Effect of separate presentation of the elements on within-compound learning in autoshaping

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Five experiments used an autoshaping procedure with pigeon subjects to explore the consequences of separate-element presentation for within-compound associations. When a keylight compound had initially been reinforced, separate presentation of one element reduced responding to the other. This was true whether that separate-element presentation was itself reinforced or nonreinforced. That suggests that the detrimental effect of separate-element presentation results from an effect on the within-compound association, rather than one on the association of either element with the US. When the compound had initially been nonreinforced, a moderate level of reinforcement of one element resulted in responding to the other element. However, more extensive reinforcement reduced that responding. Moreover, an attempt to reverse the adverse consequences of extensive separate-element presentation by further exposure to the compound was not successful. These results comment on the associative mechanisms underlying performance in sensory preconditioning and related paradigms.

There is now substantial evidence that in the course of Pavlovian conditioning associations are formed among simultaneously presented components of a compound conditioned stimulus (CS). Such associations have been reported in a range of conditioning preparations: conditioned suppression (e.g., Rescorla, 1980) and flavor-aversion learning in rats (e.g., Fudim, 1978; Holman, 1980; Rescorla & Cunningham, 1978), autoshaping in pigeons (Rescorla, 1981), and instrumental learning with color and odor cues in bees (e.g., Couvillon & Bitterman, 1982). Moreover, associations between components appear to develop in the course of various standard Pavlovian paradigms, such as conditioned inhibition, blocking, and overshadowing (e.g., Rescorla, 1981; Speers, Gillan, & Rescorla, 1980). These associations are important both because they have theoretical implications for many Pavlovian phenomena and because they may serve as a model for how organisms form integrated event representations (see Rescorla & Durlach, 1981).

Associations among CS components may affect behavior in a variety of ways, but they are typically identified experimentally by changing the response to one component and measuring the response change induced in the other component. For instance, in a sensory preconditioning procedure, initial exposure to AB is followed by pairing B with an unconditioned stimulus (US). If a response is then observed when A is tested alone, the presence of an A-B association is inferred. A

good deal is known about the parameters that affect the acquisition of such associations (e.g., Thompson, 1972; Rescorla & Durlach, 1981).

However, evidence for these associations is markedly undermined if one of the components is repeatedly presented outside of the compound (Rescorla & Durlach, 1981; Rescorla & Freberg, 1978). The purpose of the present series of experiments was to explore further the range and manner of operation of that detrimental effect of separate-element presentation. It used an autoshaping preparation to examine the consequences of separate presentation of one element of a compound on responding to the other element. Experiments 1-3 examined the effects on previously reinforced color-pattern compounds of separate presentations of the patterns. They found that both reinforced and nonreinforced presentations of the patterns attenuated subsequently measured responding to the colors. Experiments 4 and 5 explored the consequences of separate-element presentation in a more standard sensory preconditioning procedure in which the compound is nonreinforced.

EXPERIMENT 1

We have previously reported the occurrence of within-compound associations in an autoshaping preparation using a sensory preconditioning procedure (e.g., Rescorla, 1981). In such a procedure, initial nonreinforced exposure to AB is followed by autoshaping on B and then testing of the response to A. The first three experiments reported here employed a related, but less frequently used, design. Initial reinforced AB presentations were followed by extinction of responding to B and then testing of the response to A. Evidence for a within-compound A-B association comes from the loss in re-

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sponding to A contingent on the extinction of the B stimulus with which it had cooccurred.

In order to rule out certain nonspecific effects of extinguishing a B stimulus, we gave each animal reinforced presentations of two compounds, AB and CD, and then extinguished either B or D. The question of Experiment 1 is whether the animal will display differential responding to A and C, depending on whether B or D had been extinguished (cf. Rescorla & Cunningham, 1979, Experiment 2).

Method

Subjects and Apparatus. The subjects were 16 female Carneau pigeons, about 1 year old and maintained at 75% of their free-feeding weights. They had previously participated in an autoshaping experiment that used a response key and stimuli different from those employed here. Treatments in the present experiment were arranged to be orthogonal to those experimental histories.

The apparatus was made up of four identical operant chambers, each measuring $27 \times 27 \times 35$ cm. The metal front panel of each chamber had a 5×5 cm food magazine in its center, located 5 cm above the wire-mesh floor. Three response keys, 2.5 cm in diameter, were located one directly above the hopper and one on either side of the center of the front wall 20 cm above the floor. Located behind the right-hand key was an IEE in-line projector that permitted the transillumination of the key with two color and two pattern stimuli. The key was divided into quadrants such that the left- and right-hand quadrants could be illuminated by either orange (O) or magenta (M) light; the upper and lower quadrants could have either of two patterns of black figures on white backgrounds: circular dots (D) spaced about 1 mm apart or miniature sine waves (S) about 1 mm long and spaced about 1 mm apart. When either colors or patterns were presented separately, the remainder of the key was black; when they were presented simultaneously, 1-mm black lines marked the quadrant boundaries. In addition, the entire key could be illuminated by a uniform white stimulus (W). These stimuli were generated by Ektachrome slides of drawings composed of Color-aid artist's paper. The remaining walls and ceiling of the chambers were composed of clear Plexiglas.

These chambers were placed in sound- and light-attenuating shells with ventilation fans providing background noise of 62 dB re $20 \mu\text{N/m}^2$. On the rear wall of those shells was mounted a 6-W bulb that was continuously illuminated during the session, except during the operation of the food hopper. That hopper contained Purina Pigeon Grain.

Procedure. Because these birds had previously received autoshaping training in another experiment, no magazine experience was necessary. However, to guarantee consistent orientation to the response key, we initially gave all birds two sessions in which presentations of the white stimulus were reinforced. On each day, they received 24 5-sec presentations of W followed immediately by 5 sec of access to the hopper, delivered at a mean intertrial interval of 1 min.

On each of the next 3 days, all birds received 12 reinforced exposures to each of two stimulus compounds. For half the birds, these were OS and MD, and for half they were MS and OD. All stimulus presentations were 5 sec long and terminated in 5 sec of grain. The intertrial interval averaged 1 min.

On each of the next 3 days, all birds received nonreinforced presentations of one of the pattern stimuli. Each day contained 24 5-sec presentations at a mean intertrial interval of 1 min. For half the birds in each group this stimulus was S, and for half it was D.

On the next day, each bird was tested for responding to the colors. The session began with 12 additional nonreinforced presentations of the appropriate pattern stimulus and then continued with 6 nonreinforced presentations each of O and M. The

question of interest is whether responding to O and M will reflect the extinction treatments of their compounded patterns.

Results and Discussion

Responding developed rapidly both to the W and the compound stimuli. By the end of compound training, the mean number of responses per minute to the compounds was 54. Mean responding to the pattern undergoing extinction was moderately high, at a rate of 24/min on the first day. However, by the end of extinction, the rate had dropped to less than 1/min. Responding to the colors in the test session was higher than that previously observed to the patterns, and at similar levels for the two hues. But more importantly, responding to a color was differential, depending on the prior treatment of its pattern. The mean response rate for the color whose pattern had not undergone extinction was 58/min; that for the color whose pattern had been extinguished was 41 [Wilcoxon $T(10) = 4$; $p < .05$].

This dependence of responding to the color on treatment of the patterns indicates that reinforced presentations of the compound had resulted in color-pattern associations. This outcome agrees with that of other autoshaping experiments that have used the more standard sensory-preconditioning procedures to demonstrate such associations after nonreinforced compound presentations (e.g., Rescorla, 1981).

The present detrimental effect of pattern presentation on responding to the colors admits of three associative interpretations, only one of which assumes that the within-compound association is itself adversely affected. One obvious interpretation is analogous to that usually given for sensory preconditioning experiments: the separate presentation of B extinguishes its association with the US and therefore allows the A-B association to be of less benefit to A. A second possibility has been described by Rescorla and Freberg (1978) and given some experimental support by Holland (1981): Separate presentation of B may associatively activate the representation of A in the absence of reinforcement, thereby extinguishing A-US associations established during reinforcement of the compound. Finally, one might argue that separate presentation of B weakens the A-B association and in that manner prevents A from using any strength conditioned to B. According to this last interpretation, our ability to identify within-compound associations with this procedure depends on their destruction through separate element presentation. Whichever of these interpretations is adopted, the specificity of the impact of B's treatment on responding to an A with which it previously cooccurred allows us to infer the presence of an A-B association. However, only the last identifies the A-B association as itself vulnerable to extinction.

EXPERIMENT 2

In this experiment, an attempt was made to determine whether some of the previously observed effect of separate B presentations is attributable to weakening of

the A-B association. The strategy adopted was to present B apart from A, but under circumstances that should undermine neither the A-US nor the B-US association. This was accomplished by giving reinforced presentations of B alone after the initial reinforced presentations of the AB compound. Under those circumstances, the B-US association is obviously maintained; moreover, any activation of A's representation by B is also followed by the US, thereby presumably preventing loss of the A-US association. However, even if B is reinforced, its presentation apart from A might be expected to extinguish the A-B association. Consequently, a loss in responding to A as a result of B's separate reinforcement would indicate that the A-B association had been weakened. As in the previous experiment, each bird was exposed to multiple compounds so that the specificity of the treatment of a component to its associate could be assessed.

Method

Subjects and Apparatus. The subjects were 16 naive female Carneaux pigeons about 6 months old and maintained at 75% of their free-feeding weights. The apparatus was composed of eight operant chambers identical in all essentials to those used in Experiment 1. The left-hand response key permitted the presentation of four elemental stimuli, red (R) and green (G) light and 1-mm black stripes separated by 1 mm on a white background and oriented in either the horizontal (H) or vertical (V) direction. The colors could be projected on the left-hand portion of the key and the orientations on the right-hand portion. When they were presented simultaneously, a 1-mm black line separated them; when only the color or orientations were presented, the other part of the key remained dark.

Procedure. The birds were initially magazine trained by being placed in the chambers with the hoppers activated. After the birds began eating, the hoppers were activated for progressively shorter times at longer intervals until the birds ate regularly during a 5-sec presentation. On the next 2 days, all birds received 44 5-sec hopper presentations, spaced a mean of 1 min apart.

On each of the next 10 days, all birds received reinforced presentations of each of two compounds. Half the birds received 12 5-sec presentations each of the red-horizontal (RH) and the green-vertical (GV) compounds. All presentations terminated in 5 sec of grain availability. The other half of the birds received the same treatment with the RV and GH compounds. The intertrial interval was 1 min.

On each of the next 7 days, all birds received 24 5-sec reinforced presentations of one of the orientations. Half of the birds in each of the above groups received reinforcement of V and half of H. The intertrial interval was 1 min.

The next day began with 12 reinforced presentations of the appropriate orientation, followed immediately by test presentations of R and G. Because of the low levels of responding to the reinforced compounds, 12 nonreinforced presentations each of R and G were given in order to increase the sensitivity of the test. On the next day, all birds received 12 nonreinforced presentations each of H and V to assess the impact of the additional reinforcements of one orientation.

Results and Discussion

Responding developed gradually to the compounds, to a final mean level of 39 responses/min. Responding to the orientations alone during the second phase of the experiment was somewhat lower, attaining a final mean rate of 30 responses/min.

The data of most interest, from the final tests of the colors and orientations, are shown in Figure 1. The left-

Figure 1. Mean response rates during the color and orientation elements in the test sessions of Experiment 2. To the left are the response rates during the colors following additional reinforcement (+) or not (0) to the paired orientations. To the right are the response rates during those orientations.

hand side of that figure displays responding to the colors as a function of whether the paired orientation had received additional training (+) or not (0). Responding proved greater in the latter case [Wilcoxon $T(16) = 10$, $p < .02$]. The right-hand side of Figure 1 displays responding to the orientations separated according to whether they had received further reinforcement (+) or not (0). The greater responding to the former was reliable [Wilcoxon $T(16) = 3.5$, $p < .01$]. There was only slight evidence of extinction during the course of either test session.

These data suggest that separate reinforced presentation of B after initial AB+ presentation does disrupt responding to A; responding to an A stimulus was superior when that reinforcement of B was omitted. Because the final test verified that such reinforcements of B acted to increase its own conditioned strength, the decremental effect on A does not seem attributable to a depression in the value of B. Moreover, there is no reason to anticipate that this treatment should have especially disrupted one A-US association rather than another. Consequently, these results seem to provide evidence that separate B presentations undermine the A-B association.

It is of interest to note that this experiment may be viewed in another context. One frequently employed Pavlovian paradigm is a blocking procedure in which conditioning of an AB compound is preceded or not by separate conditioning of B. The most frequent finding is

that such conditioning of B reduces the associative strength that accrues to A as a result of the AB+ trials. The present experiment used the same procedures, except that the B+ trials followed, rather than preceded, reinforcement of AB. Those separate reinforcements of one element had a detrimental effect on conditioning of the other despite this reversal in the order of trial presentation. However, the interpretation given here in terms of changes in the associations between A and B is quite different from that normally given of blocking results. The discussion of Experiment 3 elaborates on this point.

EXPERIMENT 3

Experiments 1 and 2 found, under somewhat different conditions, that both reinforced and nonreinforced presentations of a component can attenuate responding to the other component of a previous reinforced compound. Experiment 3 sought to compare the magnitudes of the two decremental effects under otherwise similar conditions. Birds were initially given reinforced presentation of two compounds, AB and CD. They then received reinforced presentations of either B or D and an equivalent number of nonreinforced presentations of the other. Finally, A and C were tested to evaluate the magnitude of the decremental effect of those presentations of B and D. To the degree that the decrement produced by presenting B and D acts primarily by disrupting the A-B and the C-D associations, responding to A and C should be similar. To the degree that changes in the associations of the components with the US are involved, responding should be higher to the component whose associate had been paired with the US.

Method

Subjects and Apparatus. The subjects were 16 female Carneau pigeons with histories similar to those of the animals in Experiment 1. They were maintained as in previous experiments, and the apparatus was that of Experiment 1.

Procedure. Since the birds had previously received autoshaping in other experiments, no magazine training was necessary. On the first 6 days of the experiment, all birds were given 12 5-sec reinforced presentations of each of two compounds. For half the birds, these were the OS and MD compounds used in Experiment 1; for the remaining half, they were the MS and OD compounds. The mean intertrial interval was 1 min.

On each of the next 7 days, all animals learned a discrimination between the two pattern stimuli. Half of each of the above groups received 12 5-sec reinforced presentations of D and 12 5-sec nonreinforced presentations of S; the other half of the animals received the same treatments with D and S interchanged. The mean intertrial interval was 1 min.

On the next day, all birds were given a single test session. That session began with continued discrimination of the patterns for six presentations of each and continued with six nonreinforced presentations each of M and O.

Results and Discussion

Responding to the compounds developed to a level like that of Experiment 1. On the final day of compound training, the mean response rate was 55 responses/min. As a result of discrimination training, responding to

the reinforced pattern rose slightly to a final mean level of 62 responses/min, whereas that to the nonreinforced pattern dropped to a final level of 8 responses/min.

The data of most interest are from the test presentations of the colors. The mean response rate during the color whose pattern had been reinforced was 21, whereas that during the color whose pattern had been nonreinforced was 22.

Although the present experiment does not contain a nonexposed comparison condition, the low level of responding to both colors, compared with that to the compound, suggests that separate pattern presentation had a decremental effect on both colors, like that observed in previous experiments. But it is clear that differential reinforcement of the patterns had little differential effect on the responding to the colors with which they had jointly been presented. That suggests that the decremental effect of separate presentations of a component of a compound is similar whether or not those separate presentations are reinforced. The implication is that the principal effect is on the A-B association rather than on the current value of B.

It may be noted that, like Experiment 2, Experiment 3 presented the trials of a blocking design in a different temporal order. In some blocking procedures (e.g., Rescorla, 1981), initial discrimination training of the form A+, B— is followed by reinforcement of two compounds, AC and BD. The issue is whether subsequent separate test presentations of C and D will show the former to have less conditioning because its reinforcement took place in the presence of an already well-conditioned stimulus. The typical answer is affirmative, indicating that the conditioned strength of A and B, rather than their simple prior frequency of occurrence, governs conditioning of C and D. The sensitivity of responding in the present experiment to frequency of prior presentation rather than the value of A and B suggests that the blocking-like result observed in Experiment 2 is not attributable to the same kind of competition process normally implicated in blocking experiments.

EXPERIMENT 4

Experiments 1-3 examined the separate presentation of the elements of a previously reinforced compound. But they have also implications for more standard sensory preconditioning experiments that use nonreinforced compounds. In a typical sensory preconditioning design, nonreinforced presentation of AB is followed by separate reinforced presentation of B and test of A. One suggestion of the preceding results is that the separate reinforced presentation of B may not only condition B but also disrupt the A-B association. Consequently, the ability to detect previously established A-B associations may be undermined if the reinforcement of B involves its repeated presentation. Rescorla (1980) has reported evidence to support this conclusion for conditioned suppression. He found maximum evidence of sensory pre-

conditioning when the B-reinforced stage of the experiment involved only a moderate number of presentations of B; a larger number of presentations produced greater conditioning of B but less suppression to A.

The present experiment examined this implication in an autoshaping paradigm. Each bird was exposed to two color-orientation compounds, and then received sufficient pairings of one orientation to generate substantial pecking to it. Concurrently, each bird received more extensive autoshaping with the other orientation. Finally, the birds were tested for responding to both color stimuli. The question of interest is whether responding will be greater to the color paired with the less-reinforced pattern.

Method

Subjects and Apparatus. The subjects were 16 female Carneau pigeons with histories like those of Experiment 1. They were maintained in the manner of the previous experiments, and the apparatus was that of Experiment 2. In addition to the red (R), green (G), horizontal (H), and vertical (V) stimuli, the left-hand response key permitted the presentation of an X formed by two 1-mm black lines intersecting at the center of an otherwise white key.

Procedure. All birds received 3 days of initial autoshaping with the X stimulus. Each day contained 24 5-sec reinforced presentations of X, spaced at a mean intertrial interval of 1 min. Conditioning of that stimulus was continued throughout the remainder of the experiment to guarantee a high likelihood that the birds would continue to orient toward that key.

On each of the next 3 days, the birds were exposed to 12 5-sec nonreinforced presentations of each of two color-orientation compounds. For half the birds, the compounds were RH and GV; for the other half, they were RV and GH. In addition, all birds received six intermixed 5-sec reinforced presentations of the X. The mean intertrial interval was 1 min.

On each of the next 5 days, the birds received reinforced presentations of the orientations. Half of the birds in each group received six reinforced presentations of H and 24 reinforced presentations of V on each day; the other half received 6 V+ and 24 H+ trials each day. Stimulus durations were 5 sec, and the mean intertrial interval was 1 min.

On the next day, the birds continued the treatment of the preceding day for 3 and 12 reinforced presentations of the appropriate orientations and then received six nonreinforced 5-sec presentations each of R and G.

Results and Discussion

Responding developed rapidly during the X stimulus, but there was little behavior during the nonreinforced compounds. On the final day of this phase, the mean response rate during X was 66 responses/min, whereas that during the compounds was 3 responses/min. Although responding to the reinforced orientations was low on the first day of their separate reinforcement, by the final day it rose to a mean level of 76 and 75 responses/min for the stimuli reinforced 6 and 24 times per day, respectively.

The data of most interest are those from the test presentations of the colors. During that test, the mean response rates were 26 and 14 responses/min for the colors whose orientations had been reinforced 6 and 24 times per day, respectively. That greater responding to

the color whose orientation had been reinforced fewer times was reliable [Wilcoxon $T(16) = 10.5$, $p < .01$]. Thus, these results confirm for the autoshaping situation the implication that sensory preconditioning is most easily observed when conditioning of one of the elements does not involve extensive presentation. Separate presentation undermines the A-B association even if that presentation is carried out in the service of producing substantial conditioning of B.

It may be noted that, unlike the between-subject design used by Rescorla (1980) to study conditioned suppression, the present within-subject design controls for the general effects of amount of conditioning and exposure to the US. The same subjects showed differential responding to two stimuli that differed only in the amounts of conditioning of their partners. Thus, this experiment provides a superior demonstration of the deleterious effects of extensive conditioning of one element in a sensory preconditioning design.

EXPERIMENT 5

In the preceding experiments, separate presentation of one element of an AB compound undermined the ability of the other element to produce a response. Analogous data have previously been reported for separate presentation of the tested element itself (e.g., Rescorla & Durlach, 1981). But Rescorla and Durlach also reported that the detrimental effects of separate presentation of the to-be-tested element are not reversible; attempts to retrain the A-B association by presenting A and B together again after separate presentation of A have not been successful in again allowing A to produce a response. The present experiment examined whether this failure of retraining was also true of separate presentations of the B stimulus in a sensory preconditioning procedure.

Method

Subjects and Apparatus. The subjects were 16 female Carneau pigeons with histories like those of Experiment 1 and maintained as in previous experiments. The apparatus was that of Experiment 1. In addition to the orange (O), magenta (M), dots (D), and sine waves (S), the left-hand key permitted full illumination with white light (W).

Procedure. Initially, the animals were pretrained to peck at W, with the intention that reinforcement of this stimulus would maintain orientation toward the key. On each of 4 days, the birds received 24 5-sec presentations of W, each terminating in 5 sec of grain availability. The mean intertrial interval was 1 min.

On each of the next 3 days, the birds were exposed to color-pattern compounds. Half the birds received 12 nonreinforced 5-sec presentations each of OD and of MS on each day. The other half received the same treatment with the OS and MD compounds. In addition, each bird received six intermixed reinforced presentations of W on each day. The mean intertrial interval was 1 min.

For the remainder of the experiment, the birds were divided into two groups, matched on the compounds they had received. Table 1 depicts the treatment for the subset of each group that experienced the OD and MS compounds. After exposure to

Table 1
Design of Experiment 5

	Phase 1	Phase 2	Phase 3	Phase 4	Test
Group 1	OD— MS—	D— S—	Omitted	D+, S+	O, M
Group 2	OD— MS—	D— S—	OD— MS—	D+, S+	O, M

those compounds, the birds in Group 1 received extinction presentation of either S or D. On each of 3 days, they received 24 5-sec nonreinforced presentations of one pattern stimulus, intermixed with six reinforced presentations of W. On the next 3 days, they received autoshaping with both pattern stimuli. On each day, they received 12 reinforced 5-sec presentations each of S and D, spaced at a mean intertrial interval of 1 min. Finally, they were tested for responding to O and M. On the single test day, they first received six reinforced presentations each of S and D and then six nonreinforced presentations each of O and M. The purpose of this group was to verify within this experiment that separate nonreinforced presentation of S or D reduced the evidence for sensory preconditioning in the color with which it had been paired.

After their exposure to the compounds, the animals in Group 2 received a treatment designed to extinguish both color-pattern associations but then to retrain one of those associations. These animals received 3 days of extinction, on each of which they were given 24 nonreinforced presentations of both S and D, intermixed with 6 reinforced presentations of W. Then they received an additional 3 days on each of which they received 24 nonreinforced presentations of one of the color-pattern compounds, intermixed with six reinforced presentations of W. Finally, they were given the same sequence of conditioning of S and D and testing of O and M as was administered to the other set of animals. The issue here is whether once both compounds have been disrupted, that disruption can be reversed by repeated reexposure to one of the compounds.

Results and Discussion

Initial conditioning of W was rapid, but there was little responding to the color-pattern compounds during their initial exposure. Similarly, animals responded little to the separate presentation of the pattern elements during the extinction phase or to the color-pattern compound during the "retraining" phase. Despite the differences in separate exposure, there was little difference in autoshaping to the patterns. By the final day of such training, the mean response rate was 59 responses/min but was not differential depending upon the prior treatments.

The data of most interest are from the nonreinforced test exposures of the colors, shown in Figure 2. As in previous experiments, performance did not vary as a function of the hue identity; consequently, the results have been collapsed over hue. To the left are the results from the first set of animals, which received separate exposure of one pattern but not of another. The colors whose pattern had been separately exposed (labeled E) produced substantially less responding than did the other color (C) [Wilcoxon $T(8) = 2$, $p < .05$]. To the right are the data from the animals for which both compounds had received extinction but one had been given retraining. It is clear that the compound that had been

retrained (labeled R) did not show more responding than did the compound simply extinguished (E). Despite receiving twice the number of compound trials that were sufficient to establish learning originally, these animals showed no evidence of retraining. These data suggest that the disruption produced by separate presentation of the to-be-reinforced element in a sensory preconditioning experiment cannot easily be reversed by simple reexposure to the compound. As noted by Rescorla and Durlach (1981), the difficulty of retraining may set within-compound associations apart from the between-stimulus learning for which Pavlovian theories have been developed.

It should be noted that the overall level of responding in this experiment was lower than that observed in Experiment 4. This presumably reflects the additional depressive effect of the relatively extensive reinforcement of both patterns prior to the final testing of the colors.

GENERAL DISCUSSION

These experiments demonstrate that the detrimental effect of separately presenting the elements of a compound occurs primarily because it disrupts the within-compound association. That disruption occurs whether the separate presentation follows reinforced or nonrein-

Figure 2. Mean response rate during the test session of Experiment 5. To the left are the response rates during colors when the paired patterns had either received extinction (E) or not (C) prior to being reinforced by food. To the right are the response rates during colors whose paired patterns had been extinguished but then either received retraining (R) or not (E) with the colors.

forced presentation of the compound and whether it increases or decreases the response to the separately presented element. Moreover, the damage so done to the within-compound association is apparently not easily repaired by simple reexposure to the compound.

These observations on the effects of separately presenting the to-be-conditioned element of a compound parallel earlier ones for the effects of separately presenting the to-be-tested element of the compound. Using flavor-aversion and sodium-deficit procedures to study within-compound associations in rats, Rescorla and Freberg (1978) reported loss in responding when the to-be-tested element was exposed separately. More recently, Rescorla and Durlach (1981) made similar observations for autoshaping procedures. Moreover, Freberg (1979) and Rescorla and Durlach (1981) reported that these losses were not necessarily reversible by simple reexposure to the compound. Consequently, the detrimental effects on the within-compound A-B association are similar whether it is A or B that is separately presented. That suggests a symmetry in the manner of action of the association that is unusual in Pavlovian conditioning.

Despite the similarity of these findings to ones reported earlier for flavor stimuli, one may wish to be cautious in generalizing the present results. For instance, we have used only a small set of stimuli (color-pattern compounds) in the present work. Quite different results might be obtained with stimuli that are in different modalities or are arrayed differently spatially. Although other work in this laboratory suggests that the designation of the color as the tested element is not critical to the present results, we know little of the role of perceptual relations among the elements. Those relations are demonstrably important in some associative settings (e.g., Rescorla, 1980).

One difference between the stimuli used here and those employed in other studies of within-compound associations deserves special mention. In the present studies, the absence of one of the elements may itself be thought of as a stimulus. When an element is omitted from a color-pattern compound, the unilluminated portion of the key may itself serve as a new element. This may have several implications for the present experiments. First, this blank portion of the key may become associated with both color and pattern elements in the course of extinction and testing. With designs like those used here, this would result in both patterns and both colors having a common associate. Such an associate may actually lead us to underestimate the degree to which there is a unique association between a color and its compounded pattern. Second, what we have described as separate presentation of an element may actually involve its presentation compounded with a different element. Although Freberg (1979) found that presenting flavor elements either separately or in a new compound had similar detrimental effects on within-compound associations, there have been few systematic

comparisons of these two modes of presenting an element outside of its original compound.

It should also be noted that the loss in A-B association observed here might be substantially less if the separate element presentations were intermixed with the presentations of the AB compound. Other evidence suggests that the A-B association is not completely destroyed in the course of A+/AB- conditioned inhibition training (e.g., Rescorla, 1981).

Nevertheless, the present results have implications for an alternative theoretical account of within-compound learning suggested by Rescorla and Durlach (1981). They argued that presentation of an AB compound might result in the formation of a single representation of the event, rather than in separate representations of A and B that become associated. According to that account, subsequent reinforcement of B activates the AB representation so as effectively to pair it with the reinforcer. When A is later tested, it too activates the AB representation and leads to responding because of the conditioning to AB. The consequence of repeated separate presentation of either A or B would be to encourage the formation of their separate representations such that the individual events would no longer activate the representation of the compound. For instance, interposing presentations of B between AB and B+ training would reduce the likelihood that B would activate AB on its reinforced trials and thus reduce conditioning of AB as exhibited by responding to A. This account makes understandable the failure of reexposure to AB to restore the responding to A. Separate presentations of B do not destroy the AB learning but rather make it unavailable to B on the reinforced trials; consequently, giving additional AB exposure should have no restorative effect.

However, some results of the present experiments require that such an account be elaborated. In Experiments 2 and 3, test responding to A after AB reinforcement was reduced by subsequent reinforcement of B. But there is no reason from this account to suppose that those B+ trials should have any decremental effect on the conditioning of AB. Such B+ trials might reduce B's ability to activate the AB representation, but since AB was previously directly conditioned, that should have little consequence for responding to A. Similarly, in Experiment 4, there is no reason to anticipate that additional B+ trials should reduce the conditioning that the initial B+ trials had given to AB.

One approach to this sort of result was suggested by James (1890) in an interesting discussion of a related situation. He argued that if either A or B is presented separately after exposure to the AB compound, then the organism forms a separate representation not only of the presented element, but also of the nonpresented element. By comparison of the presented B with the activated AB representation, the organism is able to generate a representation of A. In that case, the B+

procedure of Experiments 2, 3, and 4 could result in the detachment of both A and B representations from the AB representation and, hence, could reduce responding to A. It is clear that if this line of theory development is to be followed, more formal rules for the circumstances of the formation of individual event representations are needed.

Whatever their theoretical importance, the present experiments have practical implications for the detection of learning. Procedures like those used here have become standard for the assessment of associations between originally relatively neutral stimuli. But those procedures demand that one of the elements be separately presented so as to change its value prior to the test of the other element. The present results suggest that the details of that separate presentation may be of critical importance if one is to estimate accurately the magnitude of the association of interest without simultaneously changing it. But they also suggest that, in conditioning procedures in which associations between elements might produce confounding sources of responding, the effects of those associations on performance can be reduced by separate presentations of the elements.

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