ON THE FAILURE AND FACILITATION OF CONDITIONAL DISCRIMINATION

BEN A. WILLIAMS

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Pigeons acquired a conditional discrimination in an autoshaping procedure in which certain stimulus combinations (form plus color) were followed by food, whereas others were not followed by food. Although the discrimination normally was acquired quickly, it was completely prevented when the color elements of the stimulus compounds were presented during the intertrial intervals preceding the trials in which both stimulus elements were available. This failure of discrimination was then prevented by having the colors serve as houselights rather than being localized on the response key and by pretraining procedures in which the colors were utilized in simpler discriminations. The results suggest that stimulus salience plays a critical role in determining whether conditional discriminations will be acquired, as the effects of all of the different operations could be understood in terms of increasing or decreasing the salience of the color elements, above or below some threshold value.

Key words: conditional discrimination, autoshaping, attention, stimulus validity, successive discrimination, pigeons

The concept of relative stimulus validity has played an important role in theoretical accounts of stimulus control. According to that concept, conditioning to a stimulus is not merely the function of its association with reinforcement but also is a function of how the degree of that association compares with the degree of association for other stimuli that also are present. This phenomenon is illustrated by the well known study of Wagner, Logan, Haberlandt, and Price (1968), who compared the acquisition of stimulus control by a light for two groups of rats, each of which received the light paired with reinforcement on 50% of the trials. For both groups the light was presented in compound with two tones, which alternated over trials. The groups differed with respect to the correlation between the tones and reinforcement: For one group, one of the tones was always paired with the reinforcer, whereas the second tone was always

associated with extinction; for the second group, each of the two tones was followed by reinforcement on 50% of the trials. For the correlated group, the light failed to gain stimulus control. For the uncorrelated group, however, which received an identical series of light-reinforcer pairings, substantial control by the light did occur. Thus, in the correlated group, the fact that the tones were relatively more predictive of reinforcement prevented stimulus control by the light.

Although relative validity (or predictiveness) appears to be a critical concept for understanding the acquisition of simple discriminations, its application to conditional discriminations seems much more complicated. The problem is that a stimulus considered in isolation may bear a predictive relation to the reinforcer that is quite different from that when the stimulus is considered as part of a stimulus compound. That is, a stimulus may be a poor predictor of reinforcement when considered in isolation but be a strong predictor when considered in conjunction with a second stimulus. The issue is how these different measures of stimulus validity interact to determine whether control by the stimulus element will occur.

An example of the problem posed by conditional discriminations comes from the investigation of the "feature-positive effect" (Jenkins

This research was supported by NIMH research grants 1 R03 MH3499-01 and 1 R01 MH35572-01. Portions of this research were reported at the 1981 meeting of the Psychonomics Society. The author thanks Drs. Marcia Spetch and Edmund Fantino for their helpful comments on an earlier version of the manuscript. Reprint requests should be addressed to Ben A. Williams, Department of Psychology, C-009, University of California, San Diego, La Jolla, California 92093.

& Sainsbury, 1970). When animals are successively presented with two stimuli that differ only with respect to a single distinctive feature, differential responding occurs very quickly when the stimulus with the feature is positive but often does not occur when the feature is located on the negative stimulus. The apparent reason for the failure is that the subject learns not to respond to the feature itself (since, considered in isolation, it is associated with extinction) and then responds to one of the other features that is common to both stimuli (which, considering both positive and negative trials, is associated with reward on 50% of the trials). Such a finding is puzzling because the animal must discriminate the feature in order to avoid pecking it, so the question becomes why the subject does not use the feature as a conditional cue, which would instruct the subject that the common features have different values on different trials. In other words, why is the relative validity of the distinctive feature based on its relation to reward in isolation, instead of its relation as part of the stimulus compound?

The present series of experiments reports a new phenomenon, analogous to the feature-negative effect, showing that pigeons fail to acquire a simple conditional discrimination even after prolonged training. The basic discrimination studied throughout all of the experiments involved the simultaneous presentation of two response keys in an autoshaping procedure. One key was illuminated with either red or green; the second key was illuminated with a line or a circle. The discrimination contingency was imposed by presenting food after the combinations of red + circle and green + line and no food after the combinations of red + line and green + circle. Responding was not required for reinforcement at any time during training. Conditional discrimination has been studied previously with an autoshaping procedure (Looney, Cohen, Brady, & Cohen, 1977) but with the elements presented successively rather than simultaneously.

The major variable of interest was whether the color key was illuminated during the intertrial interval (ITI) separating the different trial presentations. The color that was scheduled on the next trial was presented prior to the onset of the trial throughout the ITI. Be-

cause stimulus control by both colors and forms was necessary for acquisition of the discrimination, one prediction is that their simultaneous presentation should generate competition between the two cues for attention, so presenting one of the cues prior to the onset of the second might be expected to facilitate the discrimination. On the other hand, when the colors are considered in isolation, their presentation during the ITI greatly reduces their own predictiveness of reinforcement, so such a manipulation might be expected to retard the discrimination. The issue, therefore, is which method of calculating stimulus validity—that for the colors as part of the stimulus compound or that for the colors in isolation—would determine how the discrimination would be acquired.

EXPERIMENT I

METHOD

Subjects

Eight experimentally naive White Carneaux pigeons were maintained at 80% of their free-feeding body weights by additional feeding, when necessary, after the completion of an experimental session.

Apparatus

The conditioning chamber was assembled with components of a Coulbourn modular test cage, Model # E10-10. The top, and front and back walls were aluminum, and the two sides were made of clear glass. A set of metal grids served as the floor. The bird's chamber was 30.5 cm high, 30.5 cm deep, and 25 cm wide. On the left side of the front panel were mounted two response keys, arranged top to bottom, spaced 3.0 cm apart, edge to edge, with each key 2.5 cm in diameter. The bottom edge of the bottom key was 16.3 cm from the grid floor. The stimuli were projected onto the rear of the keys by 28-V 12-stimulus projectors (Coulbourn Model #E21-18, bulb #1820). The bottom key was illuminated with either a diffuse red or green light, which covered the entire key. The top key was illuminated with either a white circle, 1.3 cm in diameter, on a dark background, or a white horizontal line, .6 cm in width and 2.5 cm in length, also on a dark background. Located on the middle seg-

ment of the front panel was the grain hopper, with an opening 5.7 cm high and 5.4 cm wide, with the bottom edge 2.5 cm off the floor. Located on the right side of the front panel, directly below the ceiling, was a shielded 28-V dc houselight that provided diffuse white light for the entire chamber at all times during an experimental session. The interior chamber was enclosed in a larger sound-insulated chamber, which was equipped with a loud ventilating fan that served to mask extraneous noise.

Procedure

All subjects were trained to eat from the grain hopper on the first day of training. The hopper was raised when the bird was placed in the chamber and remained up until the bird ate for 30 seconds. The hopper was then lowered and raised repeatedly until the bird ate immediately upon its presentation. Throughout this first session neither response key was illuminated.

The autoshaping procedure, with the discrimination imposed from the first session, was begun the next day. Both keylights were illuminated simultaneously for 5 sec, followed by 3-sec access to the grain hopper on positive (S+) trials and by the keys darkening for the same 3-sec period on negative (S-) trials. Separating all trials was a constant 25-sec ITI. Positive and negative trials were interspersed on a quasirandom basis, determined by a Gerbrands cam stepper (Model #G4642). Positive trials were those on which the combinations of green + line or red + circle were presented; negative trials were presentations of green + circle or red + line. Forty presentations of each trial type were given each session, for a total of 160 trials per sessions.

Four subjects were assigned to each of the two experimental conditions. The control group received the procedure just outlined, as neither keylight was illuminated except during the 5-sec trial periods. The ITI group received the identical procedure with one modification: The color that was scheduled to occur on a trial was presented during the entire ITI preceding the trial.

After 20 sessions under the conditions just described, the experimental conditions were reversed, with the control group now having the colors illuminated during the ITI, and the ITI group having the colors illuminated only

during the trial periods. Training on those conditions continued for 10 sessions.

RESULTS

Figure 1 shows the proportion of the total pecks, summed over both keys, that occurred to the S+ combinations. All subjects in the control condition acquired differential behavior to the positive and negative compounds over the first 20 sessions of training. In contrast, none of the subjects in the ITI condition acquired the discrimination, as the discrimination index remained near .50 throughout the first phase of training.

The second segment of Figure 1 shows the effect of reversing the conditions for the two groups (note that the unfilled/filled circles correspond to the original group designations, not the conditions in effect during the second phase of training). When subjects in the control group had the colors on in the ITI, a transient disruption of the discrimination occurred, followed by recovery to the previous level. Thus, the effect seen in the first segment of Figure 1 was not reversible, as presenting the color in the ITI did not abolish the discrimination once it was established.

For the subjects in the ITI group, removing the colors during the ITI produced an immediate change in discrimination behavior, which continued over the 10 sessions of training (although one subject did not learn the discrimination: see Table 1). This implies that the disruptive effects of the colors in the ITI

Fig. 1. Proportions of the responses to the stimulus compounds that were correct, averaged over subjects in Experiment 1. Note that the group designations refer to the initial assignment, so that the control group in the reversal phase had the colors on during the ITI.

did not continue after the colors were removed from the ITI.

Table 1 shows the data for individual subjects during the last four sessions of each phase of training. In addition to the discrimination index, the table shows the percentage of pecks that occurred to the color key, separately for S+ and S- trials. First considering the ITI group, it is evident that none of the subjects emitted any significant amount of behavior to the color key, during either phase of training. Apparently, the effect of presenting the colors during the ITI was to eliminate pecking to it, and pecking still did not occur after the colors were presented only during those trial periods.

The subjects in the control group were more variable in their pattern of pecking. Two of the four subjects never pecked the color key during the initial phase of training, despite the colors being presented only during trial periods. The remaining two subjects distributed their pecks equally between the color and form cues, although not randomly across trials. That is, during one S+ combination they always pecked the form cue, whereas during the other S+ compound they pecked the color cue (the two subjects had the opposite pattern).

When the control group was presented the colors during the ITI (the reversal condition), the percentage of correct pecks was affected very little, but there was a major change in the distribution of pecks. Namely, the two subjects that previously had emitted approximately 50% of their pecks to the color key now ceased pecking the color key entirely. Thus,

changes in the distribution of pecking were independent of discrimination accuracy.

DISCUSSION

The results of Experiment 1 show that a conditional discrimination can be entirely prevented if one of the stimuli is presented continuously. This result is just the opposite of that predicted on the basis of competition between the two cues, as it was assumed that having prior information about the colors would facilitate the discrimination rather than prevent it. Apparently, therefore, presentation of the colors during the ITI had some effect other than providing information about the predictive value of the form cues.

The simplest explanation of the results is that the continuous presentation of the colors during the ITI caused the colors to be ignored as salient events, perhaps because they did not predict the temporal occurrence of food. The details of performance were partially consistent with this "loss-of-salience" hypothesis. Table 1 shows that none of the subjects of the ITI group developed any significant pecking to the colors. Failure to peck the colors is obviously consistent with the notion that the birds learned to ignore the colors as effective stimuli. But it is also clear that responding to the colors is not a reliable index of the use of the colors as conditional cues. This is shown by the behavior of the control group when the conditions were reversed. Whereas Figure 1 shows that their discrimination accuracy was only momentarily disrupted by the switch, Table 1 shows that all of the subjects completely ceased responding to the colors.

The major difficulty with the "loss-of-salience" hypothesis is that the ITI group quickly acquired the discrimination after the reversal of conditions, when the colors were removed from the ITI. Of major interest was the rate of acquisition. If it were true that the colors had lost salience during the first phase of training, then it should be expected that this loss would carry over to the second phase of training. As shown by the right segment of Figure 1, however, the rate of acquisition was not retarded, at least in comparison to the original rate of acquisition for the control group. Thus, if the salience of the colors was affected during the ITI condition, those effects apparently were temporary in nature.

Table 1

Percentages of total pecks that were correct and percentage of total pecks to the color key, shown separately for S+ and S- trials. Data are from Experiment 1.

		INITIAL CONDITIONS			REVERSAL		
		correct %	% color pecks S+	% S-	% correct	% color pecks S+	% S-
ITI GROUP	S-1	51	0	0	50	0	0
	S-2	50	0	0	72	0	0
	S-3	50	0	0	80	0	5
	S-4	51	0	0	81	0	0
CONTROL	S-5	65	0	0	55	0	0
	S-6	69	45	88	79	0	1
	S-7	87	0	0	93	0	0
	S-8	82	51	36	85	2	0

EXPERIMENT 2

The foregoing discussion assumes that the failure of discrimination seen with the ITI group in Experiment 1 is a reliable phenomenon. It is possible, however, that it is restricted to some idiosyncratic feature of the stimulus arrangement that was used. For example, there was apparently some difference in the salience of the form and color elements, as control subjects emitted somewhat more responding to the form elements (see Table 1). In order to establish the generality of the finding, therefore, Experiment 2 used a different stimulus arrangement.

A second issue investigated by Experiment 2 was whether the failure of discrimination depended on the presentation of the colors during the ITI, per se, or whether it depended on the color key remaining unchanged at the time of trial onset. It is possible that the subject notices only those stimuli that vary just prior to reinforcer delivery, so that the discrimination could be facilitated if the colors changed at the trial onset. To test this possibility, the color key was once again illuminated during the ITI, but now the color that was illuminated was the color from the just-preceding trial. If a different color was then scheduled, the color key then changed at the time of trial onset simultaneously with the illumination of the form key.

METHOD

Subjects

Four experimentally naive White Carneaux pigeons were maintained of 80% of their free-feeding body weights.

Apparatus

The conditioning chamber was identical to that used in Experiment 1 except for the location of the response keys on the front panel. Instead of the vertical arrangement of Experiment 1, the response keys were arranged side-to-side. The response key associated with the color stimuli was located in the center of the chamber, approximately 13 cm above the grain hopper. The key associated with the form stimulus was located at the same level as the color key, but 5.7 cm to its right, measured edge to edge. The stimuli presented were the same as those in Experiment 1, with one exception. In place of the white circle used in Experiment 1

that was 1.3 cm in diameter, a smaller circle was used, .6 cm in diameter. This substitution was made in order to make the two form stimuli also differ in brightness.

Procedure

The initial condition presented to all subjects was similar to the ITI conditions described for Experiment 1. Trial periods were 5 sec in duration, with combinations of red + circle and green + line being positive trials, followed by 3 sec of food, whereas combinations of red + line and green + circle were negative trials, followed by periods with both keylights extinguished for the 3-sec period. The color cue that had occurred on the last trial was then continued throughout the 25-sec ITI. The color for the next trial, if different, was then presented at the beginning of the 5-sec trial period.

The ITI condition was continued for a total of 25 sessions, each 160 trials in duration. All subjects were then switched to the control condition for 20 sessions, where the only change was that the color key was no longer illuminated during the ITI.

RESULTS

Figure 2 shows the results for individual subjects. The first segment shows the results with the ITI condition, as none of the subjects showed any evidence of acquiring the discrimination. The second segment shows the effect of removing the colors during the ITI, and there all subjects acquired the discrimination, at least to some degree.

The distribution of pecks to the individual stimulus elements was similar for all subjects and similar to that of the ITI subjects in Experiment 1. That is, all subjects pecked only the form key during the ITI condition and continued that pattern after the switch to the control condition. One subject, represented by the unfilled circles in Figure 2, did peck the color key occasionally (5 to 10% of its total pecks during the second phase of training).

DISCUSSION

The results of Experiment 2 show that the failure of discrimination with the ITI condition has at least some generality. Although the stimulus elements used in Experiment 2 were similar to those of Experiment 1, the arrangement of the response keys was substantially

Fig. 2. Proportions of the responses to the S+ compounds for individual subjects in Experiment 2. Colors were on during the ITI during the first 25 sessions and off for the last 20 sessions.

different, and yet identical results were obtained. The arrangement of response keys could be an important variable, since observation of the color key was necessary for the acquisition of the discrimination. The arrangement of the color key was explicitly intended to encourage such observation for both experiments, as the color key was always the one closer to the food hopper. Yet in both cases, the colors were not utilized as conditional cues when they are presented in the ITI.

The results also show that changing the color just prior to reinforcement was not sufficient to cause attention to color. This is somewhat surprising, since the stimulus change that occurred on the color key prior to reinforcement might be expected to enhance the attention value of that stimulus. Nevertheless, the effect of presenting the colors during the ITI was sufficiently strong to override any such attention-enhancement effect.

EXPERIMENT 3

The data of the first two experiments show that the acquisition of the conditional discrimination could be prevented completely by presentation of the color elements throughout the ITI. Experiment 3 asks whether a similar effect occurs when the colors are presented only

during a portion of the ITI. For one group the colors were illuminated only after 10 seconds of the 25-sec ITI had elapsed and then remained illuminated for the remaining 15 seconds of the ITI and throughout the 5-sec trial period where the form key was also illuminated. For the second group, the color key was not illuminated until 20 sec of the ITI had elapsed.

METHOD

The subjects were eight experimentally naive White Carneaux pigeons maintained at 80% of their free-feeding weights. The apparatus was the same as Experiment 1.

The procedure was identical to Experiment 1 in all respects except for the presentation of the colors during the ITI. For the 15/25 group the color key was dark for the first 10 sec of the ITI and then remained on during the last 15 sec. For the 5/25 group, the color key was dark for the first 20 sec and was illuminated during the last 5 sec. For both groups the colors then remained on during the trial when the form key was also illuminated. Training continued for 20 sessions.

RESULTS

The mean proportion of correct responses for each group is shown in Figure 3. One subject from the 5/25 group was excluded because it never developed key pecking to either response key. Thus, the mean for that group includes only three subjects rather than four. It is evident from Figure 3 that the 5/25 group produced discrimination performance comparable to that of the control group of Experiment 1 (and perhaps even faster discrimination). For the 15/25 group, on the other hand, discrimination acquisition was generally poor, with the greater-than-chance accuracy due primarily to one subject.

During the last four sessions shown in Figure 3, the percentage of pecks that were to the S+ stimulus compounds was 94, 82, and 99 for the three subjects in the 5/25 group, and 51, 50, 57, and 85 for the four subjects in the 15/25 group. The groups also differed with respect to the distribution of pecks to the two keys. None of the 15/25 subjects emitted a significant amount of pecking to the color key, either during the ITI or during the trial itself. On the other hand, all three of the 5/25 subjects pecked the color key at a high rate during the

BLOCKS OF TWO SESSIONS

Fig. 3. Proportions of the responses to the S+ stimulus averaged over subjects in the two groups of Experiment 3.

5-sec period in which it was on alone but then switched their pecking to the form key when it was illuminated during the trial period. For two of the 5/25 subjects there was a small amount of pecking to the color key during the trial period as well, although these apparently were run-over pecks from the period that preceded.

DISCUSSION

The results of Experiment 3 show that the conditional discrimination can be prevented by presentation of the colors during only a portion of the ITI. However, the proportion of the ITI that is involved does appear to be the critical variable. There was no apparent attenuation of the acquisition of the discrimination when the color key was illuminated only during the last 5 sec of the ITI, but a major effect when it was illuminated during the last 15 sec (although one subject did learn even under the latter condition). Because the latter condition entailed that there were 10 sec of the ITI when the color key was not illuminated, this implies that the discrimination could be retarded even when the color key was not continuously illuminated.

The failure of the 15/25 subjects either to develop pecking to the color key, or to use color as a conditional cue, has a parallel in the findings on simple autoshaping. Gibbon, Locurto, and Terrace (1975) reported that autoshaping did not occur if the trial periods oc-

cupied 75% of the total session time. Such a finding shows that autoshaping does not occur simply because the S+ is alternated with a period of extinction, which is the implication of most major theories of conditioning (e.g., Rescorla & Wagner, 1972). Rather, there is some threshold level of predictiveness that is necessary, where the calculation of predictiveness also includes signal frequency as a major factor (cf. Gibbon, 1981). The present data suggest that a comparable effect operates for the acquisition of conditional discriminations, as the presentation of the color cues for more than half of the ITI seems sufficient to prevent the utilization of the colors as conditional cues.

EXPERIMENT 4

The first three experiments demonstrate that presentation of the colors during the ITI prevents the conditional discrimination from being acquired. It remains unclear, however, whether the failure of discrimination is unique to the conditional discrimination problem. It is possible, for example, that the continuous presentation of the colors would have prevented the use of the colors in the acquisition of any discrimination contingency. As noted above, there is some evidence for this from studies on autoshaping (Gibbon et al., 1975) in which pecking to a keylight signal failed to occur when the signal was presented for durations longer than the ITI.

To test this possibility, Experiment 4 once again employed the same continuous presentations of the colors during the ITI but with a simpler contingency. The problem was in fact one-half of the conditional discrimination that had been used previously. That is, two of the four stimulus combinations were used, so that the combination of red + circle was always followed by food, whereas the combination of green + circle was never followed by food. In addition to involving a smaller number of stimulus compounds, this simpler problem also imposed a correlation between color and food that had not occurred previously, i.e., green now was never associated with food, whereas previously each color had been paired with food on 50% of the trials. After training with this simpler discrimination, the pigeons then were presented the original conditional discrimination involving all four stimulus compounds.

METHOD

Four experimentally naive White Carneaux pigeons were maintained at 80% of their free-feeding body weights. The apparatus was the same as Experiment 1.

After the first session that was used for hopper training, all subjects were immediately exposed to an autoshaping procedure involving the combinations of red + circle and green + circle. The circle was presented during each 5-sec trial period and was followed by food when accompanied by red but no food when accompanied by green. The colors alternated quasirandomly across trials, with the color that was scheduled for a particular trial being presented throughout the ITI (25 sec) preceding the trial. A total of 16 sessions were conducted under these conditions.

After the discrimination involving only the two stimulus combinations, the remaining two combinations were added, using a procedure identical to the ITI conditions of Experiment 1. A total of 20 sessions were conducted under these conditions.

RESULTS

The first segment of Figure 4 shows the acquisition of the discrimination that involved only the red + circle vs. green + circle combinations. All subjects acquired the discrimination, showing that the presentation of the colors during the ITI did not prevent the discrimination in the same manner that it did with the more complex discrimination that was used in the earlier experiments.

The second segment of Figure 4 shows the discrimination performance after the remaining two stimulus combinations were added. Although the discrimination was initially disrupted, all subjects rapidly improved their discrimination performance over the next 5 to 10 sessions. Thus, the failure of discrimination that occurred in the earlier experiments was prevented when the discrimination was preceded by training with the easier discrimination.

Figure 5 shows the discrimination performance for the second phase broken into trials that involved the old stimulus combinations (those involving the circle) vs. those that were new (those involving the lines). The results are presented in terms of the means of the four subjects because all subjects showed similar

BLOCKS OF FOUR SESSIONS

Fig. 4. Proportions of the responses that were to the S+ stimuli, for individual subjects in Experiment 4. The first segment represents the discrimination involving only the compounds that included the circle. The second segment represented the discrimination involving all four stimulus compounds that were used in previous experiments.

behavior. As is evident, performance with the old stimulus combinations was somewhat disrupted (compare the last block of Phase 1 in Figure 4 with the first block in Figure 5) but remained considerably above chance. In contrast, discrimination with the new combinations was initially at a chance level, then gradually increased, but remained consistently inferior to the discrimination with the old combinations. The difference seen in Figure 5 was due entirely to responding to the S- combinations: Subjects generally responded with low rates on green + circle trials but at high rates on the red + line trials.

DISCUSSION

Experiment 4 demonstrates that the continuous presentation of the colors during the ITI is not sufficient to prevent the discrimination based on color. The issue posed, therefore, is why the discrimination was learned in the present case but not in Experiments 1 and 2. Either of two procedural differences may account for the discrepant results. First, in Experiment 4 the colors themselves were differently correlated with reinforcement, as food occurred only following red, never following green. Thus, the

Fig. 5. Data corresponding to the second segment of Figure 4, broken down into old stimulus compounds (circle) and new stimulus compounds (line). The data are the averages of the four subjects in Experiment 4.

initial discrimination presented in Phase 1 was not a conditional discrimination in a true sense. It is possible, therefore, that simple discriminations and conditional discriminations are affected differently by the continuous presence of the color cues during the ITI. Second, the discrimination used in Phase 1 was less complex, in the sense that two rather than four stimulus compounds were involved. Thus, it may be that some threshold level of discrimination difficulty is necessary, independent of whether the discrimination is conditional in nature, before the effect of continuous color presentations becomes evident.

A second major finding of Experiment 4 was the successful acquisition of the conditional discrimination during Phase 2, after prior training on the simpler discrimination. It is perhaps not surprising that differential behavior to the stimulus compounds involving the circle continued to occur during Phase 2, since

the red + circle and green + circle compounds had been highly discriminated during Phase 1. More surprising was the subsequent acquisition of the discrimination between green + line and red + line, which had not been presented previously. Unlike Experiments 1 and 2, here all subjects acquired differential behavior to these new stimuli, despite the color again being present in the ITI. This implies that the prior training in Phase 1 with the easier discrimination increased the salience of the colors, such that the normally deleterious effect of color presentation during the ITI was prevented. Such a possibility suggests that other methods of changing the salience of the color cues might also facilitate the conditional discrimination.

EXPERIMENT 5

One implication of the results of Experiment 4 is that the acquisition of the conditional discrimination is dependent on the frequency with which the different stimulus combinations are interspersed. That is, if training with red + circle vs. green + circle had been followed by training with green + line vs. red + line (instead of training with all four compounds interspersed together), it seems certain that the second simple discrimination also would have been learned. Thus, the issue is why the conditional discrimination is not acquired when the different combinations are interspersed across trials within a session (e.g., the conditions of Experiment 1), rather than across blocks of sessions.

Experiment 5 investigated whether the method of interspersal is a critical variable. The four stimulus combinations were divided according to the form stimulus involved, so that some sessions involved training only with red + circle vs. green + circle, whereas other sessions involved green + line vs. red + line. One group of subjects had the different problems presented on alternate sessions; a second group had the two discriminations presented for alternate blocks of five sessions.

METHOD

The subjects were eight experimentally naive White Carneaux pigeons maintained at 80% of their free-feeding weights. The apparatus was the same as Experiment 2.

The subjects were assigned to two groups that were presented different periods of training with the problems of red + circle (S+) vs. green + circle (S-), and green + line (S+) vs. red + line (S-). The procedure was the same for both problems, except for the form stimulus that was presented. The color scheduled for the next trial was presented at the beginning of the ITI (25 sec) and then continued throughout the trial period (5 sec), during which time the form element was added. Response-independent food was presented after S+ trials; no food after S- trials. A total of 160 trials were given each session, with the S+ and S- trials quasirandomly alternated.

Group 1 was presented the two problems on alternate days for 25 days of training (there were occasional exceptions to strict alternation because of programming errors, which will be noted in the results section). Group 5 was presented each problem for five consecutive sessions at a time. This continued for 20 sessions (2 periods of training for each problem). Group 5 subjects were then presented 10 sessions of training with the original problem, where all four stimulus combinations were randomly interspersed within each session.

RESULTS

Figure 6 shows the discrimination performance of individual subjects in Group 1. Considerable variability occurred across the various subjects, so each will be discussed separately. Subject 1 failed to learn either problem as its discrimination ratio remained at .50 through training. Subject 2 also failed to show any differential behavior during the first 20 sessions of training but then did respond with a discrimination ratio of .70 on the twenty-second session with Problem 2. Its discrimination ratio then continued around 60% for the three consecutive sessions with Problem 1. Subject 3 displayed the best discrimination of the subjects in Group 1, as it began showing differential behavior on Sessions 9 to 10. Its levels of performance was then quite variable for the remainder of training, generally hovering between .65 to .85 correct. Subject 4 was similar to S-2 in showing differential behavior only after the first 16 sessions. However, because of a programming error, S-4 received five consecutive sessions of training with Problem 1 during Sessions 11 to 15, and the first evidence of discrimination occurred on Session 17 when Prob-

lem 1 was returned. Note also that there were several sessions in which differential behavior occurred to Problem 1 but not to Problem 2. Thus, it is not clear whether S-4 would have learned the discrimination had the five consecutive sessions with Problem 1 not been presented.

The individual subjects in Group 5 are shown in Figure 7. Here a very different pattern is seen, which was similar over subjects. During the first presentation of Problem 1, all subjects showed evidence of discrimination during the second or third session. A similar pattern occurred during the first presentation of Problem 2, with the exception of S-5, which did not discriminate. Similar patterns then occurred during the second exposure to both problems, as the first session (and sometimes more) was always associated with non-differ-

Fig. 6. Proportion of responses that were to the S+ for individual subjects in Group 1 of Experiment 5. Note that the two discriminations were presented on alternate sessions (but see text for some exceptions).

Fig. 7. Proportions of responses that were to the S+ stimuli, for individual subjects in Group 5 of Experiment 5. Note that the two discriminations were presented for alternate periods of five sessions. The last segment of the graph depicts performance on the discrimination when all four stimulus compounds were interspersed, subdivided according to the form element that was involved in the stimulus compound.

ential behavior and then the discriminations were reacquired.

The final segment of Figure 7 shows the results of presenting the original conditional discrimination in which all four stimuli were interspersed across trials within a session. Performance on the two problems (trials involving the circle vs. trials involving the line) are presented separately to be consistent with the previous portions of the figure. Three of the four subjects acquired the conditional discrimination within the first five sessions, while the fourth (S-5) failed to learn the problem during the entire ten sessions of training (although it occasionally displayed above-chance performance). Note that for the remaining subjects (especially S-6 and S-7), there was a difference between the two problems on the first session of conditional discrimination training, as bet-

ter discrimination occurred for Problem 2, which had been presented during the immediately preceding period of training. However, the difference between the two problems disappeared over the next two to three sessions.

DISCUSSION

The results of Experiment 5 show that the period of training with each of the two problems is an important determinant of the acquisition of the conditional discrimination. Subjects with one-session training periods displayed generally poor discrimination (although three of four subjects did eventually learn the problem), while those with five-session training periods acquired both problems rapidly. Given the results for earlier problems that no subject acquired the discrimination when the two problems were interspersed within a session, the implication is that there is a critical duration of training that is necessary, which is somewhere near the one-session period.

The finding most useful in interpreting the results was the return to a chance level of performance that occurred for the Group-5 subjects when they were given their second exposure to each problem. Whereas a high level of discrimination had occurred by the fifth session of the first exposure to each problem, none of the subjects showed any positive transfer on the first session of the second exposure, suggesting that they had to relearn the discrimination completely. Since the first session of the five-day blocks can be viewed as similar to each session of the one-day blocks of Group 1, understanding the pattern of the Group-5 subjects should be helpful in understanding the complete failure of discrimination that occurred in earlier experiments.

The nondifferential behavior that occurred on the first session of the second exposure for Group 5 suggests that red and green were not functioning as conditional cues in a true sense. That is, the subject could learn to respond or not respond as a function of the color cue (since within each training block the colors were differentially associated with food), rather than learn that the reward value of the form cues was dependent on the color that was also present. Thus, for Problem 1 the subjects learned that red predicted food and green no food; then for Problem 2 they learned just the reverse. It is thus not surprising that the re-ex-

posure to Problem 1 then resulted in chance performance, as the initial learning that had occurred with Problem 1 had been abolished by the discrimination reversal procedure.

Although the preceding interpretation can explain the difference between Group 1 and Group 5, it does not explain why the Group-5 subjects were able to acquire the conditional discrimination that was presented during the last 10 sessions of training. If the subjects were learning a simple discrimination reversal involving red and green, why should such training produce positive transfer when the simple discrimination strategy was no longer effective? The most likely answer to this question is that given for the results of Experiment 4. Namely, training with the simple discrimination in which red and green were correlated with food/no food somehow increased the salience of the color cues, so that the detrimental effect of their continuous presentation during the ITI was counteracted.

EXPERIMENT 6

The last experiment to be reported deals with an anomaly that arises when the results from the preceding experiments are compared to previous studies that have investigated the role of "situational cues" in discrimination. The latter are often said to play an important role because they are assumed to acquire associative strength with respect to the reinforcer and then "block" acquisition of associative strength to other cues that are later paired with reinforcement (cf. Blanchard & Honig, 1976; Tomie, 1976). But the role of a situational cue (e.g., a houselight that is continuously present) seems at least conceptually similar to the role of colors in Experiments 1 and 2. The issue is why the continuous presentation of the color cues in these experiments prevented the acquisition of the discrimination involving those stimuli, whereas previous work suggests that situational cues gain stimulus control very quickly.

One simple answer to this question is in terms of stimulus salience. It is possible that localization of the colors on the response key resulted in a stimulus that the subject quickly came to ignore, in contrast to such diffuse stimuli as a houselight or tone, which typically are used as situational cues. Consequently, the

role of the localization of the colors was explicitly investigated.

The simplest method to reduce the localized quality of the color cues was to insure that the colors illuminated the entire chamber with ambient light. To accomplish this, the same procedure as Experiment 1 was used but with the houselight extinguished. Thus, the only illumination during the ITI was the light from the response key, which provided a red or green cast to all of the features of the chamber.

METHOD

Four experimentally naive White Carneaux pigeons were maintained at 80% of their free-feeding body weights. The apparatus was the same as Experiment 1.

Because pigeons typically do not autoshape in the absence of a houselight, it was first necessary to establish key pecking with a houselight present. To accomplish this, the same procedure as the ITI condition of Experiment 1 was used for the first five sessions of training. The first day was devoted to hopper training, and the next four sessions involved presentations of the conditional discrimination with the houselight present. Throughout this training the colors were illuminated during the ITI and then remained on during the 5-sec-trial periods along with the forms.

After four sessions of training with the houselight illuminated, it was extinguished for the remainder of the first phase of training, with no other changes in procedure. Thus, the only illumination in the chamber came from the response keys, except for the light provided by the food hopper during reinforcement. A total of 24 sessions were presented with the houselight absent. Then 20 additional sessions were given with the houselight once again illuminated.

RESULTS

All subjects began pecking the response key associated with the forms at high rates during the initial four sessions of training with the houselight illuminated. None of the subjects responded differentially to the different stimulus combinations, however, so the discrimination data for those sessions will not be presented. The effect of removing the houselight was to disrupt temporarily the key pecking of

two subjects but not that of the others. Recovery from the disruption then gradually occurred over the next four sessions.

The first segment of Figure 8 shows the discrimination performance for the 24 sessions in which the houselight was not illuminated. Unlike the results seen in Figures 1 and 2, here all subjects acquired the discrimination, although one responded differentially only in the last block of training. Apparently, removing the houselight was sufficient to counteract the effects of the colors being presented during the ITI, presumably because the colors were no longer localized on the response key. In agreement with Experiment 1, none of the subjects pecked the color key, either during the trial periods or during the ITI.

The second segment of Figure 8 shows the effect of returning the houselight, while leaving all other features of the procedure unchanged. Despite the high level of discrimination seen in the last block of training with the houselight absent, all subjects reverted to chance performance. This was not due to any change in behavior on S+ trials. Instead, all subjects now began responding on S- trials, so that nondifferential behavior was the result.

After the initial period of nondifferential behavior, three of the four subjects reacquired the discrimination. The fourth failed to learn the discrimination even after 20 sessions of training. That subject was also the one that

had the poorest discrimination in Phase 1 when the houselight was absent.

It should be noted that the procedure used during the second phase of training shown in Figure 8 was identical to that of the ITI condition shown in Figure 1. The fact that three of the four subjects acquired the discrimination shows that the preceding training with the houselight absent somehow facilitated the subsequent discrimination with the houselight present, despite the nondifferential behavior that occurred during the first block of sessions of Phase 2.

DISCUSSION

Experiment 6 shows that the failure of discrimination seen in Experiments 1 to 3 depended critically on the localization of the color cues on the response key. When the procedure was changed to where the colors also provided ambient illumination of the entire chamber, the conditional discrimination was acquired. The role of stimulus localization is surprising, since it seems unlikely that the subjects could avoid seeing the colors in the earlier experiments because the color key was spatially adjacent to the form key, which the subjects always pecked. Assuming that the subjects did see the color stimuli when the houselight was present, some further analysis seems required for why the localization variable played such an important role.

There are at least two potentially important ways that the houselight-off condition of Experiment 6 differed from the ITI conditions of the earlier experiments. One is a difference in the salience of the colors, as using the response keys as the only source of illumination in the chamber may have had the effect of increasing the attention-value of the color stimuli. For human observers this was indeed the case, as the colors created a much more dominant stimulus when the houselight was not present. If this interpretation is correct, the implication is that effects of presenting the colors continuously in the ITI only occur when the colors were below some threshold attention value.

A second possible effect of not using the houselight was in terms of the colors being reflected on the response key associated with the forms, which the subjects pecked during the trial periods. This meant that the compound stimulus no longer involved elements that

were spatially separate, but rather both the form and color information was available on the same response key. Such stimulus compounds may then have been easier to learn than those consisting of distinctly separate elements.

One piece of evidence that helps differentiate these two accounts is the pattern of behavior when the houselight was once again illuminated in Phase 2. Initially the discrimination was abolished but then reoccurred for three of the four subjects. Since the conditions of Phase 2 were exactly like those of the ITI conditions of Experiment 1, where no learning occurred, the implication is that the prior training with the houselight absent somehow facilitated the discrimination when the houselight was returned. Such facilitation should not be expected on the basis of the second hypothesis just presented, since there is no obvious reason why learning about one type of stimulus compound (both form and color on the same key when the houselight was off) should facilitate subsequent learning about a different type of compound (color and form on different keys). The facilitation effect is more consistent with an account in terms of stimulus salience, since learning about the colors during Phase 1 with the houselight on may have increased the general attention value of color (cf. Mackintosh, 1975) such that it no longer could be "tuned-out" by being continuously present during the ITI. Such an account is also consistent with previous studies showing learning about "situational cues," since such cues presumably have had a high salience value.

GENERAL DISCUSSION

The major finding of the present series of experiments was that a simple conditional discrimination can be prevented totally by presenting one of the cues (the colors) continuously during the ITI. Subsequent experiments then showed that the failure of discrimination could be overcome by at least two methods—by having the color cues serve as houselights rather than as being localized on the intelligence panel, and by giving prior training with an easier discrimination in which the colors were directly associated with the presence/absence of food.

At a descriptive level, all of the results are consistent with an explanation that assumes the color cues were involved in two predictive relations, which operated at different rates. One involved the relation with the form cues, as the presence of the colors determined the reinforcement value of the forms. The second was between the colors and food itself. Presumably the second relationship was learned more quickly, so that the subjects learned that the colors did not predict the temporal occurrence of food, since the colors were continuously presented during the ITI. Because stimuli that do not predict the reinforcer are believed to lose salience (cf. Mackintosh, 1975), such a loss of salience could then carry over to all subsequent uses of the stimuli. A possible scenario, therefore, would be as follows: Subjects presented the colors in the ITI learned not to attend to the colors because they did not predict food. The colors were then unavailable for subsequent use as conditional cues, on the assumption that the acquisition of the conditional discrimination occurred more slowly than the loss of stimulus salience. Accordingly, the reason that other operations prevented the failure of discrimination was that those operations raised the salience of the color cues to a point above the value needed for the conditional discrimination to occur.

It may be argued that the results can be given a simpler explanation, which does not require changes in stimulus salience as an explanatory concept. Namely, the subjects learned not to look at the color key when colors were on during the ITI, because that key provided no information about reinforcement. But there are several reasons why such an account is inadequate. First, the two response keys were spatially adjacent, so it seems unlikely that the pigeons could have avoided seeing the colors while pecking the forms. More importantly, such an account fails to explain that the subjects readily acquired the discrimination when the colors were no longer illuminated in the ITI (Phase 2 of Experiment 1). If they had learned not to attend to the location of the colors, it should be expected that the failure of discrimination would persist, i.e., if the subjects were not looking at the color key, they had no way of knowing whether the colors were illuminated. The implication is that the process that prevented attention to the color cues was dynamic in character and dependent

on the subject perceiving that the colors were or were not illuminated during the ITI.

The "failure to look" hypothesis is also deceptive in its simplicity because it ignores the crucial empirical question. Namely, what were the functional determinants causing such a failure to occur? It was not just that the colors were on continuously during the ITI, since Experiment 4 showed that the discrimination would be acquired if the colors themselves were correlated with the presence/absence of food. Moreover, Experiment 5 showed that the critical variable was the period over which the consistent color-food correlation was maintained. The critical issue is the dynamic process underlying the differential effects of "consistent vs. inconsistent" color-food associations.

It could be argued that interpretation in terms of changes in salience has no real explanatory power, since salience must be inferred after the fact and means nothing more than the relative ease with which a stimulus gains control. Although such an argument has some merit, it should be recognized that the concept does have independent meaning when embedded in models of discrimination learning. Indeed, perhaps the major issue in the theoretical analysis of discrimination learning has been whether salience is a static parameter or whether it is dynamic, varying with the history of the discrimination contingencies (e.g., Rescorla & Wagner, 1972, vs. Mackintosh, 1975).

The present results are relevant to this issue because any model that assumes salience is a fixed parameter implies that a discrimination will always be learned, given sufficient training, as long as the stimulus attribute uniquely associated with reinforcement is discriminable (e.g., Rescorla & Wagner, 1972). Since the control conditions showed that pigeons are sensitive to reinforcement contingencies associated with stimulus compounds, and given that the S+ compounds continued to be uniquely associated with reinforcement even during the ITI conditions, the implication is that the discrimination eventually should have been learned. In fact, however, the failure to learn apparently would have persisted indefinitely, suggesting that any discrimination model that assumes static meters for salience will be deficient. This problem is not unique to the present data, as a variety of findings show that complex discriminations often are never learned, even after extensive training, despite

it being clear on other grounds that the subjects are sensitive to the discriminative stimuli (e.g., Williams, 1971, 1972, 1976).

The persistent failure of learning seen in the present experiments seems more consistent with discrimination models that assume salience is a dependent variable (Frey & Sears, 1978; Mackintosh, 1975; Pearce & Hall, 1980). The results of Experiments 4 and 5 in particular, in which the utilization of color as a conditional cue was shown to depend on the period of consistent color-food correlations, suggest strongly that attention to color was indeed a dynamic process. However, other features of the data are less consistent with such an interpretation. As noted in the discussion of Experiment 1, the finding that the conditional discrimination was quickly acquired after the colors were removed from the ITI suggests that changes in salience did not occur, since such changes should persist during the next phase of training. It may be, however, that a comparison of rates of acquisition across different phases of the experiment is not a sensitive method for detecting such changes, so this issue cannot be resolved without further research.

REFERENCES

- Blanchard, R., & Honig, W. K. Surprise value of food determines its effectiveness as a reinforcer. *Journal of Experimental Psychology: Animal Behavior Processes*, 1976, 2, 67-74.
- Frey, P. W., & Sears, R. J. Model of conditioning incorporating the Rescorla-Wagner associative axiom, a dynamic attention process, and a catastrophe rule. *Psychological Review*, 1978, 85, 321-340.
- Gibbon, J. The contingency problem in autoshaping. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), *Autoshaping and conditioning theory*. New York: Academic Press, 1981.
- Gibbon, J., Locurto, C., & Terrace, H. S. Signal-food contingency and signal frequency in a continuous trials auto-shaping paradigm. *Animal Learning and Behavior*, 1975, 3, 317-324.
- Jenkins, H. M., & Sainsbury, R. S. Discrimination learning with the distinctive feature on positive or negative trials. In D. I. Mostofsky (Ed.), *Attention: Contemporary theory and analysis*. New York: Appleton-Century-Crofts, 1970.
- Looney, T. A., Cohen, L. R., Brady, J. H., & Cohen, P. S. Conditional discrimination performance by pigeons on a response-independent procedure. *Journal of the Experimental Analysis of Behavior*, 1977, 27, 363-370.
- Mackintosh, N. J. A theory of attention: Variations in the associability of stimuli with reinforcement. *Psychological Review*, 1975, 82, 276-298.

- Pearce, J. M., & Hall, G. A model for Pavlovian learning: Variations in the effectiveness of conditioned but not of unconditioned stimuli. *Psychological Review*, 1980, **87**, 532-552.
- Rescorla, R. A., & Wagner, A. R. A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current research and theory*. New York: Appleton-Century-Crofts, 1972.
- Tomie, A. Interference with autoshaping by prior context conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, 1976, **2**, 323-334.
- Wagner, A. R., Logan, F. A., Haberlandt, K., & Price, T. Stimulus selection in animal discrimination learning. *Journal of Experimental Psychology*, 1968, **76**, 171-180.
- Williams, B. A. Color alternation learning in the pigeon under fixed-ratio schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 129-140.
- Williams, B. A. Probability learning as a function of momentary reinforcement probability. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 363-368.
- Williams, B. A. Double alternation learning in pigeons. *Journal of General Psychology*, 1976, **94**, 285-293.

Received January 28, 1982

Final acceptance June 10, 1982