Overshadowing by food of stimulus control by a keylight in a two-element serial compound

M. E. RILLING, R. C. HOWARD, and C. M. JOHNSON
Michigan State University, East Lansing, Michigan 48824

Pigeons were given successive discrimination training in which pecking during a choice period when the key was white was either reinforced or not, depending upon the prior presence or absence of a discriminative stimulus, which was a two-element serial compound. The compound consisted of a keylight and food, with food presented second or first in a forward or backward pairing for different groups of pigeons. In Experiment 1, the sequence was an S+ indicating reinforced trials, while in Experiment 2, the sequence was an S- indicating nonreinforced trials. Following acquisition of discriminated operant behavior, a sequence generalization test was administered during which all possible orders of the two stimuli were presented on test trials prior to the onset of the choice period. The results showed that food overshadowed stimulus control by the color of the light on the key on the sequence-generalization test, independently of whether food was presented first or second during training and independently of whether food was associated with reinforcement or nonreinforcement. The similarity of results for the two experiments suggests that overshadowing occurs independently of whether the compound is a discriminative stimulus for reinforcement or nonreinforcement. Simultaneous presentation of elements of a compound stimulus is not necessary for overshadowing because the phenomenon was captured with sequentially presented stimuli.

In most research on stimulus control (see Rilling, 1977, for a review), a single event is employed as a discriminative stimulus. In a series of experiments that stimulated the present investigation, Weisman and Dodd (1979) extended research on stimulus control to the case in which two events presented successively function as positive discriminative stimuli. Their paradigm is based on a procedure containing two components. The first component consists of the presentation of the discriminative stimuli, and in the second component, responding is either reinforced or extinguished depending upon the stimuli presented during the first component. For example, in one experiment the first component consisted of 5-sec presentations of green and red lights, which were labeled "A" and "B". Responding on a white key during the second component was only reinforced following the presentation of the AB sequence. On S- trials, responding during white was not reinforced following sequences other than AB. By convention, the absence of either A or B is designated as X, so the absence of both stimuli is designated "XX" or S-. During acquisition, only sequence AB was reinforced; in addition, all nine possible two-event combinations of sequences A, B, and X were presented without reinforcement (i.e., in extinction). The dependent variable was how rapidly the test sequences associated with extinction were differentiated from the test se-

quences associated with reinforcement. The results of this experiment indicated that Stimulus B, the second element in the sequence, acquired the most stimulus control over responding. A second experiment employed a generalization procedure in which the animals were first given discrimination training followed by a sequence-generalization test in which the two elements, A and B, were presented in all possible stimulus sequences. The results of this experiment again demonstrated that Element B acquired more stimulus control than Element A.

Weisman and Dodd (1979) restricted their research to serial compounds in which the elements were assumed to be of equal salience. In the present experiments, food is employed as one of the elements in the two-element sequence in order to investigate overshadowing. Overshadowing of a stimulus, A, may be defined as a reduction in stimulus control produced after training in which A is always presented together (concurrently or serially) with another stimulus, B. In the first experiment, the AB compound was presented as S+ prior to reinforcement, while in the second experiment, the AB compound was presented as S- prior to nonreinforcement. This design permitted an analysis of whether stimulus control by a sequential compound was dependent upon whether the compound served as a discriminative stimulus for reinforcement or nonreinforcement.

EXPERIMENT 1

The purpose of Experiment 1 was to determine

Requests for reprints may be sent to Mark Rilling, Department of Psychology, Michigan State University, East Lansing, Michigan 48824.

if food overshadowed a discriminative stimulus on the key when the AB sequence was presented as a discriminative stimulus preceding reinforcement. One experimental group received food as a discriminative stimulus in a forward pairing arrangement in which a keylight was presented first and food was presented second. The overshadowing prediction for the forward pairing group is that the presence of food as the second element reduces stimulus control by the first element. The second experimental group received food as a discriminative stimulus in a backward pairing arrangement in which food was presented first and the keylight was presented second. The overshadowing prediction for the backward pairing group is that the presence of food as the first element reduces stimulus control by the second element.

A necessary condition for demonstrating sequential overshadowing is that the dominant element of the compound stimulus reduces the amount of stimulus control by the other elements as compared with control conditions in which the weaker element is presented in the absence of the dominant element. In order to provide a control group and to allow comparison with the experiments of Weisman and Dodd, a keylight-keylight control group was employed in which the AB sequence consisted of the successive presentation of red and green stimuli on the key. To serve as a control for the backward pairing condition, another group was trained with each of the two elements of the compound presented separately. On half of the positive trials, the discriminative stimulus was food followed by a trace interval equal to the duration of the stimulus on the key for the backward pairing group. On the other half of the positive trials, the discriminative stimulus was a colored light on the key followed immediately by the second component. If food overshadows the discriminative stimulus on the key in a backward pairing arrangement, then less control should be obtained for Element B of the sequence in the backward pairing group than in the unpaired control group in which Element B is presented alone.

Method

Subjects. Thirty-two White Carneaux pigeons were maintained at 80% of their free-feeding weights. The pigeons were housed in individual cages and given free access to grit and water. The colony in which the pigeons were housed was continuously illuminated by standard basement ceiling lights.

Apparatus. Two standard three-key Lehigh Valley Electronics experimental chambers were used. The center key of each chamber was illuminated with a green, red, or white stimulus. The stimuli were projected onto the key using an Industrial Electronics Engineering inline projector (Model 10-0W78-1820-L). A house-light consisting of a GE 1820 lamp illuminated the food hopper during reinforcement. The onset of reinforcement was controlled by a Lehigh Valley Electronic Photosensor (Model 221-10). A fan, providing masking noise and ventilation, remained on during the sessions. The chambers were maintained in a separate room from the scheduling and recording equipment.

Pretraining. The pigeons were initially magazine trained and autoshaped to peck the center key. An autoshaping trial consisted of the illumination of the key with the white stimulus for 8 sec followed by access to a grain-filled hopper for 3.5 sec. The mean intertrial interval between autoshaping trials was 2 min. Each session of autoshaping was 60 min in duration and was terminated after two consecutive sessions when a pigeon emitted 100 or more responses to the white stimulus during a session.

After autoshaping, the pigeons received three 30-min sessions on a variable interval (VI) 15-sec schedule using the procedure developed by Catania and Reynolds (1968). During the sessions, the key was illuminated with the white stimulus.

Training. Following pretraining, the pigeons were divided into four groups based on the nature of the discriminative stimuli: (1) a forward pairing group in which the discriminative stimulus was the presentation of a color stimulus on the key, followed by food; (2) a backward pairing group in which the discriminative stimulus began with the presentation of food followed by the presentation of a color stimulus on the key; (3) a keylight-keylight control group in which the discriminative stimulus consisted of the successive presentation of two different colors on the key; and (4) an overshadowing control group in which the discriminative stimuli were presented separately to match the conditions in the backward conditioning group.

Discrimination training was conducted as follows. A reinforced trial (S+) began with a 3-sec presentation of Stimulus A followed, after a .5-sec interstimulus interval (ISI), by a 3-sec presentation of Stimulus B. This AB sequence was followed, after a .5-sec RI (Retention Interval), by the illumination of the center key with the white stimulus; pecking the white key was reinforced on a variable interval schedule. Only one reinforcement was given during S+, so these trials always terminated with food. The average duration of the variable interval was 15 sec, with a range from 1.5 to 44 sec. A nonreinforced trial (S-) began with the presentation of the white stimulus, which terminated automatically after 15 sec without reinforcement. The absence of either A or B is designated as X and indicates that the key was dark. An interval of 7-sec, designated XX, was interpolated between the beginning of an S- trial and the onset of the white stimulus. Thus, an S+ trial began with the stimulus sequence AB followed by the illumination of the key with white light. An S- trial began with no stimulus presentation, XX, followed by the illumination of the key with white light. The S+ and S- trials were presented randomly, and a 20-sec intertrial interval separated trials. Each session consisted of 60 trials.

For each group the durations of A and B were each 3 sec. For the forward pairing group, the AB sequence consisted of the illumination of the key for 3 sec, with the red stimulus for half of the pigeons and the green stimulus for the other half (A), followed by 3 sec of access to grain (B). For the backward pairing group, A was 3 sec access to grain and B was either red or green for a duration of 3 sec. For half of the pigeons in the keylight-keylight group, A was the green stimulus and B was the red stimulus, while for the other half of the pigeons, the stimuli were reversed.

For the overshadowing control group there were two positive stimuli presented alone, which corresponded to the elements in the backward conditioning sequence. On half the trials, the positive stimulus was AX, consisting of food followed by X for 3 sec in place of B, followed by the onset of white. On the other half of the trials, the positive stimulus was XB, consisting of the presentation of a stimulus on the key alone for 3 sec prior to the onset of the white keylight.

The mean rates of responding during white on both positive and negative trials were computed daily. From these response rates, a discrimination index was computed according to the following equation: Discrimination index = (mean response rate on positive trials)/(mean response rate on positive trials + mean response rate on negative trials). A discrimination index of .50 indicates chance performance, while a discrimination index of 1.00 indicates perfect discrimination. The criterion for completion

of discrimination training was a discrimination ratio of .90 for 2 consecutive days.

Testing. Sequence-generalization testing was carried out as follows. Each test stimulus consisted of the successive presentation of two stimulus elements for 3 sec each. The stimuli consisted of all pairwise combinations of A, B, and X, with each stimulus element in the first and second position: AA, AB, AX, BA, BB, BX, XA, XB, and XX.

A testing session began with 10 warm-up trials on the discrimination task. Then a testing sequence was presented followed by a 15-sec presentation of the white stimulus, which terminated without reinforcement. The test trial was followed by six trials of normal discrimination training and another test stimulus. This pattern was continued until all nine stimuli were presented. In each session, every bird received only one presentation of each sequence with the order of presentation varied across pigeons. Each pigeon received nine sessions of testing, with the order of testing determined by a Latin square design.

The dependent variable during testing was the rate of responding during the choice period following each of the nine test stimuli averaged over the nine sessions of testing.

Results

Acquisition. The trials to criterion for the backward pairing (18 sessions), the forward pairing (14 sessions), and the keylight-keylight control (21 sessions) groups were not significantly different ($p > .05$), but these groups differed significantly ($p < .05$) from the overshadowing control group (49 sessions). This indicates that the presence of food as a discriminative stimulus did not alter rate of acquisition as compared with the keylight-keylight control group, in which both elements of the AB sequence were keylights. An ANOVA performed on the acquisition data indicated that trials to criterion significantly varied across groups [$F(3,23) = 10.27, p < .001$]. Group comparisons were made with a Duncan Multiple range test.

Sequence generalization. Figure 1 shows the average rate of responding to each of the nine test stimuli during the choice period for the four groups during the sequence-generalization test. The data were first analyzed for each of the four groups to determine how the sequence of stimuli during the generalization test determines the rate of responding. The Newman-Keuls test was used to compare elements within a group with the probability set at $p < .05$. For both experimental groups displayed in the upper panels of Figure 1, sequences containing food generally controlled a higher rate of responding than sequences not containing food. In the forward pairing group, displayed in the upper right panel of Figure 1, the three sequences containing food as one of the elements (AB, BA, BB), and the sequence with food alone in the training position (XB), showed significantly more responding than the sequences in which neither element contained food (AA, XA, AX, and XX). The sequence with food contiguous with the second component (XB) demonstrated significantly more responding than a sequence (BX) in which food was followed by a delay interval. The rate of respond-

Figure 1. Mean rate of responding during the sequence-generalization test sessions in Experiment 1.

ing to the sequences containing the keylight alone without food (AA, AX, and XA) was significantly less than the rate to the S+ (AB), but significantly greater than the rate of responding to the S- (XX). This latter difference indicates that the keylight did gain some stimulus control over responding. The rate of responding to the keylight alone was essentially identical whether it was presented first (AX) or second (XA).

In the backward pairing group, the upper left panel of Figure 1, the three sequences containing food as one of the elements (AA, AB, BA) each showed significantly more responding than the sequences in which neither element contained food (BB, BX, XB, and XX). The rate of responding with food in the first position (AX) was not significantly different from the rate of responding with food in the second position (XA). The difference between sequence AB vs. sequence BA was not significant. The keylight alone acquired some stimulus control over responding. The rate of responding to the sequences containing the keylight alone (BB, BX, XB) was significantly less than S+ (AB) and significantly greater than S- (XX). The keylight also controlled a higher rate of responding when presented alone in the second position (XB) or when the order was reversed (BX or BB).

Next, consider the data for the two control groups, which are displayed in the lower panel of Figure 1. For the keylight-keylight control group, presented in the lower right panel of Figure 1, there were no

significant differences among the two-event sequences containing A and B (AA, AB, BA, BB) and the sequences in which either A or B was contiguous with white (XA and AB), so the control group was effective in producing approximately equal rates of responding to these stimuli. Each of the preceding sequences showed a significantly higher rate of responding than was obtained in response to the negative stimulus (XX). Intermediate rates of responding, less than AB and greater than XX, were only obtained when X was inserted between A (AX) or B (BX) and white. Sequence AX demonstrated significantly less responding than the other sequences, except BX and XX. Responding to sequence BX was significantly greater than S- (XX). The insertion of X following a stimulus resulted in a greater loss of stimulus control for A than for B.

In the overshadowing control group, the two positive stimuli were food X (AX) and X keylight (XB). The overshadowing control procedure generated rates of responding that were not significantly different among the following stimuli: AA, AB, AX, BA, XA, and XB. Therefore, this control group was also effective in producing approximately equal rates of responding to most of the test stimuli. Only Sequence BX generated a significantly lower rate of responding than each of the preceding stimuli. All of the sequences were significantly greater than S- (XX).

By comparing the forward and backward pairing groups with the keylight-keylight control group, it is possible to determine the effects of the addition of food in an AB sequence on overshadowing of the keylight. An analysis of variance performed on the data showed that the forward, backward, and keylight-keylight control groups differed significantly in rate of responding to the different sequences as a function of the occurrence and position of food during training in the AB sequence [$F(16,168) = 6.24, p < .01$].

Figure 1 shows that in the backward pairing group, sequences containing the keylight alone (BB, BX, and XB) controlled lower rates of responding than were obtained for the same sequences in the two control groups. This is the basic finding indicating that the addition of food in the backward pairing group overshadowed the keylight. In comparing the backward pairing group in which A was food and B was the discriminative stimulus with the keylight-keylight control, elements containing B were found to control significantly less responding in the backward group than in the keylight-keylight group: BB [$F(1,26) = 16.6, p < .01$]; BX [$F(1,26) = 6.21, p < .05$]; and XB [$F(1,26) = 5.43, p < .05$].

The comparison of the backward group with the overshadowing control group demonstrates that when the keylight is presented alone in conjunction with food in the experimental group, it gains less

control over responding than when it is presented alone. In comparing the backward pairing group with the overshadowing control group, responding to BB [$F(1,18) = 11.31, p < .01$] and XB [$F(1,18) = 4.79, p < .05$] was significantly lower for the backward group than for the overshadowing control group. The rate of responding to BX was not significantly different between groups [$F(1,18) = 2.99, p > .05$]. This may be due to the introduction of a delay (X) in testing because the rate of responding for AX was significantly higher in the overshadowing control [$F(1,18) = 7.14, p < .05$].

In order to determine if overshadowing was obtained in the forward pairing group, comparisons were made between this group and the keylight-keylight control group. The finding indicating overshadowing was that the rate of responding to sequences AA and XA in the forward group was lower than the rate of responding to these sequences in the keylight-keylight groups. The test sequences containing only A showed significantly less control over responding in the forward pairing group as compared with the keylight-keylight control group: AA [$F(1,29) = 7.54, p < .05$] and XA [$F(1,29) = 11.87, p < .01$]. The sequence AX, however, was not significantly different from the keylight-keylight control group.

There are three sequences in each of the experimental groups in which the keylight was presented alone without food. In five of the six comparisons between the experimental groups and the keylight-keylight control group, responding to the keylight alone was reduced in the experimental groups as compared with the control groups. Therefore, taken as a whole, these data provide support for the hypothesis that food overshadowed the color of the stimulus on the key.

EXPERIMENT 2

In these experiments, the AB sequence is a unique discriminative stimulus determining whether responding during white is reinforced or extinguished. In Experiment 1, food overshadowed the discriminative stimulus on the key when the AB sequence terminated with food. In Experiment 2, the contingencies of reinforcement were reversed from those of Experiment 1 so that the AB sequence was always associated with nonreinforcement. The purpose of this experiment was to determine if food overshadowed the keylight when each element of the AB sequence was a discriminative stimulus for nonreinforcement.

Experiments by Terry and Wagner (1975) and Bottjer and Hearst (1979) have demonstrated that a pretrial US functions as a discriminative stimulus for nonreinforcement. In Terry and Wagner's experiment, a brief electric shock delivered to the orbit of a rabbit's eye was a discriminative stimulus indicating

that a subsequent CS terminated without shock. Using an autoshaping paradigm with food as the feature, Bottjer and Hearst (1979) found that the acquisition of discriminated responding occurred more rapidly when food preceded only reinforced trials than when it preceded only nonreinforced trials.

In previous research on overshadowing (Mackintosh, 1974), the compound stimulus was always associated with reinforcement. An instance in which a compound stimulus was associated with nonreinforcement is a blocking experiment by Von Saal and Jenkins (1970). The extensive research on inhibitory stimulus control reviewed by Rilling (1977) demonstrates that stimuli associated with extinction acquire inhibitory stimulus control over responding. By associating the AB compound with nonreinforcement, the present experiment posed the question of whether food overshadowed a keylight when each event in a serial compound signaled extinction.

Method

Subjects. Twenty-four White Carneaux pigeons were maintained at 80% of their free-feeding weights. The birds were housed individually and given free access to grit and water. The pigeon colony was continuously illuminated by overhead fluorescent lighting.

Apparatus. The same chambers used in Experiment 1 were employed in Experiment 2.

Procedure. Three groups of pigeons were employed. The two experimental groups were a forward pairing group in which Element A was a keylight and Element B was food, and a backward pairing group in which Element A was food and Element B was the keylight. The third group was a keylight-keylight control group in which each element of the AB sequence was a discriminative stimulus on the key. Increased rates of responding to the discriminative stimuli for the experimental groups as compared with the control group provide evidence of loss of stimulus control because the AB sequence itself controlled a low rate of responding as a result of discrimination training as S-. Pretraining was identical to the method utilized in Experiment 1. Following pretraining, the pigeons were divided into three groups: (1) a forward pairing group in which the discriminative stimulus was a keylight-food presentation; (2) a backward pairing group in which the discriminative stimulus began with the presentation of food followed by a keylight; and (3) a keylight-keylight control group in which the discriminative stimulus was a green stimulus followed by a red stimulus on the same key.

The procedure for Experiment 2 was identical to that of Experiment 1 except that the discriminative stimulus was presented prior to nonreinforced rather than reinforced trials as in Experiment 1. That is, AB sequences signaled S- trials and XX signaled S+ trials.

The testing procedure was identical to the testing procedure employed in Experiment 1.

Results

Acquisition. The keylight-keylight control group required more sessions to reach criterion on the discrimination than either the food-keylight or keylight-food experimental groups. The control group required a mean of 38.8 sessions to reach criterion, whereas the food-keylight and keylight-food groups required means of 17.6 and 13.8 sessions, respectively. Due

to the finding that the control group had a significantly larger variance than the experimental groups [$F_{\max}(3,7) = 1,354, p < .01$], degrees of freedom were adjusted according to Box's suggestion (see Winer, 1962, p. 206) prior to conducting an analysis of variance on these acquisition data. The results of this analysis yielded a significant treatment effect [$F(1,7) = 11.7, p < .05$]. Subsequent analyses used Dunnett's *t* test to compare the two experimental groups with the control group. Both the food-keylight group, [$t(7) = 3.8, p < .01$] and the keylight-food group [$t(7) = 4.5, p < .01$] were significantly different from the keylight-keylight control group. These analyses indicate that when food is one of the discriminative stimuli in an AB sequence, acquisition of a discrimination is facilitated in comparison with a group that does not have food as a discriminative stimulus. This facilitation was evident whether food was in the first or second position of an AB sequence.

Another comparison of interest is whether the keylight-keylight control group in Experiment 1 acquired the discrimination faster than the keylight-keylight control group in Experiment 2. In Experiment 1, the discriminative stimuli preceded S+, whereas in Experiment 2, the discriminative stimuli preceded S-. Since the variance of the control group of Experiment 2 was significantly greater than that of Experiment 1 [$F(7,7) = 55.6, p < .01$], degrees of freedom were adjusted prior to statistical analysis. Experiment-2 controls took significantly longer to reach criterion than the Experiment-1 controls [38.8 vs. 21.2 days; $t(7) = 2.6, p < .05$]. Thus, birds in the present experiments learned the discrimination faster if the keylight discriminative stimuli preceded S+ rather than S-.

Sequence generalization. Figure 2 shows the results of the sequence-generalization test as the average rate of responding to each of the nine test stimuli for the three groups. As a result of discriminative training, the highest rate of responding during white was obtained following S+(XX), and the lowest rate of responding during white was obtained following S- (AB), the negative stimulus. The groups differed in their rates of responding to S+, with the control group showing a substantially higher rate of responding to S+ than was obtained for the experimental groups. In order to permit a comparison between the groups, the data were transformed by arbitrarily assigning the S+ stimulus a value of 100% and expressing the data for the other test stimuli in terms of the percentage of responses to S+. The analysis of variance was then computed on the transformed data.

The data were first analyzed for each of the three groups to determine how the sequence of stimuli during the generalization test determined the rate of responding. The Newman-Keuls test was again used to compare elements within a group with the

Figure 2. Mean rate of responding during the sequence-generalization test sessions in Experiment 2.

probability set at the $< .05$ level. For the backward pairing group, the test sequences can be divided into two sets. Each test sequence containing food, Element A, controlled a low rate of responding that was not significantly greater than the rate of responding to the AB sequence employed as S-. These sequences were: AA, AX, BA, and XA. The other set consisted of those test sequences consisting of Element B, the discriminative stimulus on the key without food, sequences BB, BX, and XB. These sequences controlled relatively high rates of responding that were not significantly less than the rate of responding to S+ (XX). Sequences BB, BX, and XB each showed significantly greater responding than did AB, BA, AA, AX, and XA, demonstrating that Stimulus B, the stimulus on the key, failed to acquire control over a low rate of responding.

The results for the forward pairing group demonstrate greater sensitivity to the order of the AB sequence than was obtained for the backward pairing group. Sequences containing food did not invariably control a low rate of responding. Only when food was contiguous with the white key in the second position employed during discrimination training, Sequences BB and XB, was there no significant difference from the rate of responding to the AB sequence employed as S-. Two sequences containing food

reversed from the order employed during training, BA and BX, showed significantly more responding than was obtained with the normal AB sequence. The finding that reversing the order of S- from AB to BA produced a significant increase in the rate of responding is evidence that the birds in the forward pairing group were sensitive to the order in which the stimuli occurred.

Sequences AA, AX, and XA, consisting of the presentation of the discriminative stimulus on the key without food, controlled relatively high rates of responding that were not significantly different from the rate of responding to S+ (XX), but were each significantly greater than responding to S-. The data for sequences AA, AX, and XA suggest that the keylight was completely overshadowed by food as a discriminative stimulus for nonreinforcement.

In summary, the data for the forward and backward pairing groups demonstrate that food in the position employed during training, not the discriminative stimulus on the key, acquired control over the low rate of responding.

The data for the control group are presented in the lower panel of Figure 2. The data show that any sequence containing A and B as the two elements (AA, AB, BA, or BB) or a sequence containing A or B as the last event (XA and XB) controlled a low rate of responding that was not significantly greater than the rate of responding to S- (AB) that was obtained. These data suggest that the birds in the control group failed to differentiate Stimulus A from Stimulus B when the AB sequence predicted nonreinforcement. Each element was equally effective in controlling a low rate of responding. The presentation of A or B alone followed by X (AX and BX) produced rates of responding that were not significantly different from the rate of responding to S+ (XX). The only exception was sequence XA, which produced an intermediate rate of responding significantly less than that to S+ and significantly greater than that to S-. In summary, the data for the control group demonstrated that any two-element sequence consisting of A and B or the single-element sequences of A or B in the second position acquired control over a low rate of responding.

By comparing the forward and backward conditioning groups with the control group, it is possible to determine if food overshadowed the keylight. An analysis of variance performed on the data showed that the forward, backward, and control groups differed significantly in the percentage of responding to the sequences as a function of the occurrence and position of food during testing in the AB sequence [$F(16,168) = 9.67, p < .01$].

In Experiment 2, the AB sequence preceded nonreinforcement and acquired control over a low rate of responding during white. Therefore, overshadowing

is measured as a significant increase in responding on test trials for the forward and backward conditioning groups as compared with the control group. To determine changes in stimulus control between individual sequences, the data were analyzed using the Newman-Keuls test. A comparison of the backward conditioning group, in which A was food and B was the discriminative stimulus, with the control group demonstrated that elements containing B alone contiguous with white, BB and XB, controlled significantly more responding in the backward conditioning group than in the control group. The addition of food in the backward conditioning group overshadowed the discriminative stimulus on the key, which was reflected in increased responding when it was presented alone in sequences BB and XB on test trials.

In the forward conditioning group, more responses were obtained following sequences containing the keylight alone than were obtained for the control group. Test sequence AA showed significantly more responses in the forward conditioning group than were obtained for the control group. The groups were not significantly different with respect to Sequence AX. The data for Sequence AA suggest that the presence of food in the forward conditioning group overshadowed the discriminative stimulus on the key. Therefore, the major effect of the addition of food was to essentially eliminate control by the discriminative stimulus on the key to function as a discriminative stimulus for nonreinforcement.

DISCUSSION

When food and a keylight were presented in a serial compound as discriminative stimuli for successive operant behavior, food overshadowed the keylight, demonstrating that the salience of food was the primary determinant of stimulus control. Therefore, these data confirm Staddon's (1974) assumption that food overshadows the stimulus on the key. Two types of serial compounds were employed, with food presented in a forward or backward pairing arrangement. In the backward pairing condition, the keylight had a more favorable temporal relationship with the events that terminated the sequence. Nevertheless, food still dominated stimulus control in the backward pairing arrangement, demonstrating that salience was more important than recency.

The keylight acquired stimulus control, so that overshadowing was not complete when the AB sequence was S+ and terminated with food in Experiment 1. Food was more effective in overshadowing the keylight when the sequence functioned as S- and terminated with nonreinforcement in Experiment 2. Although the AB sequence controlled a low rate of responding and was an effective S-, high rates of responding similar to those to S+ were observed for the sequences containing the keylight alone: AA, AX, and XA.

Weisman and Dodd (1979) obtained more evidence of control by each sequence in the sequence-generalization test than was observed in the similar keylight-keylight condition of Experiment 1. Figure 1 shows that little differentiation of test sequences from AB occurred, in contrast with the more extensive differentiation obtained during the sequence-generalization test by Weisman and Dodd. The differences between these two experiments are most likely attributable to the different procedures employed during discrimination training prior to the sequence-generalization test. Weisman and Dodd employed a differentiation procedure in which each of the eight sequences other than S+ was established as a negative discriminative stimulus. In the present experiment, the only negative discriminative stimulus presented prior to the sequence-generalization test was S-. Thus, these data suggest that the differentiation procedure facilitated the acquisition of stimulus control by the order of the AB sequence.

A comparison of the data of Experiment 1 with the data of Experiment 2 is relevant to the question of whether the acquisition of stimulus control by a sequence preceding reinforcement is the same or different from the acquisition of stimulus control by a sequence preceding nonreinforcement. The present data add to the well-established findings, reviewed by Hearst (1978), associating the discriminative stimulus with extinction retards acquisition.

The overshadowing paradigm was originally conceived as a procedure in which stimulus control by the less salient element of a compound stimulus was reduced when the less salient element was presented simultaneously with a more salient element. The present results demonstrate that simultaneous presentation of the elements of the compound stimulus is not necessary to obtain overshadowing. Overshadowing was consistently obtained in the present experiments when the compounds were presented sequentially, independently of whether a forward or backward pairing arrangement was employed. Another experiment in which forward and backward pairings of a CS with a US were employed as discriminative stimuli is that of Terry (1976), who used eyelid conditioning in the rabbit as the dependent variable. Less conditioning was observed on trials in which the standard pairings of the CS with the US were shortly preceded by a presentation of the US prior to the CS than on trials in which a prior US was not presented. The data of several experiments, including those of Domjan and Best's (1977) work on overshadowing in taste aversion learning, indicate that one of the properties of a US is that of overshadowing a CS when a sequential compound is employed as a discriminative stimulus.

In the typical operant conditioning experiment with pigeons, the three elements with the potential for stimulus control are food, the stimulus on the key, and the response-produced stimuli of pecking

the key. Each of these elements has been demonstrated to produce stimulus control. For example, Rilling (1967) demonstrated that the number of responses on the key acquires stimulus control. In the present experiments, more overshadowing was obtained when the keylight was presented in the backward rather than in a forward pairing arrangement. Our observations indicated that the backward pairing arrangement produced less pecking on the key than the forward pairing arrangement. It is possible that the stimulus control by the keylight in the forward position is increased by response-produced stimuli. However, most theories of learning predict that the associative value of a stimulus preceding food in the forward pairing arrangement is greater than that of a stimulus in a backward pairing arrangement. Therefore, the present experiments were not designed to differentiate between stimulus control by the events on the key and stimulus control by response-produced stimuli.

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