

## Occasion Setting without Feature-Positive Discrimination Training

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In four experiments rats received training in which a brief conditioned stimulus, *x*, occurred during presentations of an extended feature stimulus, *A*; a second brief stimulus, *y*, occurred during presentations of a second feature, *B*. In Experiment 1 both *x* and *y* were paired with food and, in a subsequent test, they elicited more conditioned responding when they were presented in the feature with which they had been trained than when they were presented in the alternative feature. The results of Experiments 2 and 3 suggested that this effect was not the result of a return of unconditioned responding to *x* and *y* when they were presented outside the training feature. Experiment 4 employed a blocking test to demonstrate that neither was the effect caused by a restoration of associability enhancing the rate of extinction to *x* and *y* outside the training feature. These results suggest that this training procedure gave the features occasion-setting properties. The implications of this possibility for the various accounts of occasion setting are discussed. © 1992 Academic Press, Inc.

In a positive occasion-setting discrimination a target conditioned stimulus (CS) is reinforced when it is accompanied by a second, feature stimulus, but not when it is presented alone. An animal trained on a discrimination of this type will respond more to the CS in the presence of the feature than in its absence. The most straightforward explanation of this discrimination is that during training the feature acquires Pavlovian associative strength which summates with that of the CS (e.g., Wagner & Brandon, 1991). However, performance on occasion-setting discriminations has attracted interest precisely because the control exerted by the feature over responding to the CS does not always depend on the simple Pavlovian properties of the feature (e.g., Rescorla, 1985; Ross & Holland,

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1981). In these cases the feature has been referred to as an "occasion setter" (e.g., Holland, 1983). A number of mechanisms have been proposed to explain how an occasion setter exerts its control over conditioned responding. Perhaps the most frequent suggestion is that it facilitates retrieval or use of the target CS-US association (Holland, 1983; Rescorla, 1985), but other accounts have been proposed which appeal to the notions of generalization decrement (e.g., Wilson & Pearce, 1989, 1990) and to the formation of configural cues (e.g., Ross & Holland, 1981).

The observation that conditioning can be context-specific constitutes an interesting parallel to the phenomenon of occasion setting. In appetitive conditioning procedures, if a stimulus is conditioned in a distinctive context, that stimulus will elicit more conditioned responding if it is presented in the training context than if it is presented in some other context of similar associative strength (e.g., Hall & Honey, 1989; but see also Bonardi, Honey, & Hall, 1990; Hall & Honey, 1990)—suggesting that the training context has control over responding to the CS that does not depend on its Pavlovian properties. Thus a context, like an occasion setter, can modulate conditioned responding to a CS without recourse to Pavlovian conditioning. This shared feature of contexts and occasion setters has been taken to suggest that both might operate by means of the same mechanism (e.g., Bouton & Swartzentruber, 1986; Swartzentruber, 1991). The present experiments exploited this parallel to generate predictions about occasion setting—specifically about the conditions under which occasion setters are formed.

Although a number of theories have been proposed to describe how an occasion setter acts on the CS-US association (e.g., Davidson, Aparicio, & Rescorla, 1988; Davidson & Rescorla, 1986; Holland, 1986a, 1986b, 1989; Rescorla, 1985), relatively little attention has been paid to the conditions required for occasion-setter formation (but see, e.g., Holland, 1986a; Rescorla, 1988). It is, however, typically assumed that what may be called "explicit" training is necessary, training in which the CS is not only reinforced in the presence of the feature, but is also explicitly *nonreinforced* in the feature's absence. This assumption implies that the omission of these nonreinforced CS presentations will prevent the feature from acquiring occasion-setting properties. I shall refer to such a training procedure, in which the CS is reinforced during the feature but never occurs in its absence, as "nonexplicit" training. The analogy that is being suggested between occasion setting and contextual control casts doubt on the claim that nonexplicit training cannot produce occasion setting, however. It is already well established that contextual control can be established by a training procedure in which the target CS is never presented outside the training context (e.g., Bonardi *et al.*, 1990; Hall & Honey, 1989, 1990). If the parallel that is being proposed is correct, therefore, it should also be possible to establish occasion setting with nonexplicit

training. The present series of experiments was designed to investigate this issue.

### EXPERIMENT 1

The training procedure used in these experiments was similar to that employed by Wilson and Pearce (Wilson & Pearce, 1989, 1990; see also Kimmel & Ray, 1978): animals experienced presentations of a 3-min feature stimulus, during which a number of brief, 5-s target CSs were presented. In the first experiment animals were given nonexplicit training with two features, A and B. One of two target CSs, *x*, was reinforced during presentations of A, whereas a second CS, *y*, was reinforced during presentations of B. The question of interest was whether the features A and B would acquire occasion-setting control over responding to *x* and *y*.

In order to demonstrate that a feature is an occasion setter, it is necessary to establish not only that the feature exerts control over conditioned responding to the CS, but also that this control is not mediated by the feature's Pavlovian associative strength. The former was easily achieved in this experiment by examining whether animals responded more to the CS in the presence of the training feature than in its absence. And to rule out the possibility that this effect was Pavlovian in origin, responding to the CS during the training feature was compared to that in the presence of a second feature of the same Pavlovian associative strength as the training feature. This was achieved using a between-subjects comparison in the following manner (cf. Lovibond, Preston, & Mackintosh, 1984). After training, the animals were divided into two groups. Group S (same) received nonreinforced presentations of *x* in A, and of *y* in B—so that each target CS was presented during the feature in which it had been trained—whereas Group D (different) received the converse arrangement, presentations of *x* in B, and of *y* in A. The symmetry of the design ensured that the Pavlovian associative strength of A and B was the same. Thus if nonexplicit training does not make the feature an occasion setter, but leaves it as a simple Pavlovian CS, conditioned responding to *x*, say, should be as vigorous regardless of whether it is presented in A or in B. But if nonexplicit training does produce occasion setting, then the training procedure will establish A as an occasion setter for *x*, and B as an occasion setter for *y*. Thus presenting *x* in B rather than in its training feature A should produce an attenuation of conditioned responding to *x*. Consequently during the test one would expect less responding to *x* and *y* in group D than in group S.

Of course even if this effect were to be obtained it could be interpreted in a number of ways, not all requiring the assumption that A and B are occasion setters. Presenting *x* and *y* in a new feature might, for example, alter the level of unconditioned responding or the associability commanded

by these stimuli, either of which could influence the conditioned responding that they elicit. These possibilities were addressed in Experiments 2, 3, and 4.

### *Method*

*Subjects.* The subjects, 16 naive male hooded (Lister) rats with a mean ad libitum weight of 315 g (range: 300–338 g), were housed in pairs. Before the start of training they were reduced to 80% of their ad libitum weight and were maintained at this level for the rest of the experiment by being fed a restricted amount of food at the end of each session.

*Apparatus.* The apparatus consisted of four Campden Instruments lever-boxes. Each of the boxes contained a recessed food tray to which 45-mg mixed-composition food pellets could be delivered. Access to this food tray was by means of a rectangular aperture 6 cm high  $\times$  5 cm wide. A transparent plastic flap of the same dimensions was attached by a hinge to the top of the entrance to the food tray. Pushing this flap inward from its vertical resting position allowed subjects to gain entry to the food tray. This movement actuated a microswitch and each closing of this switch was recorded as a single response. The flap automatically returned to its resting position when the rat removed its snout from the food tray. Illumination was provided by a 2.8-W 14-V houselight which was mounted centrally in the front wall; this light was always on except when the dark stimulus was presented. Two 2.8-W 24-V jewel lights were mounted in the front wall, one on either side of the food magazine. Two speakers were mounted on the back wall through which a 73-dB, 7-Hz clicker; an 85-dB tone; and an 84-dB (scale A) white noise could be delivered from a Campden Instruments tone generator and a white noise generator. The boxes were housed in sound- and light-attenuating shells; masking noise was provided by the operation of ventilating fans contained in these shells. The apparatus was controlled by BBC microcomputers programmed in a version of BASIC.

*Procedure.* In the first 30-min session the animals were trained to retrieve food pellets from the food tray. These pellets were delivered according to a variable time (VT) 60-s schedule.

Each of the subsequent training sessions consisted of four presentations of a 3-min feature stimulus. Each feature was preceded by a 6-min intertrial interval (ITI); in addition there was a 3-min period at both the start and the end of each session during which no events were programmed to occur. There were two training sessions daily, one in the morning (AM) and the other in the afternoon (PM). One of these daily sessions consisted of four clicker trials, the other of four dark trials; each feature could be presented either AM or PM according to an alternating double alternation sequence (i.e., clicker (C) AM, dark (D) PM; D AM, C PM; D AM, C PM; C AM, D PM, etc.). During each feature presentation there were a number

of presentations of a 5-s target CS, each of which was followed by the delivery of a food pellet. Two CSs were employed, a burst of white noise, and a flashing light produced by pulsing the two jewel lights at 2 Hz. For half the animals the noise was reinforced during the clicker, and the flashing light during the dark; for the remaining animals this arrangement was reversed. The CSs were programmed to occur at semirandom intervals during the feature, with the constraints that each CS was preceded by a 5-s pre-CS period, and that six CSs occurred during each feature presentation. There was a total of eight sessions with each feature in this stage.

Then subjects were given a single test session with each feature. Subjects in group S received presentations of  $x$  in A, and of  $y$  in B, exactly as during training. Subjects in group D received the converse arrangement—presentations of  $x$  in B and of  $y$  in A. In other respects the test sessions were identical to the training sessions except that, first, there were two rather than four feature presentations in each session, and, second, no reinforcers were delivered.

In this experiment conditioned responding to the CS was assessed using an elevation ratio of form  $a/a+b$ , where  $a$  was the total number of magazine entry responses made during CS presentations in each session, and  $b$  the total number of responses made during the pre-CS periods. Inspection of the data suggested that the physical identity of the feature did not influence responding, but that response rates occasionally differed according to whether the target CS was the noise or the flashing light. Accordingly the factor CS (noise or light) was included as a factor in the analyses reported below. Finally, a significance level of  $p < .05$  was adopted in all analyses.

### Results

During initial training subjects learned to elevate their rates of magazine entry during CS presentations, and this was observed to a similar extent in the two groups. The mean elevation ratios for the last training session are shown on the left of Fig. 1; an analysis of variance performed on these data with group (S or D) and CS (noise or light) as factors revealed no significant effects or interactions, largest  $F(1, 14) = 1.11$ . The mean rate of responding during the pre-CS periods in this session was 5.97 rpm for group S and 8.03 rpm for group D; an analysis of variance with group and CS as factors revealed no significant effects or interactions, largest  $F(1, 14) = 1.57$ . Thus there was no evidence for any difference between the two groups at the end of training.

The data of central interest, response rates during the CS in the test, are shown on the right of Fig. 1. For subjects in group S each CS was presented in the feature with which it had been trained; these animals continued to show a mean elevation ratio similar to that observed at the

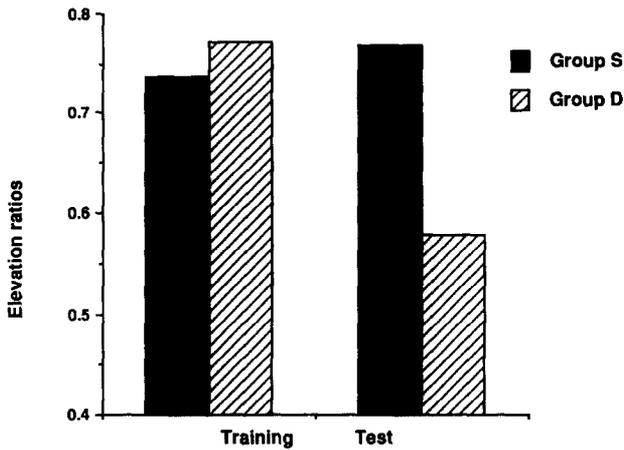


FIG. 1. Group mean elevation ratios for group S (same) and group D (different) during the last training session and the test session of Experiment 1.

end of training. In contrast, subjects in group D, for whom each CS was presented in the alternative feature, displayed markedly lower mean elevation ratios. This impression was confirmed by an analysis of variance with group (S or D) and CS (noise or light) as factors, which revealed a significant main effect of group,  $F(1, 14) = 6.27$ . No other effects or interactions were significant, largest  $F(1, 14) = 1.17$ . Responding to the CS was, nevertheless, still elevated in group D. This is not inconsistent with the occasion-setting interpretation, however. If there were any generalization between the two CSs, for example, this would permit some transfer of each feature's occasion-setting properties to the other CS; generalization between the two features would have the same effect. The mean rate of responding during the pre-CS periods was 4.32 rpm for group S and 6.38 rpm for group D; an analysis of variance with group and CS as factors revealed no significant effects or interactions, largest  $F(1, 14) = 3.53$ .

### Discussion

In Experiment 1 subjects in group S, who experienced each CS in the presence of the training feature at test, responded at a significantly higher rate than subjects in group D, for whom each CS was presented in the alternative feature. This effect cannot be explained in terms of the Pavlovian properties of features A and B, but is consistent with the notion that the nonexplicit training procedure endowed the features with occasion-setting properties. However, this result is not in itself sufficient evidence that occasion setting was obtained, as there is at least one other explanation deserving consideration. This account appeals to the phe-

nomenon of dishabituation. When a stimulus is presented for the first time it elicits an unconditioned response that eventually habituates. It is possible that presenting the CS in a different feature for some reason reverses this process, producing "dishabituation," or a return of unconditioned responding; indeed, such an effect is an explicit prediction of a theory proposed by Wagner (e.g., 1981). In the present procedure unconditioned responding could compete with the target response of magazine entry, with the result that at test the CS would appear to elicit less conditioned responding in group D than in group S. Experiments 2 and 3 were designed to evaluate this interpretation.

## EXPERIMENT 2

The training procedure of Experiment 2 was identical to that of Experiment 1, but with two important exceptions. First, CS presentations were never followed by reinforcement. Second, a response baseline was introduced by rewarding animals for making magazine entry responses according to a variable interval (VI) 60-s schedule. It was anticipated that when a target CS was first presented it would elicit an unconditioned response that would eventually habituate, and moreover that this unconditioned response would compete with the target baseline response of magazine entry, and suppress baseline responding during the CS. Habituation to the CS would thus be measurable as a reduction in this suppression of baseline responding. In the test phase subjects in group S experienced each CS in the feature in which it had been trained, whereas subjects in group D were presented with each CS in the alternative feature. The question of interest was whether any return of unconditioned responding would be observed in group D. If the decrement in conditioned responding in group D observed in Experiment 1 was the product of competition from unconditioned responding, a similar return of unconditioned responding should be observed in group D in the present experiment.

The outcome of this test has a further significance. If the results of these experiments may be taken to demonstrate that nonexplicit training produces occasion setting, Experiment 2 may also elucidate the mechanism of this occasion-setting effect. Although an occasion setter is usually regarded as a conditional cue that controls access to the CS-US association, there are several other accounts of occasion-setting effects that appeal to rather different mechanisms. One of these, proposed by Wilson and Pearce (1989, 1990) employs the notion of generalization decrement. Wilson and Pearce suggested that occasion setting is a product of Pavlovian conditioning to the stimulus complex that is present when reinforcement is delivered—a combination of the feature and the CS. Presenting the CS alone, or in another feature, induces "generalization decrement" in this stimulus complex, so that the CS elicits less responding than when it is

presented in the training feature. A related account appeals to learning about configural cues (e.g., Ross & Holland, 1981). It is assumed that when a particular CS is reinforced in the presence of a particular feature, the animal perceives not only the CS and the feature, but also a special "configural" cue that is present only when that particular CS is presented during that particular feature, and that acquires associative strength (cf. Rescorla, 1972). When the CS is presented alone or, as in the present experiment, in a *different* feature, the configural cue that acquired associative strength during training is no longer present—in the latter case presumably being replaced by a new one specific to the new CS–feature combination. In both cases the absence of the original configural cue attenuates conditioned responding.

These two accounts share an important property—in the present experiment they predict that presenting the CS in a new feature results in the animal experiencing an effectively novel CS. According to Wilson and Pearce's account, the CS–feature complex that acquired associative strength in training suffers generalization decrement, whereas according to the configural cue account the configural cue that was present during training is replaced by a new one, peculiar to the new CS–feature combination. In each case, therefore, the test stimulus is to some extent novel, and so a return of unconditioned responding should be observed. Experiment 2 therefore may also be regarded as a test of these two accounts of occasion setting.

### *Method*

*Subjects and apparatus.* The experiment was performed in two replications. The subjects, 16 naive male hooded (Lister) rats with a mean ad libitum weight of 315 g (range: 300–338 g), were housed in pairs and maintained exactly as in Experiment 1. The apparatus was the same as that used in Experiment 1.

*Procedure.* The procedure was identical to that of Experiment 1, except in the following respects. After the animals had been magazine trained they received a single session during which the magazine entry response was consistently reinforced with the delivery of a food pellet. Each subject had to earn a minimum of 75 pellets during this session. Then all subjects received two, 30-min sessions during which they were rewarded for magazine entry according to a VI schedule. The schedule was VI 30 s in the first of these sessions and VI 60 s in the second. The VI 60-s schedule remained in operation throughout the experiment. Then all animals received two preexposure sessions, one consisting of four presentations of the clicker and the other of four presentations of dark. No CSs were presented during these sessions, which were designed to eliminate unconditioned suppression to the features and hence to ensure a steady rate of baseline responding. Then training proper commenced, with animals

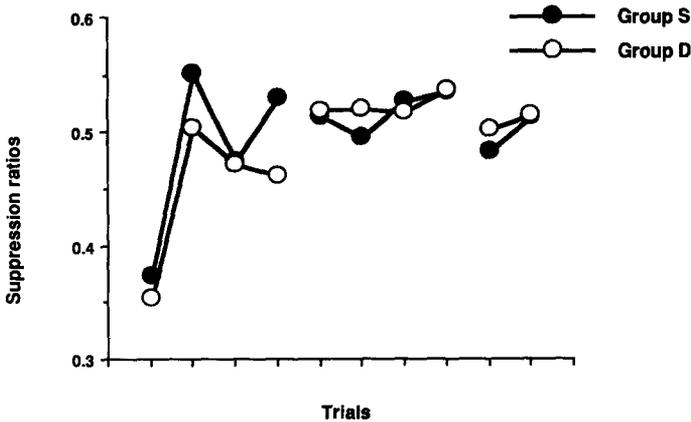


FIG. 2. Group mean suppression ratios for group S (same) and group D (different) for each trial of the first training session (left panel), the last training session (center panel), and the test session (right panel) of Experiment 2.

being given eight training sessions with each feature. These sessions were identical to the training sessions of Experiment 1 except that CS presentations were never followed by reinforcement, and the VI 60-s schedule was in operation. Finally the animals were divided into two groups and tested. Group S received presentations of CS  $x$  in feature A and CS  $y$  in feature B, exactly as they had experienced during training; for group D these arrangements were reversed. The test sessions were otherwise identical to those of Experiment 1, except that the VI 60-s schedule remained in operation.

In this experiment unconditioned responding to the CS was assessed using a suppression ratio of form  $a/a+b$ , where  $a$  was the total number of magazine entry responses made during CS presentations in each session, and  $b$  the total number of responses made during the pre-CS periods.

### Results and Discussion

The left panel of Fig. 2 shows responding during each trial of the first training session. On the first trial it is evident that animals responded less in the presence of the CS than in its absence, but that this effect had dissipated by the second trial. This is consistent with the notion that the CS initially elicited unconditioned responding which interfered with the baseline response of magazine entry, and that this unconditioned effect rapidly habituated. An analysis of variance performed on the data from the first two trials of this session with group (S or D), CS (noise or light), replication, and trial as factors revealed a significant main effect of trial,  $F(1, 12) = 27.34$ , which did not interact with group,  $F < 1$ . No other effects or interactions were significant, largest  $F(1, 12) = 3.49$ . The mean

TABLE 1

Trial:	1	2	3	4
Session 1				
Rep. 1				
S	7.38	6.07	7.57	7.94
D	5.88	7.19	7.25	7.82
Rep. 2				
S	4.25	5.32	6.63	6.57
D	4.13	5.07	6.38	7.38
Session 8				
Rep. 1				
S	14.75	14.82	10.88	8.13
D	13.94	11.19	8.13	9.13
Rep. 2				
S	9.13	11.57	9.38	7.94
D	7.07	12.07	9.07	7.88

rate of pre-CS responding for groups S and D are shown in the top half of Table 1. An analysis of variance performed on the data from the first two trials of this session with group, CS, replication, and trial as factors revealed no significant effects or interactions, largest  $F(1, 12) = 2.93$ . Suppression ratios remained at .50 for the rest of training: an analysis of variance performed on the data from the last session of training (see center panel of Fig. 2) with group (S or D), CS (light or noise), trial, and replication as factors revealed no effect of trial or group  $\times$  trial interaction,  $F_s < 1$ ; no other effects or interactions were significant, largest  $F(1, 12) = 3.31$ . The mean rates of responding during the pre-CS periods during this session are shown in the bottom half of Table 1. An analysis of variance with group, CS, trial, and replication as factors revealed a significant main effect of trial,  $F(3, 36) = 10.19$ , and a significant interaction between this factor and replication,  $F(3, 36) = 5.75$ . This appeared to reflect the fact that scores increased between trials 1 and 2 in the second replication but not in the first. This interaction did not interact with group,  $F(1, 12) = 1.31$ . No other effects or interactions were significant, largest  $F(1, 12) = 1.59$ .

The data of central interest, the suppression ratios during the test phase, are shown in the right panel of Fig. 2. There was no evidence of any return of unconditioned responding to the CS in group D, which if anything showed less suppression than group S. An analysis of variance with group (S or D), CS (noise or light), trial (1 and 2), and replication as factors confirmed this description of the data, revealing no group  $\times$  trial interaction,  $F < 1$ . The interaction between replication and trial was significant, however  $F(1, 12) = 7.85$ . This appeared to reflect the fact

TABLE 2

Trial:	1	2
Rep. 1		
S	23.88	23.88
D	23.63	19.25
Rep. 2		
S	19.50	18.25
D	18.88	26.25

that suppression ratios were lower on the first trial than the second in the first replication, the corresponding ratios being .461 and .541, respectively, but that the converse was true in the second, the corresponding values being .526 and .490; this effect did not interact with group,  $F(1, 12) = 3.86$ . No other effects or interactions were significant, largest  $F(1, 12) = 3.03$ . The mean rates of pre-CS responding during the test are shown in Table 2. An analysis of variance performed on these data with group, CS, trial, and replication as factors revealed no significant effects or interactions, largest  $F(1, 12) = 2.98$ .

### EXPERIMENT 3

The results of Experiment 2 demonstrate that unconditioned responding does not return when a CS that has been preexposed in one particular feature is presented in a different feature. This is problematic for the argument that, in Experiment 1, conditioned responding to  $x$  and  $y$  in group D was attenuated because of competition from dishabituated unconditioned responses. Moreover, the failure to observe any dishabituation provides no support for the predictions made by the configural cue and generalization decrement accounts of occasion setting. Experiment 3 aimed to provide further support for these conclusions. The first aim of the experiment was to replicate Experiment 1 in such a way that the result could not easily be explained in terms of competition from unconditioned responding. This was achieved by using a different measure of conditioning. All subjects were therefore rewarded for lever-pressing according to a VI 60-s schedule throughout the experiment. On the basis of pilot data we anticipated that pairing the CS with food would engender a conditioned response directed toward the food magazine which, by competing with lever-pressing, would produce a reduction in lever-pressing. If presenting the CS in a new feature attenuates conditioned responding, this should therefore increase the rate of lever-pressing, whereas if an increase in unconditioned responding is produced by presenting the CS in a new feature, this would most likely have the opposite effect.

Anticipating that we would succeed in replicating the result of Exper-

iment 1, the second aim of the experiment was to provide further evidence that the apparent reduction in the CS's associative strength was not mediated by an increase in the stimulus's novelty when it was presented in a new feature. So we included an additional pair of groups in order to replicate the results of Experiments 1 and 2 within the same experiment, and under as similar conditions as possible. If under almost identical conditions presenting the CS in a new feature attenuates conditioned responding but has no discernible effect on unconditioned responding to that stimulus, it becomes more difficult to argue that the former effect is mediated by the CS being perceived as novel in a new feature. For this reason both conditioned and unconditioned responding were measured in the same manner in the present experiment: we anticipated that unconditioned responding to the CS would interfere with lever-pressing, as it had interfered with magazine entry in Experiment 2.

Four groups of animals were employed. All subjects experienced presentations of CS x in feature A and of CS y in feature B. For subjects in groups C/S (conditioning-same) and C/D (conditioning-different) all CS presentations were followed by food delivery, whereas for subjects in groups H/S (habituation-same) and H/D (habituation-different) CS presentations were nonreinforced. In the test phase subjects in groups C/S and H/S received, as in training, presentations of CS x in feature A, and presentations of CS y in feature B. Subjects in groups C/D and H/D experienced the opposite arrangement, of CS x in feature B and of CS y in feature A. On the basis of the results of Experiments 1 and 2, it was anticipated that presenting the CS in a different feature would produce an attenuation of conditioned responding in group C/D, but no return of unconditioned suppression in group H/D. Hence we expected a difference at test between groups C/S and C/D, but not between groups H/S and H/D.

### *Method*

*Subjects and apparatus.* The subjects, 16 naive male hooded (Lister) rats with a mean ad libitum weight of 339 g (range: 263–381 g), were housed in pairs and maintained exactly as in Experiment 2. The apparatus was the same as that used in Experiment 2, with the exception that a response lever was inserted into each chamber, on the left-hand side of the food magazine.

*Procedure.* The procedure was identical to that of Experiment 2, except in the following respects. After the animals had been magazine trained they received a single session during which the lever-pressing response was consistently reinforced with the delivery of a food pellet. Each subject had to earn a minimum of 75 pellets during this session. Then all subjects received two, 30-min sessions during which they were rewarded for lever-pressing according to a VI schedule. The schedule was VI 30 s in the first

of these sessions and VI 60 s in the second. The VI 60-s schedule remained in operation for the rest of the experiment. Then all animals received two sessions, one consisting of four presentations of the clicker and the other of four presentations of dark. No CSs were presented during these sessions. At this point all subjects received two extra training sessions during which no stimuli were programmed to occur, but during which responding was reinforced as before. Then the animals were divided into four groups, each of which received eight training sessions with each feature. For subjects in groups C/S and C/D, CS presentations were followed by food delivery, whereas for subjects in groups H/S and H/D, CS presentations were nonreinforced. These sessions were identical to the training sessions of Experiment 2, except in the following respects. First, three rather than six CS presentations occurred during each feature presentation, and second, CS presentations in groups C/S and C/D were followed by a reinforcer of three food pellets. These changes were based on pilot data from a study investigating the best parameters for allowing the measurement of conditioned responding as suppression of lever-pressing. Finally the animals were tested. Groups C/S and H/S received presentations of CS  $x$  in feature A and CS  $y$  in feature B, exactly as they had experienced during training; for groups C/D and H/D these arrangements were reversed. The test sessions were identical to those of Experiment 1 except for the fact that the VI 60-s schedule was in operation throughout. Groups H/S and H/D received one test session with each target, whereas groups C/S and C/D received two.

In this experiment both conditioned and unconditioned responding to the CS were assessed using a suppression ratio of form  $a/a + b$ , where  $a$  was the total number of lever-press responses made during CS presentations in each session, and  $b$  the total number of responses made during the pre-CS periods.

### Results

The left panel of Fig. 3 shows responding in groups H/S and H/D during each trial of the first training session. On the first trial it is evident that, exactly as in Experiment 2, animals responded less in the presence of the CS than in its absence, but that this effect had dissipated by the second trial. An analysis of variance performed on the data from the first two trials of this session with group (H/S or H/D), CS (noise or light), and trial as factors revealed a significant main effect of trial,  $F(1, 6) = 17.88$  which did not interact with group,  $F < 1$ . No other effects or interactions were significant, largest  $F(1, 6) = 1.13$ . The mean rates of pre-CS responding are shown in the top half of Table 3. An analysis of variance performed on the data from the first two trials of this session with group, CS, and trial as factors revealed no significant effects or interactions, largest  $F(1, 6) = 3.53$ . Suppression ratios remained at .50

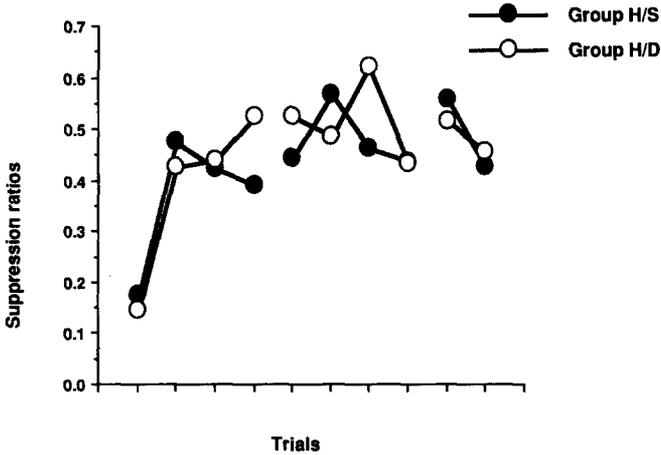


FIG. 3. Group mean suppression ratios for group H/S (habituation/same) and group H/D (habituation/different) for each trial of the first training session (left panel), the last training session (center panel), and the test session (right panel) of Experiment 3.

for the rest of training. An analysis of variance performed on the data from the last session of training (see center panel of Fig. 3) with group (H/S or H/D), CS (light or noise), and trial (1-4) as factors revealed no main effect of trial,  $F(3, 18) = 1.68$ ; no other effects or interactions were significant, largest  $F(1, 6) = 2.00$ . The mean rates of responding during the pre-CS periods are shown in the bottom half of Table 3. An analysis of variance with group, CS, and trial as factors revealed no significant effects or interactions, largest  $F(3, 18) = 2.88$ .

The results of the test phase are shown in the right panel of Fig. 3. It is evident that ratios were marginally lower on the second trial than on the first and, as in Experiment 2, there was no sign of any return of unconditioned responding in group H/D. This impression was confirmed by an analysis of variance with group, CS, and trial as factors; the main effect of trial was not significant,  $F(1, 6) = 2.00$ , and did not interact with group,  $F < 1$ . No other effects or interactions were significant, largest

TABLE 3

Trial:	1	2	3	4
	Session 1			
H/S	5.25	3.88	4.75	5.00
H/D	4.75	4.50	4.00	2.88
	Session 8			
H/S	5.88	4.88	6.25	6.00
H/D	4.50	5.13	3.50	3.88

$F(1, 6) = 1.15$ . The mean rates of pre-CS responding were 10.00 rpm for group H/S and 10.26 rpm for group H/D on trial 1; the corresponding rates were 11.76 and 12.50, for groups H/S and H/D respectively, on trial 2. An analysis of variance with group, CS, and trial as factors revealed no significant effects or interactions, largest  $F(1, 6) = 1.27$ .

As training progressed animals in groups C/S and C/D came to make fewer lever-pressing responses in the presence of the CS than in its absence. On the last session of training suppression appeared to be slightly less profound in group C/S than in group C/D: the mean suppression ratios for this session were .315 for group C/S and .241 for group C/D. However, an analysis of variance with group (C/S or C/D) and CS (noise or light) as factors revealed that this difference was not significant,  $F(1, 6) = 1.83$ ; no other effects or interactions were significant, largest  $F(1, 6) = 1.56$ . The mean rates of pre-CS responding were 17.00 rpm for group C/S and 16.63 rpm for group C/D in this session. An analysis of variance with group and CS as factors revealed no significant effects or interactions, largest  $F(1, 6) = 2.30$ .

On the first test session the scores for the two groups reflected those at the end of training in that group C/D was slightly more suppressed than group C/S; the mean suppression ratios for this session were .377 for group C/S and .322 for group C/D. However, this pattern was reversed on the second test session, during which the corresponding ratios were .414 for group C/S and .516 for group C/D. An analysis of variance performed on these data with group (C/S or C/D), CS (noise or light), and session (1 and 2) as factors revealed a significant main effect of session,  $F(1, 6) = 18.31$ , and a significant group  $\times$  session interaction,  $F(1, 6) = 8.37$ . No other effects or interactions were significant,  $F_s < 1$ . The presence of this interaction suggested that the difference between the two groups at the end of training was obscuring the results of the test sessions. In order to correct for this, the suppression ratio from the last training session was subtracted from each test score to produce corrected scores for each animal. The resulting data are presented in Fig. 4, which shows that group C/S was more suppressed than group C/D on both test sessions, and that this effect was considerably more profound on the second session. An analysis of variance performed on these corrected scores with group, CS, and session as factors confirmed this description of the data by revealing a significant main effect of session,  $F(1, 6) = 18.31$ , and a significant group  $\times$  session interaction,  $F(1, 6) = 8.37$ . Simple main effects analysis revealed that the groups did not differ on the first session,  $F < 1$ , but that they differed significantly on the second,  $F(1, 9) = 8.25$ .

The mean rates of pre-CS responding during these sessions, for groups C/S and C/D, respectively, were 20.74 and 19.50 on session 1, and 21.74 and 16.50 on session 2. An analysis of variance with group, CS, and session as factors revealed a significant main effect of CS,  $F(1, 6) = 8.53$ ,

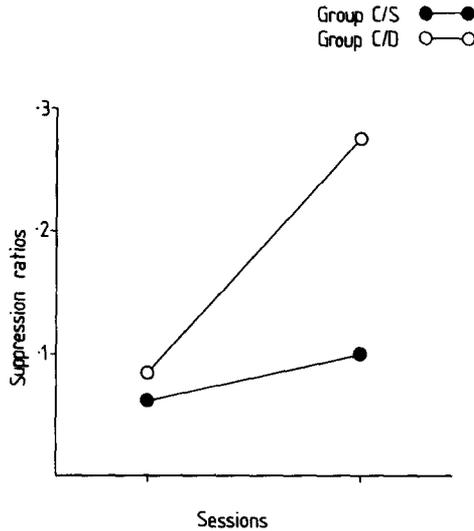


FIG. 4. Group mean corrected suppression ratios for group C/S (conditioning/same) and group C/D (conditioning/different) during the test sessions of Experiment 3.

and a significant group  $\times$  CS interaction,  $F(1, 6) = 6.74$ ; pre-CS responding was for some reason higher in group C/S (25.50 rpm) than in group C/D (18.24 rpm) when the target CS was the noise, but not when it was the light (17.00 rpm and 17.74 rpm for groups C/S and C/D, respectively). No other effects or interactions were significant, largest  $F(1, 6) = 3.39$ .

### Discussion

In Experiment 1 presenting a CS outside the training feature produced a decrement in conditioned responding, suggesting that the CS had suffered an effective loss of associative strength. The results from groups C/S and C/D of the present experiment are in accordance with this finding. By the second test session conditioned responding to the CS was significantly lower in group C/D than in group C/S, suggesting that the CS had less associative strength in this group. Moreover, the results from groups H/S and H/D confirmed those of Experiment 2, giving no indication that presenting a CS outside its training feature produces any restoration of unconditioned responding.

These observations have two implications. First, it is unlikely that the difference between groups C/S and C/D was produced by competition from dishabituated unconditioned responding in the latter group. There was no evidence for dishabituation in group H/D, and it is moreover unclear how enhanced unconditional responding in group C/D could produce the *less* profound suppression of lever-pressing that was observed in this group. Second, the results are not easily accommodated by those

accounts of occasion setting which predict that the loss of conditioned responding observed when the CS is presented in a new feature occurs because the animal experiences an effectively novel stimulus. To explain these data such theories must argue that presenting the CS in a new feature made it sufficiently novel to attenuate conditioned responding, but not enough to produce a detectable return of unconditioned responding.

Finally, there is a further interpretation of the results from groups C/S and C/D of the present experiment. It is possible that when the CS is presented in a new feature the effect is not to attenuate its associative strength but to enhance its "associability" or its capacity to be learned about. For example, in a latent inhibition procedure a preexposed stimulus will condition less rapidly than a stimulus that has not undergone preexposure; we say that the former stimulus has suffered a loss of associability. It is, moreover, well established that the effects of this latent inhibition treatment are context-specific: if a stimulus is preexposed in a distinctive context and subsequently conditioned in a different context, latent inhibition is less profound than if conditioning occurs in the context of preexposure (e.g., Channell & Hall, 1983; Hall & Channell, 1985). Associability may also be lost if the stimulus is consistently reinforced during preexposure (e.g., Hall & Pearce, 1979, 1982). Moreover, there is evidence that this associability loss occurring over the course of conditioning, like that engendered by latent inhibition training, is also context-specific (e.g., Swartzentruber & Bouton, 1986). The proposed analogy between occasion setters and contexts thus suggests that the associability of a target CS may be restored when the CS is presented in a new feature. If this were the case, then in the present experiment the target CS's associability would have been restored in group C/D, so that extinction could occur more rapidly in this group. Given that the difference between the two groups did not emerge until the second test session, this is a real possibility. This account could also explain the results of Experiment 1, insofar as testing occurred over a number of trials during the course of which some extinction could have occurred. Experiment 4 was designed to evaluate this explanation.

#### EXPERIMENT 4

Experiment 4 was designed to determine whether presenting the CS outside the training feature attenuates its associative strength or enhances its associability. These possibilities are not dissociated in the previous experiments, which rely on the demonstration that conditioned responding to the CS is attenuated when it is presented outside the training feature. The problem with this is that the level of conditioned responding is not a pure measure of the CS's associative strength, because if testing occurs over a number of trials, responding is determined also by the degree to

which the CS extinguishes during the test—which in turn is determined by the CS's associability. Accordingly the present experiment employed a different measure of the CS's associative strength—the degree to which the CS could produce blocking. Two groups of animals received training in which CS x was reinforced in feature A, and CS y in feature B. Then the ability of x and y to block acquisition of associative strength by an added cue, z, was assessed. In group S compound training of xz occurred in feature A, and of yz in feature B; in group D this arrangement was reversed. It was anticipated that, if the CS is presented in the training feature, acquisition of associative strength by z will be blocked, because the delivery of reinforcement is already well predicted by the CS. The critical question is the effect presenting the CS in a new feature has on its ability to block. If presenting the CS in a new feature attenuates its associative strength, then the occurrence of reinforcement will be predicted less well than in group D, and blocking will be attenuated. Accordingly there will be more conditioned responding to z when presented alone in group D than in group S. But if presenting the CS in a new feature merely enhances its associability and has no effect on its associative strength, no such prediction may be made. An enhancement of the associability of the CS will enhance that stimulus's capacity to be learned about—but if the associative strength of the CS is unchanged, it will remain a good predictor of the US. And if the US is well predicted, no more learning can occur, either to the pretrained CS or to the added stimulus z. Thus blocking should be unimpaired, and there should therefore be no difference in responding to z in the two groups. Moreover, although it is easy to see how unconditioned responding could interfere with conditioned responding to the CS, it is not at all clear how it could influence the ability of the CS to produce blocking. So finding a difference in the blocking ability of the CS in the two groups would provide additional evidence against the dishabituation account of the differences observed in Experiments 1 and 3.

### *Method*

*Subjects and apparatus.* The subjects, 16 naive male hooded (PVG) rats with a mean ad libitum weight of 246 g (range: 225–263 g), were housed in pairs and maintained exactly as in Experiment 1. The apparatus was the same as that used in Experiment 1.

*Procedure.* Pretraining was identical to the initial training phase of Experiment 1. After eight sessions of training with each feature the subjects were divided into two groups. There followed six sessions of compound training in which subjects in group S continued to receive presentations of x in A and y in B, as before, whereas subjects in group D received the reverse arrangement of CS x in B and y in A. Each CS was accompanied by the presentation of a third target stimulus z, a 5-s tone,

and followed by the delivery of a food pellet. Compound training was, in all other respects, identical to pretraining. The first test was identical to that of Experiment 1, except that z presentations replaced those of both x and y. Two test sessions with each feature were given, and no reinforcement occurred during these sessions. Following this test a second test was administered: this was identical to the first except for the fact that, first, there were two rather than four feature presentations per session, and, second, each tone presentation was followed by reinforcement.

### *Results and Discussion*

Acquisition of conditioned responding to the two CSs during the first phase of training proceeded uneventfully. During the last session of this stage the mean ratio was .858 for group S and .869 for group D; an analysis of variance performed on these data with group (S or D) and CS (noise or light) as factors revealed no significant effects or interactions, largest  $F(1, 14) = 1.00$ . The mean rate of pre-CS responding during this session was 2.22 rpm for group S and 2.35 rpm for group D. An analysis of variance with group and CS as factors revealed no significant effects or interactions,  $F_s < 1$ .

During compound training animals continued to respond during CS presentations. In the last session of this stage the group mean ratio was .798 for group S and .832 for group D; an analysis of variance with group (S or D) and CS (noise or light) as factors revealed no effect of group,  $F < 1$ ; no other effects or interactions were significant, largest  $F(1, 14) = 1.35$ . The rate of pre-CS responding for this session was 4.16 rpm for group S and 4.10 rpm for group D. An analysis of variance with group and CS as factors revealed no significant effects or interactions, largest  $F(1, 14) = 3.37$ .

In the first test group S responded slightly more, rather than less, than group D. The mean elevation ratios for group S were .770 and .785 for the first and second sessions, respectively; the corresponding scores for group D were .753 and .748. However, an analysis of variance performed on these data with group (S or D) and sessions as factors revealed that this difference was not significant,  $F < 1$ ; no other effects or interactions were significant,  $F_s < 1$ . The second test, in contrast, did reveal a significant difference between the groups. The results of this test are shown in Fig. 5, and it is evident that group S responded at a considerably lower level than group D. An analysis of variance performed on these data with group and sessions as factors confirmed this impression, revealing a significant main effect of group,  $F(1, 14) = 5.86$ ; no other effects or interactions were significant, largest  $F(1, 14) = 1.53$ . The mean rates of pre-CS responding during the first and second tests are shown in the top and bottom of Table 4, respectively. An analysis of variance performed on

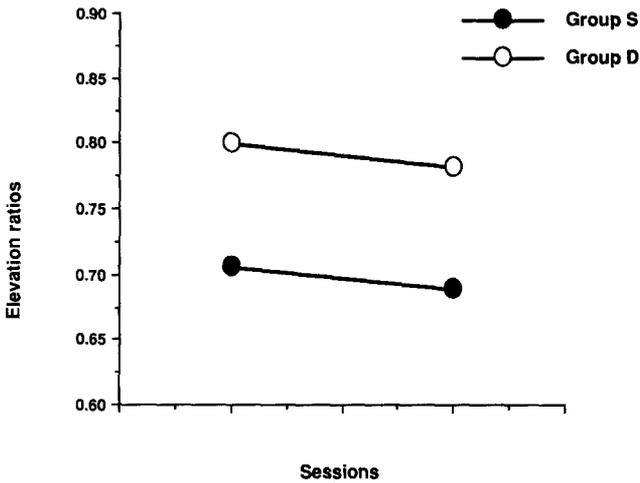


FIG. 5. Group mean elevation ratios for group S (same) and group D (different) during the test sessions of Experiment 4.

the data from each of these tests revealed no significant effects or interactions, largest  $F(1, 14) = 1.88$ .

In the second test the level of conditioned responding to the tone was significantly higher in group D than in group S. This suggests that the tone's associative strength was higher in group D than in group S, and hence that blocking was more profound in the latter group. This is consistent with the hypothesis that presenting the CS in a new feature produces a reduction in its associative strength, and not simply an enhancement of its associability. Moreover, the result provides additional evidence that the apparent reduction of conditioned responding in group D that was observed in Experiment 1 was not due to dishabituation of unconditioned responding.

The fact that the difference between the two groups in the present experiment was not readily apparent in the first test deserves some comment, but is not necessarily difficult to explain. If the hypothesis un-

TABLE 4

Session:	1	2
	Test 1	
S	3.00	1.13
D	2.69	2.56
	Test 2	
S	5.63	5.60
D	9.19	7.22

derlying these experiments is correct, the associative strength of *z*, like that of *x* and *y*, will be less readily displayed if *z* is presented under conditions that differ from those in which it was trained. During training *z* was paired with food in compound with either *x* or *y*, whereas in the first test neither *x* nor *y* nor food was present. The resultant change in conditions between training and test might have diminished *z*'s associative strength sufficiently to obscure any differences between the groups. And of course this effect would be less profound during the second test because food was present, so that the similarity to the conditions under which *z* was trained would have been increased.

### GENERAL DISCUSSION

The results of these experiments are consistent with the hypothesis that a nonexplicitly trained feature becomes an occasion setter—in other words the feature acquires control over conditioned responding to the target CS that is independent of its own Pavlovian properties. This observation has implications for existing theories of occasion setting. Holland's (1983) account, although specifying how the occasion setter operates on the CS-US association, does not specify precisely the conditions required for occasion-setter formation. Nor can Rescorla's (1985) account accommodate these findings. First, Rescorla has argued (Rescorla, 1988) that a critical factor in occasion-setter formation is that a CS with a component of inhibitory associative strength must be reinforced in the presence of the feature. According to this account explicit training produces occasion setting because the CS is nonreinforced in the absence of the feature, as this ensures that the CS will possess a component of inhibitory strength when it is reinforced during feature presentations. But these nonreinforced CS presentations are omitted in nonexplicit training, so it follows that according to Rescorla's account nonexplicit training should not produce occasion setting. In addition Rescorla asserts that an occasion setter acts by facilitating activation of the US representation. This means that an occasion setter should be equally effective at elevating responding to any CS associated with that US. But the present experiments centered around the demonstration that responding to the target CS is reduced if it is presented in a feature other than that with which it was trained. According to Rescorla's theory both features should during training come to facilitate activation of the US representation to an equal extent; thus it cannot predict the basic result that was obtained in the present experiments.

The account proposed by Wilson and Pearce (1989; see Pearce, 1987) can predict that nonexplicit training should produce occasion setting. It suggests that the process responsible for occasion setting is simply Pavlovian conditioning to the feature-CS complex, and hence it follows that pairing the feature-CS combination with reinforcement—nonexplicit training—should be sufficient for occasion-setter formation. A configural

cue account of occasion-setter formation could make the same prediction. Nevertheless, both these accounts must assume that presenting the CS in a new feature is effectively equivalent to presenting the animal with a novel stimulus. In order to account for the results from the habituation groups of Experiments 2 and 3, these accounts must therefore assume that the degree of novelty produced by presenting the CS in a different feature, although adequate to attenuate conditioned responding to a substantial degree, is not sufficient to produce enough unconditioned responding to be detectable with our procedures.

There is one other view of occasion setting that may also be able to accommodate the present findings. Bonardi (1988b, 1989) has suggested that occasion setting may be a special form of associative learning, in which the occasion setter's properties are the result of a classically conditioned association. Operationally, a positive occasion setter is present on those occasions when CS and US are paired. It is possible that the central state engendered by a CS-US pairing is a unitary representation that may enter into associations in the same way as do those produced by CS or US presentations. It is then possible to explain occasion-setter formation in associative terms, by arguing that establishing an occasion setter involves the formation of an association between the occasion setter and the central state that accompanies pairings of CS and US. Because this account views acquisition of occasion setting as essentially a process of Pavlovian conditioning, albeit one in which the reinforcer is a complex event, the laws governing acquisition of occasion setting should be the same as those governing Pavlovian conditioning. This view thus specifically predicts that a nonexplicit training procedure should be adequate to produce occasion setting. The results of the present experiments may perhaps be taken as evidence in support of such a theory. Further encouragement for this approach is obtained from a consideration of the related phenomenon of discriminative control of operant responding. There is some evidence to suggest that such control may not always be explained in terms of Pavlovian conditioning (e.g., Holman & Mackintosh, 1981; Goodall & Mackintosh, 1987; Bonardi, 1988a, 1988b). This similarity between discriminative stimuli and occasion setters has led to the proposal that—as the choice of the term occasion setter suggests (Skinner, 1938)—both may be a product of the same learning mechanism (e.g., Holland, 1983; Rescorla, 1985; Ross & LoLordo, 1987). If there is any virtue in this hypothetical parallel, then it is of interest to note that Rescorla (1990) has proposed an account of discriminative control appealing to an associative process which seems to bear a close resemblance to that suggested by Bonardi (1988b, 1989) for occasion setters.

A final point concerns the nature of the occasion setting produced by the training procedures used in the present experiments. It has been shown that nonexplicit training gives the feature properties that allow it to con-

form to the existing definition of occasion setting. One interpretation of this finding is that, as the preceding discussion assumes, nonexplicitly trained occasion setting is governed by the same mechanisms as that produced by explicit training. However, the results of the present experiments do not bear on this issue, establishing only that a nonexplicitly trained feature behaves in the same manner as that from an explicit training procedure. The question whether explicitly and nonexplicitly trained occasion setting are indeed the same must be addressed in some other manner—perhaps, for example, by using a blocking technique. It has been suggested (e.g., Ross & LoLordo, 1986) that explicitly trained occasion setters might show blocking. If nonexplicit training produces the same phenomenon, then one might expect a nonexplicitly trained feature to block the acquisition of explicitly trained occasion setting. This is a question that will require further research.

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