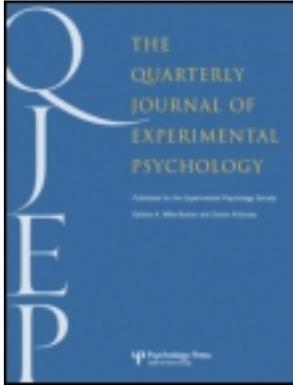


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## The Quarterly Journal of Experimental Psychology Section B: Comparative and Physiological Psychology

Publication details, including instructions for  
authors and subscription information:

<http://www.tandfonline.com/loi/pqjb20>

### Blocking of occasion setting in feature-positive discriminations

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Published online: 29 May 2007.

**To cite this article:** Charlotte Bonardi (1991) Blocking of occasion setting in feature-positive discriminations, *The Quarterly Journal of Experimental Psychology Section B: Comparative and Physiological Psychology*, 43:4, 431-448

**To link to this article:** <http://dx.doi.org/10.1080/14640749108401278>

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## **Blocking of Occasion Setting in Feature-positive Discriminations**

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In two experiments rats received feature-positive discrimination training in which brief conditioned stimuli (CSs) were paired with food during presentations of an extended feature stimulus, and non-reinforced in its absence. In Experiment 1 a novel feature was trained in compound with a second, pretrained feature. Acquisition of control over responding to the CS by the novel feature was blocked if the pretrained feature had also been trained in a feature-positive discrimination, compared to a group for whom the pretrained feature had been accompanied by uncorrelated presentations of CSs and food. Experiment 2 employed a within-subjects design. It demonstrated that the feature from a feature-positive discrimination with a particular CS,  $x$ , blocked acquisition of control by an added, novel feature over responding to  $x$ , compared to the control acquired by the same novel feature over a novel, CS  $y$ .

In a feature-positive discrimination a conditioned stimulus (CS) is reinforced when it is accompanied by a second "feature" stimulus but not when it is presented alone. This training results in more conditioned responding on trials when the feature is present than on trials when it is absent (Jenkins & Sainsbury, 1969). This outcome is often attributed to a classically conditioned association between the feature and reinforcement (e.g. Hearst & Jenkins, 1974): when the feature is present, its associative strength summates with that of the target CS to produce appropriate discrimination performance. In some cases, however, it seems that the feature modulates the level of conditioned responding to the CS independently of its own association with reinforcement (e.g. Looney & Griffin, 1978; Rescorla, 1985; Ross & Holland, 1981). The recent interest in feature-positive discriminations arises from the claim that this modulatory power of the feature is not the result of its Pavlovian properties, but that the feature is playing a "conditional" role (e.g.

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This research was financed by a grant from the Science and Engineering Research Council. I would like to thank Geoffrey Hall and Rob Honey for many helpful comments, and Alan Willis for help in running the animals.

Holland, 1983; Rescorla, 1985), modulating retrieval or use of the CS-US association. In these instances the feature may be called an occasion setter (Holland, 1983) or facilitator (Rescorla, 1985).

Most of the research on occasion setting has investigated whether occasion setters act upon a representation of the conditioned stimulus (CS), the reinforcer (US), or both (e.g. Davidson, Aparicio, & Rescorla, 1988; Davidson & Rescorla, 1986; Holland, 1986a, 1986b, 1989a; Rescorla, 1985), and several theories have been formulated about the target of occasion-setter action (e.g. Holland, 1983, 1989a; Rescorla, 1985). By comparison, relatively little attention has been paid to the conditions necessary for occasion-setter formation (but see e.g. Holland 1986a; Rescorla, 1988). As any complete account of occasion setting must explain how occasion setters are formed, the aim of the present experiments was to provide facts that might inform the development of such a theory.

One strategy for investigating this question is to exploit existing knowledge of other forms of learning. For example, considerable attention has been paid to the mechanisms underlying classical conditioning, with the result that much is known about the conditions required for Pavlovian association formation. Examining whether or not the principles governing classical conditioning apply also to the acquisition of occasion setting might aid the formulation of rules describing the acquisition of occasion-setting properties. This approach was adopted in the present paper.

One characteristic property of classical conditioning is the phenomenon of blocking. Blocking refers to the observation that pairings of the CS and US will not result in the formation of an association between them if the CS provides no new information about the delivery of the reinforcer. For example, if the target CS is reinforced in compound with a second stimulus that has already been conditioned, the target CS is redundant as a signal for the US, and conditioning to that stimulus will be reduced (Kamin, 1969). We say that acquisition of associative strength by the CS has been "blocked" by the presence of the pretrained stimulus. The notion that learning only occurs about events that provide non-redundant information is ostensibly a sensible property for any learning mechanism. On these grounds it is plausible that the same might be true of occasion setting—and if it were, this would place constraints on the conditions sufficient for occasion-setter formation and would have to be accommodated by any potential theory of occasion setting.

Ross and LoLordo (1986; see also LoLordo & Ross, 1987) conducted a series of experiments that succeeded in demonstrating that occasion setters are subject to blocking. Sadly, subsequently discovered problems with their scoring techniques led them to conclude (LoLordo & Ross, 1990) that their data could not, after all, be interpreted in this way, and that the experiments required replication. The experiments reported here constitute such a replication.

## EXPERIMENT 1

The experimental procedure used was similar to one employed by Wilson and Pearce (Wilson & Pearce, 1989, 1990; see also Kimmel & Ray, 1978). The design is shown in Table 1. In the first stage of the experiment animals in Group E (experimental) were trained on a feature-positive discrimination in which a brief CS (a 5-sec burst of white noise) was reinforced when it occurred during presentations of a 3-min feature stimulus, A, but not when it occurred alone. When the animals had mastered this discrimination and were responding more to the CS in the presence of A than in its absence, they received further training in which feature A was presented in compound with a second feature, B. As before, CS presentations were reinforced in the presence of the feature but not in its absence. The question of interest was the degree to which feature B came to control the level of conditioned responding to the CS. If occasion setting is subject to blocking, then acquisition of occasion setting by feature B, which was trained in compound with a pretrained occasion setter, should have been impaired. This was assessed by comparing Group E to a control, Group C, which was treated identically to Group E during compound training but for whom A had not been pretrained as an occasion setter. We anticipated that if blocking were to occur, B would exert less control over responding to the CS in Group E than in Group C.

Although such a result could be interpreted as evidence for blocking of occasion setting, there is a potential alternative explanation. It is likely that during pretraining A would have acquired not only occasion-setting properties, but also Pavlovian excitation in Group E. During compound training A would therefore block acquisition of Pavlovian excitation by B in this group. But if B were to possess less Pavlovian excitatory strength in Group E than in Group C, it would be less able to summate with the CS. In other words, if blocking of Pavlovian conditioning were to occur, this would produce the same pattern of results as would blocking of occasion setting. In order to control for this possibility, subjects in Group C also received presentations of A during pretraining; during these presentations both CSs and reinforcer deliveries were programmed to occur, but independently of one another. This procedure was designed to endow A with Pavlovian associative strength, but not with occasion-setting properties, because the CS was never reliably followed by reinforcement in the presence of A. This should ensure that acquisition of Pavlovian associative strength by B would be blocked in both groups, so that any difference between the two groups at test must be attributed to blocking of occasion setting.

This reasoning was based on the assumption that blocking of Pavlovian conditioning would be equally good in the two groups—but this need not necessarily be the case. For example, during pretraining food deliveries during A were signalled by the CS in Group E, but not in Group C.

TABLE 1  
Design of Experiment 1

Group	Pretraining	Compound Training	Test
E	A(n+)n-	AB(n+)n-	B(n-)n-
C	A(n/+ )n-	AB(n+)n-	B(n-)n-

*Note:* A and B refer to feature stimuli; *n* refers to the noise CS. A(n+)n- designates training in which the CS is reinforced during presentations of A and non-reinforced in its absence. A(n/+ )n- designates training in which the CS and the reinforcer are presented independently during presentations of A, and the CS is non-reinforced in A's absence.

Pavlovian conditioning to the pretrained feature might therefore have been overshadowed in Group E (e.g. Odling-Smee, 1975). This could have produced differential blocking of Pavlovian conditioning during compound training. It was thus important to provide independent evidence that any difference between the two groups in the apparent occasion-setting properties of B was not actually due to a difference in its Pavlovian properties. For this reason the level of conditioned responding to B in the absence of the CS was also examined during the test.

## Method

### *Subjects*

The subjects, 16 naive male hooded (Lister) rats with a mean free-feeding weight of 334 g (range: 325–344 g), were housed in pairs. Before the start of training they were reduced to 80% of their free-feeding 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, modified by the provision of a 60-W, 240-V strip light mounted above the white Perspex ceiling. 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 × 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 inwards 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. A light stimulus was provided by turning on the strip light. Two speakers, through which a 73-dB, 7-Hz clicker and an 84-dB (A-scale) white noise could be delivered from a Campden Instruments tone generator and a white noise generator, were mounted on the back wall. The boxes were housed in sound- and light-attenuating shells; masking noise was provided by the operation of the ventilation fans contained in these shells. The apparatus was controlled by a BBC microcomputer programmed in a version of BASIC.

### *Procedure*

*Pretraining.* In the first 30-min session the animals were trained to retrieve pellets from the food tray. These pellets were delivered according to a variable time (VT) 60-sec schedule. There followed a session in which the subjects were pre-exposed to the stimuli that were to be used as features. There were two 3-min presentations each of the clicker, the light, and the clicker-light compound. Each feature presentation was preceded by a 3-min intertrial interval (ITI); in addition, in this and all subsequent sessions there was a 3-min period at both the start and end of each session during which no events occurred.

*Stage 1.* Then the subjects were divided into two groups. All subjects received 6 3-min presentations of feature A in each of the first 10 sessions of this stage, separated by a 3-min ITI. For half the animals in each group A was the clicker; for the remainder it was the light. During both the feature and the ITI, CSs (5-sec bursts of white noise) occurred at random intervals, with the constraint that each CS was preceded by a 5-sec pre-CS period and that 6 CSs occurred during each 3-min period. For subjects in Group E, each of the 6 CSs occurring during feature presentations was followed by the delivery of a food pellet. Subjects in Group C also experienced 6 CSs and 6 food deliveries during each feature presentation, but these were programmed to occur independently of each other. This was achieved in the following manner. The feature was divided into 5-sec units, in any of which a CS or a food delivery could occur, according to the constraints described above. If food was programmed to occur, it was delivered at the start of the 5-sec unit, so that a CS could be immediately followed by food but not immediately preceded by it.

After 10 sessions there was little evidence that animals were responding substantially more during the CS in the presence of the feature than in its absence. Thus, in an attempt to improve performance on the discrimination, the number of trials per session was reduced to 4, and the ITI duration was increased to 6 min; 6 CSs occurred during each 3-min period, as before. All

other aspects of the procedure remained unchanged. Stage 1 continued for a further 10 sessions.

*Stage 2.* During Stage 2, both groups received identical training. Feature presentations continued to occur exactly as in the second part of the pretraining phase, with the difference that the feature, AB, was a compound of the clicker and the light. CSs occurred in the presence and absence of the feature, as before: all CS presentations in the presence of the feature were followed by reinforcement, whereas no reinforcers occurred in the feature's absence. There were 10 sessions in this stage.

*Test.* The subsequent test phase was identical to the compound training phase, with two exceptions. First, in place of two of the four AB compound presentations, subjects received a single presentation each of A and B in each session. The order of trials in these sessions was AB B AB A, or AB A AB B, these two types of session being presented in a double alternation. CSs occurred during these trials as before, but no food was delivered. There were four test sessions.

Conditioned responding to the CS was assessed using a "corrected" score based on the number of magazine responses made during CS presentations. More specifically, each CS was preceded by a 5-sec pre-CS period, and the total number of responses made in each pre-CS period was subtracted from the total made in the CS itself, to produce a "corrected" score. The corrected scores for CSs that occurred during the features were pooled to give mean rates of conditioned responding to the CS during the feature. The corrected scores for CSs that occurred during the ITI were pooled in exactly the same way, to produce a mean rate of responding to the CS during the ITI. During the test sessions more than one type of feature was presented in each session. The control exerted by a particular feature was therefore assessed by comparing the corrected response rate for the ITI immediately preceding that feature with the corrected rate computed for the feature itself.

In this and the subsequent experiment a criterion was adopted such that any animal that suppressed, rather than elevated, responding to the CS during the feature in each of the last four sessions of compound training was excluded. Application of this criterion resulted in the exclusion of one animal from each group in the present experiment. Finally, a significance level of  $p < 0.05$  was adopted in all analyses that follow.

## Results and Discussion

During pretraining subjects in Group E learned to make more responses to the CS in the presence of the feature than in the ITI, whereas subjects in Group C made fewer. In the last four sessions of this stage the mean corrected rates of responding to the CS were 11.88 responses per min (rpm) for Group E and -4.82 rpm for Group C during the feature, and

1.86 rpm for Group E and 1.14 rpm for Group C during the ITI. An ANOVA, with group (E or C) and feature (feature or ITI) as factors confirmed this description of the data, revealing a significant main effect of group,  $F(1, 12)=12.81$ , and a significant Group  $\times$  Feature interaction,  $F(1, 12)=9.03$ ; the main effect of feature was not significant ( $F < 1$ ). The rate of responding in pre-CS periods was higher during the feature than during the ITI; the mean response rates were 9.96 rpm for Group E and 16.82 rpm for Group C during the feature, and 4.32 rpm for Group E and 5.40 rpm for Group C during the ITI. An ANOVA with group and feature as factors revealed a significant main effect of feature,  $F(1, 12)=14.24$ , but no other effects or interactions were significant [largest  $F(1, 12)=2.09$ ].

During compound training subjects in Group E continued to respond at a higher rate to the CS in the presence of the feature than in the ITI, whereas subjects in group C acquired the ability to do so. In the last four sessions of this stage the mean corrected rates of CS responding were 13.71 rpm for Group E and 19.23 rpm for Group C during the feature, and 1.33 rpm for Group E and 4.36 rpm for Group C during the ITI. An ANOVA with group and feature as factors revealed a significant main effect of feature,  $F(1, 12)=11.24$ ; no other effects or interactions were significant [largest  $F(1, 12)=1.71$ ]. The mean pre-CS response rates were 17.23 rpm for Group E and 17.43 rpm for Group C during the feature, and 3.89 rpm for Group E and 7.01 rpm for Group C during the ITI. An ANOVA with group and feature as factors revealed a significant main effect of feature,  $F(1, 12)=22.01$ . No other effects or interactions were significant ( $F_s < 1$ ). Thus there was no sign of any difference in the rate of responding during the feature in the two groups that could have masked differences in responding to the CS.

The data of central interest, the rates of responding to the CS during B in the test, are shown in Figure 1. Subjects in Group C responded substantially more to the CS when B was present than in the ITI, whereas subjects in Group E did not. An ANOVA with group and feature as factors showed that this effect was statistically reliable; there was a significant main effect of group,  $F(1, 12)=4.94$ , of feature,  $F(1, 12)=8.23$ , and a significant Group  $\times$  Feature interaction,  $F(1, 12)=5.31$ . Simple main effects analysis (using the pooled error term) revealed that subjects in Group C responded significantly more to the CS during B than during the ITI,  $F(1, 12)=13.38$ , whereas subjects in Group E did not ( $F < 1$ ).

The group mean corrected response rates to the CS and pre-CS response rates for A and AB trials are shown in Table 2. The control exerted by these features over CS responding did not appear to differ in the two groups. This impression was confirmed by ANOVAS with group and feature as factors: there was a significant main effect of feature— $F(1, 12)=13.94$  for AB trials and  $F(1, 12)=4.88$  for A trials—but in neither case was the Group  $\times$  Feature

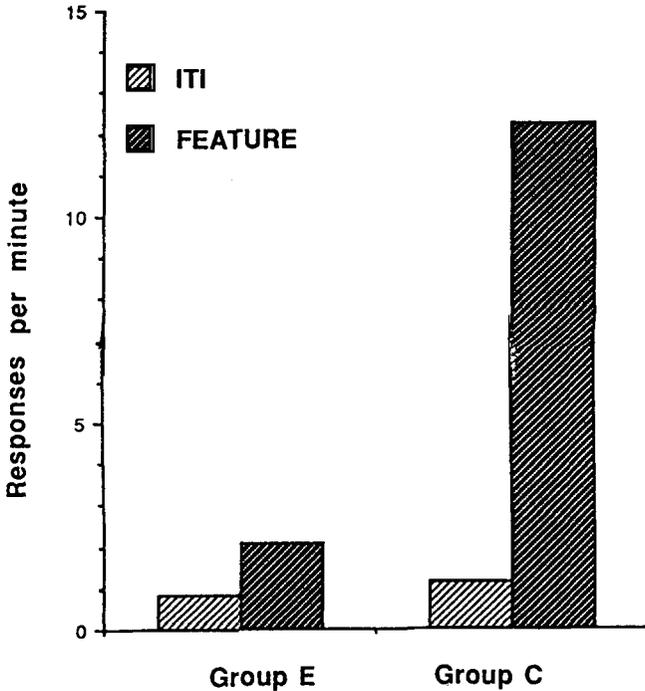


FIG. 1. Group mean response rates for Group E (experimental) and Group C (control) for responding to the CS in the added feature and in the ITI during the test phase of Experiment 1. Scores are corrected for pre-CS responding.

interaction significant ( $F_s < 1$ ) nor were the main effects of group ( $F_s < 1$ ). Analogous ANOVAS performed on the pre-CS response rates revealed significant main effects of feature for both AB trials,  $F(1, 12) = 6.25$ , and A trials,  $F(1, 12) = 23.15$ ; nothing else attained significance [largest  $F(1, 12) = 4.33$ ].

The mean rate of pre-CS responding during the added feature, B, was 7.57 rpm for Group E and 10.22 rpm for Group C during the feature, and 2.82 rpm for Group E and 6.29 rpm for Group C during the ITI. An ANOVA with group and feature as factors revealed a significant main effect of feature,  $F(1, 12) = 6.07$ ; no other effects or interactions were significant [largest  $F(1, 12) = 1.27$ ]. Thus, there was no sign that the difference between the groups in responding to the CS could be an artifact of a difference in responding during B. This failure to find a group difference in pre-CS responding also suggests that there was no difference in Pavlovian conditioning to B in the two groups. Further evidence on this point was provided by an analysis of the total number of responses made in the absence of the CS, during both B and the ITI. This measure is likely to provide a more sensitive

TABLE 2  
Mean Corrected CS Response Rates

Group	Trial			
	AB		A	
	ITI	F	ITI	F
E	1.13	17.38	0.68	5.54
C	1.25	23.75	4.08	8.21

Group	Trial			
	AB		A	
	ITI	F	ITI	F
E	3.13	11.00	1.98	13.85
C	8.88	17.13	5.93	10.65

ITI = intertrial interval.

F = feature.

measure of B's Pavlovian properties because it is based on a larger sample of responding. The mean response rates were 6.43 rpm for Group E and 10.04 rpm for Group C during the feature, and 3.09 rpm for Group E and 6.10 rpm for Group C during the ITI. An ANOVA with group and feature as factors revealed a significant main effect of feature,  $F(1, 12) = 11.67$ , but no other effects or interactions were significant [largest  $F(1, 12) = 1.34$ ]. Thus there was no evidence that the Pavlovian properties of B differed in the two groups.

In this experiment the acquisition of occasion setting by B was impaired if it was trained in compound with a pretrained occasion setter. There was, moreover, no evidence that B's Pavlovian properties differed in the two groups. The difference in B's ability to control responding to the CS must therefore be attributed to differences in B's occasion-setting power. This finding is therefore consistent with the notion that occasion setters show blocking. However, the fact remains that the argument against such a Pavlovian interpretation of the data is empirical, relying on the absence of a significant difference in conditioned responding to B in the two groups. The second experiment therefore attempted to replicate the effect using a more powerful design, in which the possibility of such an alternative interpretation was eliminated.

## EXPERIMENT 2

Experiment 2 employed a within-subjects design, as shown in Table 3. In Stage 1 all subjects received feature-positive discrimination training in which a CS,  $x$ , was reinforced in the presence of a feature, A, but not in its absence. In Stage 2 they received further training on two feature-positive discriminations. In the first  $x$  was reinforced in the presence of a compound feature, composed of the pretrained feature A and a novel feature, C;  $x$  was non-reinforced in the feature's absence. In the second discrimination a second CS,  $y$ , was reinforced in the presence of a compound feature composed of C and a second novel feature, B. Again  $y$  was non-reinforced in the feature's absence. The question of interest was the degree to which the added feature C would control conditioned responding to  $x$  and  $y$ . C was trained as an occasion setter for  $x$  in the presence of the pretrained feature A. Thus if occasion setters are subject to blocking, acquisition of occasion-setting control over responding to  $x$  by C should be blocked. But C was trained as an occasion setter for  $y$  in the presence of a novel feature, B, so that in this case no blocking should occur. Consequently at test C should exert more control over responding to  $y$  than to  $x$ . Moreover, because the same feature is being considered in each case, any blocking effect that is observed cannot be explained in terms of differential blocking of Pavlovian conditioning to the feature, as it could in the previous experiment.

## Method

*Subjects*

The subjects, 8 naive male hooded (Lister) rats with a mean free-feeding weight of 379 g (range: 325–530 g), were housed in pairs and deprived as in the previous experiment.

*Apparatus*

The apparatus was identical to that used in the previous experiment, except in the following respects. Two speakers, through which a 74-dB, 7-Hz

TABLE 3  
Design of Experiment 2

<i>Pretraining</i>	<i>Compound Training</i>	<i>Test</i>
A( $x+$ ) $x-$	AC( $x+$ ) $x-$ BC( $y+$ ) $y-$	C( $x-$ ) $x-$ C( $y-$ ) $y-$

*Note:* A, B, and C refer to feature stimuli;  $x$  and  $y$  refer to the target CSs. A( $x+$ ) $x-$  designates training in which the CS  $x$  is reinforced during presentations of A and non-reinforced in its absence.

clicker, a 79-dB, 1-kHz tone, and an 88-dB (A-scale) white noise could be delivered, were mounted on the side wall. An additional CS was provided by flashing two 24-V jewel lights, one on each side of the magazine, at 2-Hz.

### *Procedure*

*Pretraining.* In the first 30-min session the animals were magazine-trained, as in the previous experiment.

*Stage 1.* In Stage 1 all subjects received occasion-setting training with feature A and CS  $x$ . For half of the subjects A was the tone and for the remainder it was the clicker. For half of each of these subgroups  $x$  was the noise and for the remainder it was the flashing light. All other aspects of training were identical to the training procedure used in the compound training stage of Experiment 1. There were 12 sessions in this stage.

*Stage 2.* During this stage all subjects continued to receive occasion-setting training with feature A and CS  $x$ , but A presentations were now accompanied by a further stimulus C—dark, achieved by turning off the houselight. Subjects were also trained in separate sessions on a second occasion-setting discrimination with the second CS  $y$ ;  $y$  was reinforced in the presence of a second compound feature, composed of stimulus C and a second auditory stimulus, B. For subjects for whom A had been the clicker, B was the tone and vice versa. Stimulus  $y$  was non-reinforced in the absence of the feature; for subjects for whom  $x$  had been the noise,  $y$  was the light, and vice versa. In all other respects compound training sessions were identical to those of Stage 1. The two types of session were presented in double alternation sequences—either a b b a, or b a a b; these two sequences were alternated. There were ten sessions of each type of discrimination in this stage.

*Test.* The two test sessions were identical to the compound training sessions, except in the following respects. First, the only feature that was presented was C. Second, no reinforcers were delivered. Third, for two of the trials in each session  $x$  was the CS, and for the remainder  $y$  was the CS; the two types of trial in each session were presented in a double alternation, which was reversed for the second test session.

### **Results**

During Stage 1 subjects learned to respond more to the CS in the presence of the feature than in its absence. In the last two sessions of this stage the mean corrected rates of responding to the CS were 19.03 rpm during the feature and 0.77 rpm during the ITI. And ANOVA with feature (feature or ITI) as the factor confirmed that the discrimination was statistically significant,  $F(1, 7) = 14.30$ . Response rates in the pre-CS periods were higher during the

feature than during the ITI; the mean rates were 7.72 rpm during the feature and 1.03 rpm during the ITI. An ANOVA with feature as the factor revealed a significant main effect of feature,  $F(1, 7) = 31.15$ . During Stage 2 subjects continued to respond at a higher rate to  $x$  in the presence of the feature than in the ITI and acquired the ability to do the same to  $y$ . In the last two sessions of each type in this stage the mean corrected rates of responding to the CS during AC trials were 13.78 rpm during the feature and 0.27 rpm during the ITI; the corresponding rates for BC trials were 15.97 rpm and 0.63 rpm, respectively. An ANOVA with trial (AC or BC) and feature (feature or ITI) as factors revealed a significant main effect of feature,  $F(1, 7) = 14.00$ ; the effect of trial and the Feature  $\times$  Trial Interaction were not significant ( $F_s < 1$ ). The mean pre-CS response rates for AC trials were 7.91 rpm during the feature and 1.36 rpm during the ITI; the corresponding means for BC trials were 7.97 rpm and 1.81 rpm, respectively. An ANOVA with trial and feature as factors revealed a significant main effect of feature,  $F(1, 7) = 31.72$ . No other effects or interactions were significant ( $F_s < 1$ ).

The data of central interest, the rates of responding to  $x$  and  $y$  during C in the test, are shown in Figure 2. Because the feature was the same for both  $x$  and  $y$ , these data were not corrected for pre-CS responding. It is evident that feature C produced a greater elevation of responding to  $y$  than to  $x$ . An ANOVA with CS ( $x$  or  $y$ ) and feature (feature or ITI) as factors showed that this effect was statistically reliable; there was a significant main effect of CS,  $F(1, 7) = 10.38$ , and of feature,  $F(1, 7) = 21.22$ , and a significant CS  $\times$  Feature interaction,  $F(1, 7) = 8.50$ . Simple main effects analysis revealed that subjects responded significantly more to  $y$  than to  $x$  during C,  $F(1, 7) = 10.37$ ; responding to  $x$  and  $y$  did not differ during the ITI ( $F(1, 7) = 1.37$ ).

The group mean pre-CS response rates for these sessions were, for  $x$  trials, 1.50 rpm during the feature and 0.50 rpm during the ITI. The corresponding rates for  $y$  trials were 1.63 rpm and 0.97 rpm, respectively. An ANOVA with CS and feature as factors revealed no main effect of CS ( $F(1, 7) = 3.10$ ) but a significant main effect of feature,  $F(1, 7) = 6.75$ ; however, most importantly, the feature  $\times$  CS interaction was not significant ( $F < 1$ ). There is no evidence that the difference in the rates of responding to  $x$  and  $y$  could be an artifact of differences in pre-CS response rates. The present results thus replicate those of the previous experiment in finding that occasion setters are subject to blocking.

## GENERAL DISCUSSION

Two experiments testing the assertion that the acquisition of occasion setting is subject to blocking have been described. In both studies acquisition of occasion-setting properties by a feature was impaired if that feature was trained in compound with a pretrained occasion setter. These results may not

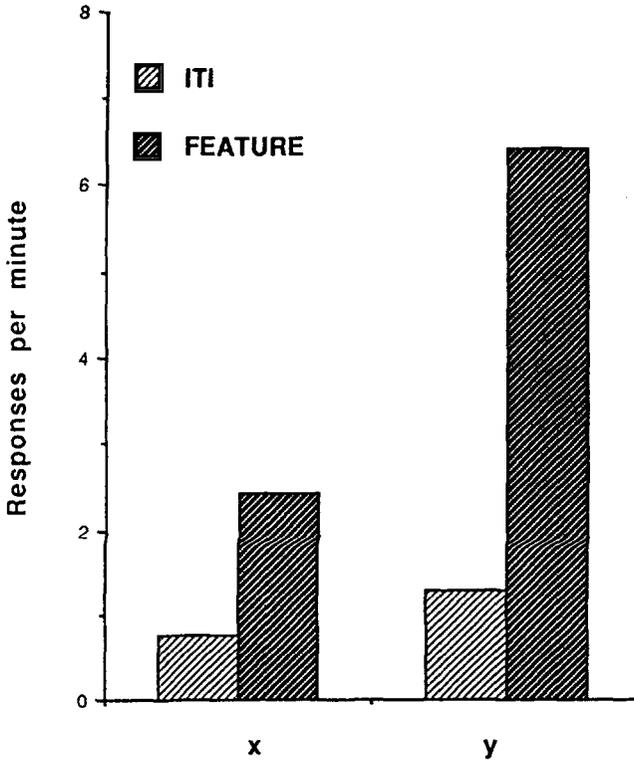


FIG. 2. Group mean response rates for responding to CSs *x* and *y*, during presentations of feature C and during the ITI, in the test phase of Experiment 2.

be explained in terms of Pavlovian conditioning. In the first experiment there was no evidence for any difference in the Pavlovian associative strength of the target feature according to whether or not it had been trained with a pretrained occasion setter. Thus the blocking effect that was observed cannot be explained readily in terms of differential Pavlovian conditioning to the feature. This point is made more powerfully in Experiment 2, in which the critical comparison was between the control exerted by the same feature over responding to two different CSs. In this case the experimental design rules out the possibility of an explanation in terms of differential conditioning to the feature.

It seems, then, that the acquisition of occasion setting is subject to blocking. This finding has a number of implications, both for existing theories of occasion setting and for the way in which these theories must be adapted to account for occasion-setter formation. Rescorla (1985) has suggested that an occasion setter lowers the activation threshold of the US

representation, so that when an excitatory CS occurs in its presence, activation of the US representation will occur more readily, and the probability of a CR will increase. Rescorla does not provide a clear statement of the exact conditions required for occasion-setter formation. However, one requirement that is implied is that the CS must acquire associative strength in the presence of the feature for the feature to acquire occasion-setting properties. If this is the case, then such an account predicts that blocking will occur. If occasion-setting training gives the pretrained feature the property of allowing the CS to activate the US representation fully, an added feature cannot acquire any more occasion-setting ability because the CS, already fully able to activate the US representation, will be able to acquire no more associative strength in its presence. However, even if this is the case, the present data cause Rescorla's model other difficulties. In the test phase of Experiment 2 the same feature, C, exerted differential control over responding to  $x$  and  $y$ —in other words, its effects were CS-specific. It was argued that this ruled out a simple Pavlovian summation account of the results, because Pavlovian summation is not CS-specific. Equally, it rules out Rescorla's occasion setting account, the crux of which is that an occasion setter's effects are on the US representation—and hence are likewise not CS-specific. In this respect the present results accord with a previous demonstration by Wilson and Pearce (1989) that the same feature may acquire differential control over responding to different CSs, and with the observation that, although it has been reported that occasion setting transfers to other occasion-set CSs, this transfer is frequently incomplete (e.g., Holland, 1989a, 1989b).

The other two main accounts of occasion setting are those proposed by Holland (1983), and by Pearce (1987). Holland's theory (1983; but see Holland, 1989a, 1989b), although it can accommodate the differential control exerted by the feature over responding to different CSs that was observed in Experiment 2, is silent as to the mechanisms underlying occasion-setter formation and does not address the issue of whether or not blocking should occur. Pearce, on the other hand, predicts the occurrence of blocking. Pearce argues that, during occasion-setting training, Pavlovian associative strength accrues neither to feature nor to CS alone, but to a compound cue present only when feature and target co-occur. Presenting the CS in the presence of the feature, by completing this compound cue, will elicit more responding than presenting the CS alone. According to this account, responding to the CS during the added feature at test is primarily determined by the amount of associative strength acquired by the compound cue of the pretrained feature, the added feature, and the CS during compound training. If, as in a blocking procedure, the pretrained feature–target compound has already been established as a signal for reinforcement, this will serve to block further acquisition of associative strength by the compound cue during the compound training stage and hence reduce the amount of responding at test.

More generally, the fact that acquisition of occasion setting is subject to blocking suggests that it shares with Pavlovian conditioning an important property—that learning will not occur if the to-be-learned-about stimulus is redundant. It may be that this observation reflects no more than a general and sensible property of learning mechanisms. But it may also have more profound implications. The discovery of blocking in classical conditioning was important because it placed constraints on the known conditions under which a classically conditioned association could form. In so doing it ruled out a potential class of models describing the conditions required for classical conditioning—for example, simple contiguity. The fact that occasion setting is also subject to blocking at least invites the possibility that occasion setting might be subject to a similar set of constraints—it might even be governed by the same learning process. This suggestion is clearly in the spirit of the model proposed by Pearce (1987), according to which acquisition of occasion setting is essentially a process of Pavlovian conditioning. Also pertinent in this respect is a suggestion made by Bonardi (1988b, 1989), who has proposed 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 explicitly predicts that occasion setters, like Pavlovian CSs, should show blocking.

The blocking of occasion setting also establishes some empirical links with the literature on 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. Bonardi, 1988a, 1988b, Goodall & Mackintosh, 1987; Holman & Mackintosh, 1981). This similarity between discriminative stimuli and occasion setters has led to the suggestion that—as the very choice of the term occasion setter suggests—both may be a product of the same learning mechanism (e.g. Holland, 1983; Rescorla, 1985; Ross & LoLordo, 1987). Holman and Mackintosh (1981) have reported that discriminative stimuli show blocking; finding that the same is true of occasion setting thus lends support to this hypothetical parallel. In this respect it is of some 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.

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*Revised manuscript received 31 January 1991*

## Effet de blocage lors d'apprentissages de discriminations "feature-positive"

Dans deux expériences, les rats étaient soumis à un apprentissage de discrimination "feature-positive" dans lequel des stimulus conditionnés brefs (CSs) étaient couplés avec de la nourriture pendant les présentations d'un stimulus caractéristique, et non renforcés en son absence. Dans l'expérience 1, une caractéristique nouvelle était utilisée en association avec une seconde caractéristique pré-apprise. L'acquisition du contrôle de la réponse au CS par la caractéristique nouvelle est bloquée si la caractéristique pré-apprise avait également été utilisée dans une discrimination "feature-positive", par comparaison à un groupe chez qui la caractéristique pré-apprise avait été accompagnée des présentations non corrélées de CSs et de la nourriture. Dans l'expérience 2, on utilise un plan intra-sujets. On montre que la caractéristique manipulée lors d'une discrimination "feature-positive", associée à un CS particulier,  $x$ , bloque l'acquisition du contrôle de la réponse à  $x$  par une caractéristique nouvelle supplémentaire, par comparaison avec ce qui se passe quand on utilise la même caractéristique nouvelle, associée à une cible  $y$ , elle aussi nouvelle.

## Bloqueo de la "señalización" en discriminaciones de rasgo positivo

En dos experimentos ratas recibieron entrenamiento de discriminación de rasgo positivo en el que estímulos condicionados breves (CSs) fueron apareados con alimento durante la presentación de un estímulo de rasgo extendido, y no fueron reforzados en su ausencia. En el experimento 1, un nuevo rasgo fue entrenado combinado con un segundo rasgo, pre-entrenado. La adquisición de control sobre la respuesta al CS por el rasgo nuevo se bloqueó si el rasgo de pre-entrenamiento había sido también entrenado en una discriminación de rasgo positivo, en comparación con un grupo para el que el rasgo pre-entrenado había sido acompañado por presentaciones no correlacionadas de CS y comida. El experimento 2 utilizó un diseño intra-sujetos. Demostró que el rasgo de una discriminación de rasgo positivo con un CS particular,  $x$ , bloqueaba la adquisición de control sobre la respuesta a  $x$  por un nuevo rasgo incorporado en comparación con el control adquirido por el nuevo rasgo sobre un nuevo CS  $y$ .