenance condition.

RESULTS

Figure 2 shows the mean key-peck responses per trial for Birds 24, 73, 89, and Q2 during each session of the experiment. Frequent re-

sponding was maintained during baseline conditions and mean responses per trial decreased to less than five in the extinction components within four days in all cases.

Three of the four birds (89, 24, and Q2) exhibited positive behavioral contrast during the first extinction session. This effect continued throughout the extinction condition for Birds Q2 and 24. It also occurred for the first 28 sessions for Bird 89 before it dissipated. During the reversal condition, Birds 24 and Q2 again exhibited the contrast effect.

Response frequencies in the return to baseline conditions for Bird 24 were approximately the same as during the original baseline. During the first return to baseline, the response frequencies of Bird 89 were lower than the original baseline; the response frequencies during the final baseline were the same as during the second baseline condition. No decrease in response frequency was observed following the return to baseline for Bird Q2.

Fig. 3. Mean responses per trial at each condition for each bird in Experiment I. AUTO refers to the 8-sec presentation of the CS followed by food. EXT refers to the 8-sec presentation of the CS alone. Keylight colors are indicated above each set of graphs. Different colors are separated from one another by the longer vertical lines.

Figure 3 shows the mean responses per trial for all sessions for Birds A1, A3, B3, and C3. Birds A1, C3, and A3 responded at higher frequencies than baseline in the unchanged component during the extinction condition in both pairs of stimulus conditions. No major differences were seen in response frequencies maintained by the four different stimulus conditions except in Bird A3. For this bird the green stimulus maintained a very low frequency of responding and a higher frequency was maintained by the yellow stimulus than by either of the other two stimuli.

DISCUSSION

This experiment showed that behavioral contrast can occur during discrimination learning when key-peck responses were initially maintained by a stimulus-reinforcer relationship. Farthing (1974) found that positive behavioral contrast was greater during the first several discrimination sessions if the difference between S+ and S- was small or moderate rather than relatively large (cf. Herrnstein, 1970). Subjectively, the yellow and white stimuli used here were similar. The yellow light was not deeply saturated, in part because the houselight provided a bright level of illumination. On the other hand, red and green key-light CSs are typically more saturated in hue, and the difference between the two is subjectively greater than that between white and yellow.

Here, contrast effects occurred regardless of whether the two color combinations used as CS+ and CS- were relatively similar (white vs. yellow) or relatively different (red vs. green). Thus, CS+/CS- similarity was not critical in the present contrast effects.

Fisher and Catania (1977) and Sperling, Perkins, and Duncan (1977) have shown that pigeons are more likely to respond first toward a keylight that is more similar in hue to that used to illuminate the food hopper. The similarity of keylight and food-hopper light was not critical in the development of behavioral contrast effects, since both white-yellow (similar to magazine light) and red-green (dissimilar to magazine light) resulted in such effects.

Eliminating reinforcer delivery after one of the CSs simultaneously doubled the average interreinforcement interval. The autoshaping literature suggests that when the duration of the trial stimulus remains constant, higher re-

sponse rates are maintained when longer intertrial intervals are in effect. Terrace, Gibbon, Farrell and Baldock (1975) found that the number of trial stimulus presentations necessary to establish autoshaped responding decreased as the length of the intertrial interval increased, and showed that terminal response rates were higher when the intertrial intervals were longer (see also Hearst and Jenkins, 1974, Footnote 3). Changes in interreinforcement intervals of the magnitude that occurred in this experiment (from about 35 to 70 sec) have not been reported to have large effects on the frequency of responding in an autoshaping procedure. However, Scull and Macphail (1976) have suggested that positive behavioral contrast shown in fixed-trial procedures may be the result of these changes.

EXPERIMENT II

This experiment assessed whether the increase in interreinforcement interval alone produced the response frequency increases in CS+ observed in the first experiment. Rates of responding maintained under the conditions studied in the first experiment were compared to those occurring under a condition in which reinforcement and the related stimulus were eliminated. In this latter condition, the interreinforcement interval was increased but discrimination learning and extinction could not occur.

A typical measure of Pavlovian induction has been response latency (Pavlov, 1927). Jenkins (1961) measured response latency while studying contrast effects on responding maintained in a fixed-trial operant procedure. The latencies between the onset of the trial stimulus and the first response also were measured to allow further comparisons between the contrast effects shown in Experiment I and the results of earlier studies of induction and contrast.

METHOD

Subjects

Four experimentally naive, mature White King pigeons maintained at 75% of their free-feeding weights were used.

Apparatus

The apparatus was the same as in Experiment I.

Procedure

The birds were trained to eat from the raised food hopper and brought to respond on an autoshaping schedule with two distinct trial stimuli (white and yellow keylight illumination) following the procedure outlined in Experiment I. Each was exposed to the three conditions shown in Figure 1. The baseline condition shown in the top panel and the extinction condition shown in the middle panel were as in Experiment I. In the third condition, shown in the lower panel, the delivery of the reinforcer following one stimulus was discontinued, and simultaneously, the related stimulus was eliminated. The sequence of these conditions for each subject and the number of sessions at each is shown in Figure 4. Each condition was repeated for each of three birds. Sessions were conducted seven days a week and each session was terminated when 30 reinforcers per stimulus were delivered.

RESULTS

The mean responses per trial for all four birds during each session of the experiment are given in Figure 4. Frequent responding occurred in the presence of both CSs when each

was followed by food. Introduction of extinction rapidly eliminated responding to that CS, but increased responding in the presence of the CS that continued to terminate with food presentation (CS+). This effect occurred in all birds and it was replicated in Birds B2 and A2. Bird C1 died during the fifth condition and therefore the replication was not possible, while Bird B1 showed no increase in response frequency over the previous baseline condition during the second extinction condition. During the stimulus elimination condition, responding of all birds during CS+ was maintained at frequencies equivalent to baseline.

Figure 5 shows mean response latencies per trial during CS+ for each bird during each session. All birds showed decreased response latencies during the extinction condition with respect to the previous baseline condition. This effect was replicated in the three birds exposed to extinction a second time. These data were more variable than the response frequency data and, in some cases, the magnitude of change was not as great as with the response frequency data.

Changes in response latencies in the unchanged component during the stimulus elimination condition was not systematic. In one

Fig. 4. Mean responses per trial emitted by each subject in Experiment II. AUTO refers to the 8-sec presentation of a CS followed by the delivery of food. EXT refers to the 8-sec presentation of the CS alone. ELIM refers to the condition in which one of the CS's and its accompanying food presentation did not occur.

bird the latencies tended to increase during this condition; in the second, the latencies were between the durations maintained during baseline and extinction while no change from baseline was seen in the remaining two birds.

Response frequencies returned to original baseline levels following both extinction conditions for Birds B2 and B1. Birds C1 and A2 showed only partial recovery of baseline. Similar recoveries were observed with response latency measures. However, for Bird B2, baseline latency recovery was incomplete following the second extinction condition.

DISCUSSION

All four birds showed reliable increases in response frequency in the unchanged component during the extinction component, replicating the effect demonstrated in Experiment I. Generally, the response frequencies in the CS+ decreased when the baseline condition was reinstated, although two birds showed only partial recovery of baseline. Simultaneous removal of both food and the accompanying CS in one component, thereby doubling the intertrial interval, had no systematic effect on response frequency. This result suggests that the induction or contrast effects obtained during the discrimination condition were not simply the result of increased intertrial intervals. The failure of the increased intertrial intervals to increase re-

sponse rates in the unchanged component within individual subjects here further suggests that the findings of Terrace et al. (1975), may be confined to between-group comparisons.

The same general effects obtained with the response frequency data were also obtained with the response latency data, although latencies tended to be quite variable and the magnitude of the contrast effect was not as great. Mackintosh (1974) suggested that the latency data may be less sensitive to contrast effects since the measure may confound a measure of response strength with a measure of reaction time. He proposed that while there may be a tendency for subjects to respond more rapidly, the addition of the discrimination task delays responding because of an additional response choice period.

GENERAL DISCUSSION

Contrary to the suggestion of Hearst and Jenkins (1974), behavioral contrast occurred during discrimination training of the auto-maintained key-peck response of pigeons. The positive and negative contrast effects were measured both as rate of key pecking and as latency of the first response during the stimulus associated with the unchanged reinforcer delivery conditions. The presence of a distinctive stimulus associated with extinction was

Fig. 5. Mean response latencies per trial for each bird in Experiment II. AUTO refers to the 8-sec presentation of a CS followed by food delivery. EXT refers to the 8-sec presentation of the CS alone. ELIM refers to the condition in which one of the CS's and its accompanying food presentation did not occur.

necessary for the contrast effect to occur; however, keylight colors and the similarity of these colors to the food hopper did not systematically affect its occurrence.

These effects parallel demonstrations of such effects during other Pavlovian, free-operant, and discrete-trial-operant discrimination training procedures (e.g., Gamzu & Schwartz, 1973; Jenkins, 1961; Pavlov, 1927; Reynolds, 1961). The effects were specifically related to the removal of reinforcement following one of the stimuli, they developed rapidly when extinction was introduced, and were reversible on reinstatement on the nondifferential condition. There was considerable variability in the magnitude of both positive and negative contrast effects across subjects, but the magnitude of the effects seemed in the same general range as that reported during other discrimination training procedures.

In some instances, positive behavioral contrast was not demonstrated (e.g., Birds 73 and B3, Experiment I) or was not clearly replicated (Bird 89, Experiment I and Bird B1, Experiment II). No differences were noted which might easily explain why these first two birds did not exhibit behavioral contrast. For example, these birds did not respond at a sufficiently high rate during the CS to suggest that a ceiling effect prevented the occurrence of contrast. The failure to replicate the contrast effect in Bird 89 may be related to the fact that this subject was maintained on the initial extinction condition for 50 sessions. A contrast effect was clearly shown during this initial extinction condition, but response frequencies gradually declined throughout the condition, dropping below the baseline level after 25 to 30 sessions. Some researchers have reported that behavioral contrast dissipates with extended discrimination training (Terrace, 1966). If extended training was responsible for the dissipation of contrast during the first extinction condition, the dissipation also may have generalized to the second extinction condition.

This variability in positive behavioral contrast effects may be an unavoidable artifact of the present autoshaping procedure. In a conventional multiple schedule, S+ is always preceded by S-. Here however, a CS+ may be preceded by either a CS+ or a CS- because of the randomization of trials. In addition, the CS+ and CS- were not temporally contiguous, as are S+ and S- in a conventional multiple

schedule, but rather are separated by an inter-trial interval of varying duration. Mackintosh, Little, and Lord (1972) showed little or no contrast when long intertrial intervals were interspersed between trials. Either or both of these procedural variations seem less than optimal for the production of behavioral contrast and may have attenuated such effects here. The consistency with which such effects were obtained in spite of these procedural departures from usual behavioral contrast demonstrations attests to the robustness of the present phenomenon.

Studies of operant behavioral contrast often have failed to demonstrate negative contrast effects that are symmetrical to the positive contrast effects (e.g., Reynolds & Limpo, 1968). That is, the mean frequency of responding maintained during the baseline condition which follows the extinction (or contrast) condition are different from the original baseline frequencies in the unchanged component. Baseline levels of responding were not recovered on several occasions (Birds C1 and A2 in Experiment II) following the reinstatement of food in a CS after extinction. As with operant behavioral contrast, the response frequencies in the unchanged component for these birds were between those maintained during baseline and extinction conditions. It has been suggested that the asymmetry of the magnitude of positive and negative contrast effects is evidence that positive and negative contrast are controlled by different variables (Marcucella & MacDonall, 1977) and this may be the case here as well.

In some accounts of behavioral contrast, the additional key-peck responses that occur during operant discrimination training with pigeons are interpreted as simply more operant responses caused by changes in reinforcement frequency or response rate changes in S-. Schwartz and Williams (1972) suggest that positively automaintained key pecks and pecks controlled by operant contingencies are similar since both are relatively long-duration responses. "This implies that an adventitious response-reinforcer contingency is partly responsible for positive automaintenance responding" (Schwartz & Williams, 1972, p. 210). One might conclude from the present experiments that only the automaintained key pecks that were controlled by response-reinforcer contingencies were affected by the contrast manip-

ulation. That is, the demonstration of contrast here affected only operant and not stimulus-reinforcer maintained responses, as has been demonstrated in previous studies of behavioral contrast.

An alternative account of behavioral contrast is the additivity theory, which Schwartz and Gamzu (1977) have summarized as follows: "Contrast occurs because a differential stimulus-reinforcer dependency is imposed upon an already existing response-reinforcer dependency, and the two sources of control combined to increase the rate of key pecking" (p. 80). Further, several investigators have suggested that the main effect of the stimulus-reinforcer dependency is confined to the time period immediately following the transition from S- to S+ (Boakes, Halliday, & Poli, 1975; Rachlin, 1973; Schwartz, Hamilton, & Silberberg, 1975). Here, the latency data from Experiment II also are consistent with this suggestion in that CS+ responses during auto-extinction occurred sooner than in the auto-auto or auto-elimination condition.

The present data raise several issues for additivity theory. First, the differential stimulus-reinforcer dependency need not be imposed on a response-reinforcer dependency to produce behavioral contrast (cf. Gamzu & Schwartz, 1973).

Second, the theory might have predicted the contrast effects demonstrated in the extinction condition studied. By extinguishing responding in the presence of the CS-, the CS+ became a better predictor of food delivery. However, with the automaintenance procedure a strong predictive stimulus-reinforcer relationship already exists with the CS+ prior to extinction. The relatively unsubstantial change introduced during extinction should not produce contrast effects as dramatic as those seen in some of the birds studied.

Third, while rate increases were observed in the extinction condition, no increases were found in the elimination condition. If additivity were to account for the rate changes in the extinction condition, similar changes should have been apparent in the elimination condition in which similar changes in predictive value were introduced.

Finally, although it is not explicitly stated in accounts of the additivity theory, the theory seems to imply that key pecking controlled by stimulus-reinforcer dependencies are not pres-

ent in an operant schedule until extinction is introduced. However, Schwartz (1977a, 1977b) has suggested that pecking under reinforcement schedules is a mixture of operant and reflexive responses. Also, key pecking rates under different components of a multiple schedule with nominally identical parameters are seldom identical, suggesting a slight differential reinforcement effect in the two components. Spealman (1976) found that differences in reinforcement frequency that were less extreme than extinction in one component were sufficient to elicit reflexive pecking. Thus, it seems likely that reflexive pecks exist during multiple schedules with nominally identical schedules in either components. The present data, in conjunction with these observations, suggest that the operant behavioral contrast effect could possibly be due to a direct increase in these reflexively controlled pecks because of a more explicit differentiation of reinforcement conditions in the two components. That is, contrast effects observed on operant baselines could be the result of the interactions between responses maintained by the unspecified stimulus-reinforcer relationship.

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Received January 23, 1979

Final acceptance August 18, 1980