

Role of Stimulus Ambiguity in Conditional Learning

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Three experiments using rats and the conditioned emotional response procedure examined the notion that when a conditioned stimulus (CS) is paired with a reinforcer (US), that CS must be ambiguous if the CS–US association is to become the target of conditional control. CS ambiguity was manipulated by varying whether the CS had been preexposed prior to conditioning. In Experiments 1 and 2, it was demonstrated that a cue that accompanied pairings of a CS and shock acquired conditional control over the CS–shock association when that CS had been preexposed, but not when it was novel. The measure of conditional control in Experiments 1 and 2 was the ability of the (conditional) cue to enhance responding to the target CS. Experiment 3 used a blocking procedure to show that this enhancement reflected an amplification of the target CS's effective associative strength. These findings extend existing knowledge of the conditions required for conditional cue formation.

A cue that signals that some other stimulus will be followed by reinforcement can come to act as an *occasion setter* (cf. Holland, 1983). Such a cue enhances the ability of the target stimulus to elicit its conditioned response and does so independently of its own direct association with the reinforcer (e.g., Holland, 1983; Rescorla, 1985). The subject's ability to retrieve or make use of the information that the target stimulus is associated with reinforcement appears to be conditional on the presence of the occasion setter.

The standard procedure for establishing a cue as an occasion setter involves reinforced presentations of the target conditioned stimulus (CS) in the presence of the conditional cue, intermixed with nonreinforced presentations of the CS in the absence of the cue. Generally, it is supposed (but see Bonardi, 1992) that these nonreinforced trials are critical in endowing the cue with occasion-setting properties, but views differ as to the reason for this. According to Rescorla (e.g., 1988), a cue becomes an occasion setter only when the CS that is being reinforced in its presence is, to some extent, inhibitory. The nonreinforced trials are held to be important, therefore, because they endow the target CS with a measure of inhibitory strength. An alternative interpretation (e.g., Bouton, 1993) stresses that the nonreinforced trials render the target CS ambiguous, in the sense that that on some occasions it is followed by the unconditioned stimulus (US)

and on other occasions not. The cue that signals the reinforced trials acquires conditional control because it serves to disambiguate the significance of the CS. This account was originally developed (e.g., Bouton & Bolles, 1985) to explain the acquisition of conditional control by contextual cues, but it is commonly believed that the mechanisms governing conditional control are similar, regardless of whether this control is exerted by a context or by a discrete cue (e.g., Bouton, 1994, p. 233; see also Bouton & Swartzentruber, 1986).

These accounts thus differ as to why the nonreinforced trials of the standard training procedure are critical for establishing occasion setting; according to Rescorla (e.g., 1988), these trials ensure that the reinforced CS has some inhibitory strength, whereas, according to the alternative, they simply ensure the ambiguity of the reinforced CS. One way to discriminate between these two hypotheses is to exploit the fact that it is possible to make a stimulus ambiguous without giving it inhibitory strength. For example, suppose the trials of an occasion-setting training procedure were rearranged so that all the nonreinforced target trials occurred first, and all trials on which the target was reinforced, signaled by the conditional cue, occurred afterwards. According to standard theories of conditioning, the target CS does not become inhibitory in these circumstances because it is nonreinforced only in the first stage of training when the US has not yet been presented. Thus, in the second stage, the added cue signals the reinforcement of a neutral rather than an inhibitory CS and, so, according to Rescorla's account, will not become a conditional cue. It can be argued, however, that such preexposure may render the stimulus ambiguous when it is eventually reinforced. According to some accounts of latent inhibition, preexposure to a stimulus allows animals to acquire some representation of the fact that the stimulus is not associated with other events (sometimes described as a CS–no-event association; see e.g., Hall, 1991). It has also been suggested that this representation

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continues to exist alongside the association formed as a consequence of subsequent CS-US pairings (e.g., Kraemer & Spear, 1992). The CS therefore becomes ambiguous, in the sense that its consequences change at the start of the conditioning stage. A cue that is first introduced during conditioning could therefore be used to resolve the ambiguity, allowing the ambiguity theory to predict that such a cue would acquire conditional control.

The experiments described below exploit this logic. The basic design involved two stages of training, with the significance of the CS being changed in the second stage at the same time as a new cue was introduced to signal its occurrence. Previous work using a two-stage procedure (Brooks & Bouton, 1993, 1994) has shown that the cue acquires conditional control when CS-US pairings are given in Stage 1 and the CS is presented alone in Stage 2. The important feature of our experiments is that the order of these treatments is reversed (see also Kraemer & Spear, 1992), with nonreinforced trials occurring in Stage 1 and reinforced trials in Stage 2. If resolution of ambiguity is the critical factor, then this procedure should be capable of establishing conditional control. However, if the CS needs to possess inhibitory properties during reinforcement for conditional control to be established, such control is no more likely to be acquired in this case than in a control condition in which no Stage 1 preexposure trials are given.

Experiment 1

The conditional training procedure used in this experiment was modeled on that used in a number of standard occasion-setting paradigms (e.g., Rescorla, 1985; Ross & Holland, 1981). Pairings of a target CS and shock were signaled by a second stimulus, which thus had the opportunity to become a conditional cue. The signal's control over responding was then evaluated by examining whether conditioned responding was greater to the target CS when it was preceded by the signal than when it was presented alone. For some animals, the target stimulus had been preexposed and was therefore ambiguous; thus, according to the ambiguity notion, the signal should have become a conditional cue for these animals. According to Rescorla (1988), on the other hand, because such preexposure does not endow the stimulus with inhibition, there is no reason to expect the signal to acquire conditional properties. The control condition was a group in which the target CS was novel; this would ensure that it was neither ambiguous nor inhibitory, so that neither account would predict that the signal should acquire any conditional control in this case. The design of the experiment is summarized in Table 1.

Table 1
Design of Experiment 1

Group	Preexposure	Conditioning	Test
PRE	Stimulus B	A → B → shock	B, A → B
CON	Stimulus C	A → B → shock	B, A → B

Note. PRE = preexposed; CON = control.

Method

Subjects

The subjects were 16 naive male Wistar rats with a mean ad lib weight of 295 g (range = 260–320 g), which were housed in pairs in plastic tub cages with sawdust bedding. The colony rooms were lit from 8 a.m. to 9 p.m. The subjects were tested during the light portion of the cycle. Before the start of training, the rats were reduced to 80% of their ad lib weights 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 (Loughborough, England) operant chambers. Each of the boxes had three walls of sheet aluminum, with a transparent plastic door as the fourth wall, and an aluminum ceiling. Each of the boxes contained a recessed food tray to which 45-mg mixed-composition food pellets could be delivered; this was situated in the center of the left wall, adjacent to the door. Access to this food tray was by a rectangular aperture 6 cm high × 5 cm wide, which was covered by a transparent plastic flap of the same dimensions. Each of the chambers was equipped with a lever, which was mounted 3.5 cm to the left of the food tray and 6 cm above the floor. Two speakers were mounted on the ceiling of the chamber; through one of these, a 30-Hz clicker and a 2-kHz tone, both at 80 dB(A), could be delivered from a Campden Instruments tone generator, and through the other an 80-dB(A) white noise could be delivered from a Campden Instruments noise generator. The floor was constructed from stainless-steel rods 0.5 cm in diameter and 1.5 cm apart; these could be electrified by a Campden Instruments shock generator (Model 521C). 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 a personal computer programmed in a version of C.

Procedure

Lever-press training. In the first 10-min session, pellets were delivered according to a variable-time (VT) 30-s schedule, and in addition each lever press was rewarded by the delivery of a single food pellet. In the second session, animals were again rewarded for lever pressing according to a continuous reinforcement (CRF) schedule, until they each had made a total of 50 responses. No response-independent food deliveries occurred during this session.

All subsequent sessions were 40 min in duration. In the third session, lever pressing was reinforced in the first 10 min according to a variable-interval (VI) 10-s schedule, in the second 10 min according to a VI 20-s schedule, in the third 10 min according to a VI 30-s schedule, and in the final 10 min according to a VI 40-s schedule. In the remaining six sessions of this stage and throughout the remainder of the experiment, lever pressing was rewarded according to a VI 60-s schedule.

Preexposure. At this point, the subjects were randomly assigned to one of two groups. In each of the twelve sessions of this stage, animals received four 30-s stimulus presentations. Animals in Group PRE (preexposed) were preexposed to Stimulus B. For half of the animals in this group, B was the tone, and, for the remainder, B was the noise. All animals in Group CON (control) were preexposed to Stimulus C, which was the clicker for all subjects. The intertrial interval (ITI) was 456 s.

Conditioning. Each of the three conditioning sessions consisted of four conditioning trials. Each trial comprised a 30-s presentation of A followed by a 30-s presentation of B, followed immediately by a 0.5-s, 0.5-mA footshock. For half the animals in each group, A was the noise and B was the tone, and the reverse was true for the remaining animals. The ITI was 432 s.

Test. Two test sessions followed, each consisting of four trials—two presentations of A immediately followed by B and two presentations of B alone. Each stimulus presentation was of 30-s duration. In the first of these sessions, for half the subjects in each group, the order of trial presentations was B, A → B, A → B, and B; for the remainder, the order was A → B, B, B, and A → B. In the second test session, each subject received the alternative trial order. The ITI was 445 s.

Data treatment. In this experiment and all those that follow, lever pressing was recorded during each CS presentation and also during the pre-CS period (i.e., the 30-s portion of the ITI that immediately preceded the onset of the CS). When the CS in question was immediately preceded by some other stimulus, the pre-CS score for this first stimulus was used. To evaluate the conditioned fear on a conditioned type of trial, conditioned suppression was computed in four-trial blocks. The pre-CS and CS scores for each of the four trials in a block were pooled to give one pre-CS score and one CS score per block. Then a suppression ratio, $a/(a + b)$, was calculated, where b was the pooled pre-CS score and a was the pooled CS score. A significance level of $p < .05$ was adopted throughout this and the subsequent experiments.

Results and Discussion

No data were recorded during the preexposure phase. The conditioning trials established suppression to Stimulus B in both groups. By the last conditioning session, the mean suppression to Stimulus B was .08 for Group PRE and .17 for Group CON. An analysis of variance (ANOVA) revealed that these scores did not differ reliably, $F(1, 14) = 1.29$. Animals in both groups also showed substantial suppression to Signal A, and this was also somewhat more profound in Group PRE. The mean suppression ratio in the last session was .08 for Group PRE and .21 for Group CON. An ANOVA revealed that this difference fell just short of statistical significance, $F(1, 14) = 4.06$, $p = .06$. The implication of this difference is discussed below. The mean rate of responding during the pre-CS period during this last conditioning session was 43.7 responses per minute (rpm) for Group PRE and 49.5 rpm for Group CON. An ANOVA revealed that these rates did not differ ($F < 1$).

During the test, the group mean suppression ratios for Stimulus B, both when it was presented alone and when it was signaled by Stimulus A, are shown in Figure 1. Both groups seemed to show more fear of B when it was signaled by A than when it was presented alone, but this effect was greater in Group PRE. This description of the data is supported by the results of an ANOVA with group (PRE or CON) and trial type (with and without A) as factors. There was no effect of group ($F < 1$), but there was a significant main effect of trial type, $F(1, 14) = 26.55$, and also a significant interaction between these two factors, $F(1, 14) = 7.64$. This interaction was explored further with simple main effects, which revealed a significant effect of trial type in Group PRE, $F(1, 14) = 31.34$, but not in Group

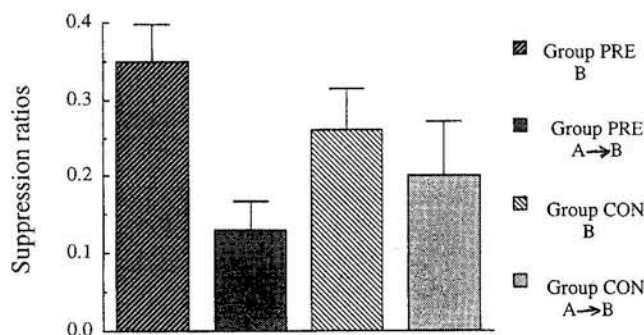


Figure 1. Group mean suppression ratios Stimulus B, both when signaled by A and when presented alone, in the test sessions of Experiment 1. PRE = preexposed; CON = control.

CON, $F(1, 14) = 2.84$. The other simple main effects were not significant, largest $F(1, 18) = 1.19$.

The group mean suppression ratio for Stimulus A during these sessions was .22 for Group PRE and .32 for Group CON. Although this difference appeared quite substantial, these scores did not differ, $F(1, 14) = 1.99$. Finally, the mean rate of pre-CS responding during the test sessions was 62.6 rpm and 49.4 rpm for Groups PRE and CON, respectively. These rates did not differ, $F(1, 14) = 1.36$.

These results appear to be consistent with the stimulus ambiguity hypothesis. Although animals in both groups seemed to show more fear of B when it was signaled by A than when it was presented alone, this effect was sizable and statistically reliable only in Group PRE, for whom B had been preexposed. If we assume that this preexposure treatment allows the animals to learn something about the consequences, or meaning, of the CS, its subsequent pairings with shock constitute a change in this meaning, thus rendering it ambiguous. Then, according to the ambiguity hypothesis, the animal will need to use the added cue A to resolve this situation, thus making A an occasion setter. On the other hand, as there is no reason to suppose that the target CS has any inhibitory strength during its training with A, Rescorla's (1988) hypothesis cannot account for the enhanced control governed by A in Group PRE.

Before we accept this interpretation, however, there is an alternative explanation that must be considered, one that stems from a consideration of the associative strength acquired by the signal itself. We have assumed that the animals' fear of B was enhanced when B was signaled by A because A had conditional control over the B-shock association. However, this enhancement could have been a consequence of the direct associative strength acquired by the signal. The conditioning procedure ensured that A was reliably paired with shock, albeit after a delay, so that a direct association between A and the shock might have formed. This means that A's associative strength could then sum with that of B when they were presented together in the test, making it look as though A had conditional control over the B-shock association.

As it stands, this factor cannot explain the present results, as A was paired with shock in both groups. Thus, the

summation effect can be expected in both groups, and yet we observed enhanced suppression to B in only one group. There is reason to think, however, that the associative strength acquired by A, and, hence, the summation effect, might be greater in Group PRE than in Group CON. In Group PRE, B was preexposed, which might have resulted in its suffering latent inhibition and made it more difficult for that stimulus subsequently to become associated with shock. This might, in turn, have undermined B's ability to overshadow A (Carr, 1974) and, thus, enhanced the amount of associative strength that A could acquire, thereby enhancing A's ability to sum with B. In Group CON, for which Stimulus B was not preexposed, B's capacity to overshadow A would be unimpaired, and so A would be correspondingly less able to enhance responding to B at test. There is some evidence for this suggestion in the results we have just presented, in that, at the end of conditioning, the associative strength of A was greater in Group PRE than in Group CON. We need to be able to reject this alternative explanation of these results before we can treat them as evidence in favor of the ambiguity hypothesis.

Experiment 2

Experiment 2 was designed to replicate the critical results of Experiment 1 under conditions in which the results could not be attributed to differential summation. The design is summarized in Table 2. There were two groups of animals, Group PRE and Group CON, both of which were given conditioning trials with two different auditory stimuli, B and D. Two visual stimuli, A and C, served as the putative conditional cues. Stimulus A signaled pairings of B with shock, and C signaled pairings of D with shock. As before, the groups differed in whether B and D had been preexposed; animals in Group PRE experienced presentations of both B and D prior to conditioning, whereas animals in Group CON were simply put in the apparatus during this stage. Thus, for Group PRE, both B and D were ambiguous during conditioning, whereas for Group CON they were not. The question of interest was, therefore, whether A and C would acquire greater conditional control over responding to their respective targets, B and D, in Group PRE than in Group CON. The way this was evaluated was as follows: In the test, responding to both B and D was examined in two types of trial. On *same* trials, B was signaled by A and D by C, exactly as they had been during conditioning. On *differ-*

ent trials, this arrangement was reversed, so that B was signaled by C and D by A. The measure of conditional control was the difference in responding on *same* and *different* trials to B and D. The reason for this choice of measure is as follows. If, during training, A had acquired control over the B → shock association, then, at test, animals should have shown substantial fear to B on *same* trials when it was signaled by A. The problem was that we needed to be sure that A elevated responding to B by its conditional control over B, rather than by means of summation with A's own associative strength. One way to solve this problem was to use, as a comparison, responding to B on *different* trials when it was signaled by C. This was because A and C, being paired with shock in an identical manner during training, would have the same associative strength, so that summation would be the same on *same* and *different* trials; but C could not have any conditional control over B because B was never presented with C during training. Thus, if the animals showed more fear to B on *same* trials than on *different* trials, this could safely be attributed to A's conditional control over the B → shock association.

The rationale of this experiment relies on the assumption that the control exerted by a conditional cue is at least in part specific to its own target CS. There is reason to suppose that such an assumption is justified, however. There is substantial evidence that, although conditional cues may affect responding to other stimuli, they generally have less effect on these transfer stimuli than on the original training stimulus (see Swartzentruber, 1995, for a review).

Method

Subjects

The subjects were 16 naive male hooded Lister rats with a mean ad lib weight of 438 g (range = 400–500 g). They were maintained exactly as in the previous experiment, except that the colony rooms were lit from 8 a.m. to 10 p.m.

Apparatus

The apparatus, four Campden Instruments operant chambers, was identical to that used in the previous experiment, with the following exceptions. First, the ceiling of each chamber was made of translucent Perspex, above which a 30-W 240-V striplight was mounted. A light stimulus was provided by operating this striplight at 100 V. The lever was 3.0 cm to the left of the magazine and 5 cm above the floor. The boxes were dimly illuminated by a 2.8-W jewel light, operated at 15 V, mounted above the food magazine; a dark stimulus could be produced by turning off this jewel light. Auditory stimuli, a 2-kHz tone and a white noise, both 80 dB(A) in intensity, could be delivered through a speaker mounted on the wall of the chamber. The floor was constructed of stainless-steel rods that could be electrified by a Grason-Stadler shock generator. The boxes were controlled by a microcomputer programmed in a version of Basic.

Procedure

All aspects of the procedure that are not specified were the same as those for Experiment 1.

Table 2
Design of Experiment 2

Group	Preexposure	Conditioning	Test
PRE	Stimuli B and D	A → B → shock	A → B, C → D (same)
CON	None	C → D → shock	C → B, A → D (diff)
		A → B → shock	A → B, C → D (same)
		C → D → shock	C → B, A → D (diff)

Note. PRE = preexposed; CON = control; same = Stimulus B signaled by A and D by C; diff = different = Stimulus B signaled by C and D by A.

Lever-press training. In the first 40-min session, animals were trained to retrieve pellets from the food tray; pellets were delivered according to a VT 60-s schedule during this session, and the lever was retracted. Animals that had not eaten all the delivered pellets were given an additional session. In the second session, animals were rewarded with a pellet each time they pressed the lever until they had made a total of 75 responses.

All subsequent sessions were 40 min in duration. In the third session, lever pressing was reinforced according to a VI 30-s schedule and in the fourth and fifth according to a VI 60-s schedule, which remained in force for the remainder of the experiment.

Preexposure. In each of the 12 sessions of this stage, animals in Group PRE experienced four presentations of B and four of D. Each stimulus was presented for 30 s, and the order of trials was quasi-random stimulus. B was the tone for all subjects, and D was the noise. Animals in Group CON received no stimuli during this stage; they were merely placed in the apparatus. The ITI was 240 s.

Conditioning. The groups received identical treatment during the conditioning stage. Each of the four conditioning sessions consisted of two presentations of B and two of D, and each of these auditory stimuli was always signaled by one of the visual stimuli, A or C. Thus, B was always immediately preceded by A and D by C. For half the animals in each group, A was the light and C was the dark, and for the other half this arrangement was reversed. Each stimulus was presented for 30 s, and at the offset of both B and D, a 0.5-s footshock was delivered. The intensity of the shock was 0.4 mA in the first session and 0.5 mA in the remaining sessions. The order of the different types of trial was quasi-random, and the ITI was 432 s. In addition, all subjects received four recovery sessions in which no stimuli or shocks were delivered but the VI schedule was in force; two of these occurred after the second conditioning session and two after the fourth.

Test. Four test sessions followed. Each consisted of four trials: one presentation of A followed by B, one of C followed by D (*same* trials because B and D were signaled by the same stimuli as they had been during conditioning), one of A followed by D, and one of C followed by B (*different* trials because B was preceded by D's signal and vice versa). In two of the four sessions, the first and fourth trials were *same* trials, and in the remaining two sessions, the second and third trials were *same* trials. No shocks were delivered during the test sessions, which in all other respects were identical to the conditioning sessions.

Data treatment. Scores were pooled over the two auditory stimuli (B and D, the noise and the tone), and also over the two counterbalanced visual stimuli (A and C, the light and the dark).

Results and Discussion

No data were recorded during the preexposure phase. The conditioning phase established suppression to all stimuli in both groups. During the last conditioning session, the mean suppression to B and D was 0.06 and 0.05 for Groups PRE and CON, respectively. An ANOVA revealed that these scores did not differ ($F < 1$). Mean suppression to A and C in this last session was 0.02 for Group PRE and 0.03 for Group CON, and these scores did not differ either ($F < 1$). The mean rate of responding during the pre-CS periods during this session was 20.6 rpm for Group PRE and 15.5 rpm for Group CON. An ANOVA revealed that these rates did not differ, $F(1, 14) = 1.73$.

The group mean suppression ratios for B and D on *same*

and *different* trials in the test are shown in Figure 2. These data were collected from two blocks of trials, but as none of the effects of interest interacted with block (see below), the scores are collapsed across the two blocks in the figure. Animals in Group PRE showed more fear on *same* trials than on *different* trials, whereas animals in Group CON, if anything, showed the opposite pattern of results. This description of the data was supported by the results of an ANOVA, with group (PRE or CON), trial type (*same* or *different*), and block as factors. This ANOVA revealed no effect of group or of trial type ($F_s < 1$), but did reveal a significant interaction between these two factors, $F(1, 14) = 13.73$. There was also a significant main effect of block, $F(1, 14) = 20.29$, which reflected the extinction that occurred over the course of testing. This effect did not interact with any of the other factors, and no other interactions were significant, largest $F(1, 14) = 1.39$.

The critical Group \times Trial Type interaction was explored further with an analysis of simple main effects; this revealed a significant effect of trial type in Group PRE, $F(1, 14) = 7.47$, and also in Group CON, $F(1, 14) = 6.28$.

The group mean suppression ratios for A and C during the test sessions were .18 and .14 for Groups PRE and CON, respectively; these scores did not differ ($F < 1$). Finally, the mean rate of pre-CS responding during the test sessions was 20.2 rpm for Group PRE and 16.5 rpm for Group CON; these rates did not differ ($F < 1$).

The results of this experiment are again in agreement with the predictions of the ambiguity hypothesis. In Group PRE, in which B and D had been preexposed prior to conditioning, the signaling stimuli A and C acquired excitatory control over responding. This was not true of Group CON. Moreover, the measure of conditional learning used in this experiment, the difference between responding to the target stimuli on *same* and *different* trials, is free from the problem noted for Experiment 1. In that experiment, the measure of conditional learning was the difference in responding to the target stimulus when it was signaled by the putative conditional cue and when it was presented alone. Any enhancement of responding by the signal could have been due to

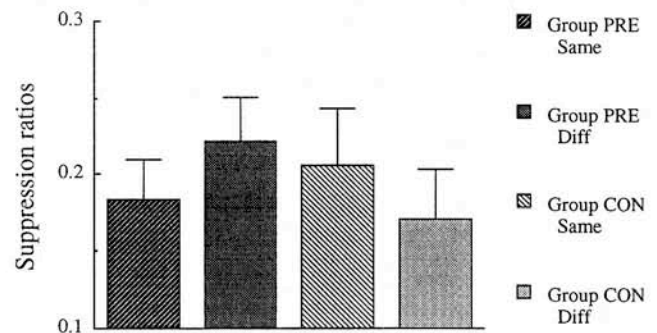


Figure 2. Group mean suppression ratios for the target stimuli B and D, on *same* trials, in which each target was preceded by its own signal, and on *different* trials, in which each target was preceded by the other signal, during the test sessions of Experiment 2. PRE = preexposed; CON = control; Diff = different.

summation of the associative strength of the signal with that of the target itself. Here, the measure of conditional learning was the difference in responding to the target according to whether it was preceded by its own signal or by another of the same associative strength. Any difference on this measure could not have been due to differential summation; thus, the difference we observed means that the signal enhanced responding to its target CS in a manner that was independent of its own association with reinforcement, and may therefore, by definition, be regarded as occasion setting. We may then conclude that, as the signal exerted conditional control over the target–shock association when the target had been preexposed, the use of an ambiguous target stimulus is sufficient to foster conditional learning.

Ruling out this potential artifact of Experiment 1 also has significance for another study, reported by Swartzentruber and Bouton (1992), that was formally similar to this study except that contexts rather than discrete stimuli served as the conditional cues. They found that context specificity of fear conditioning was observed only when the target CS had been preexposed. Their experiments, however, may have been marred by the same artifact that might have been operating in our own Experiment 1. Thus, in their first experiment, either a preexposed or a novel CS was conditioned in context A and then tested in A or in a neutral context, B. However, according to the argument outlined above, animals for whom the CS was preexposed might have conditioned better to context A than animals for whom the CS was novel. This would have resulted in a greater difference in the associative strength of the two test contexts in the preexposed animals, which might in turn have been responsible for the greater difference in responding to the target CS. Although Swartzentruber and Bouton acknowledged this possibility, they did not provide any substantive reasons for rejecting it, although they did argue that there is little evidence for summation between CSs and contexts in this preparation. The present study may, then, be taken as support for their interpretation.

Finally, the question remains as to what could be responsible for the difference observed in Group CON. Here, the somewhat unexpected result was that animals showed less suppression to the target on *same* trials, when it was preceded by its own signal, than on *different* trials. One possible explanation for this finding is in the phenomenon of associative priming. It has been suggested (e.g., Wagner, 1981), that the degree to which a stimulus is processed may vary under certain circumstances—more specifically, a predicted stimulus, because the animal expects its occurrence, might be processed more poorly than a surprising one. This poorer processing might be manifest in a number of ways, one of these being that a predicted CS might elicit less conditioned responding than one that is surprising. Recently, some evidence for precisely this assertion has been reported, in a preparation that was closely similar to the one used in this study (Honey, Hall, & Bonardi, 1993).

This finding offers a ready explanation of the present results. During the conditioning stage, all animals in Group CON experienced the target stimuli B and D, reliably preceded by their respective signals A and C. This procedure is

one that would be expected to foster the formation of associations between A and B and between C and D. Thus, at test, B and D would be well predicted on *same* trials, when each was preceded by its own signal. On *different* trials, however, both stimuli would be surprising, because the animal would expect the other target stimulus to occur. Thus, if Wagner's (1981) assertion about stimulus processing were correct, B and D would be only poorly processed on *same* trials, and conditioned responding to these stimuli would be attenuated; but on *different* trials B and D, being surprising, would be better able to elicit their conditioned responses—the result observed in Group CON. There is no reason to suppose, of course, that this priming effect would not also be at work in Group PRE, but in this group another factor is operating. In these subjects, we have argued, the cue that signals CS–US pairings acquires occasion-setting properties. Thus, although the direct signal–CS association might act to reduce the magnitude of the conditioned response, the occasion-setting power of the signal tends to enhance responding. The net result depends on the balance of these two effects. These results suggest that the latter tends to outweigh the former.

Experiment 3

The critical finding of Experiment 2 was that, after pre-exposure to the target stimulus, this stimulus elicited more conditioned responding when it was preceded by its own signal than when it was preceded by some other stimulus. We attributed this effect to the signal acting as a conditional cue, retrieving (or facilitating use of) the association between the target stimulus and reinforcement. This account implies that the target stimulus possesses more effective associative strength when it is preceded by its own signal than when it is not. If this interpretation is correct, it implies that the presence of the conditional cue should influence not just performance of the conditioned response, but other phenomena that may be taken to depend on the associative strength of the CS. One such phenomenon is *blocking*—the ability of a pretrained CS to restrict the acquisition of strength by a novel stimulus when the two stimuli are reinforced in compound (e.g., Kamin, 1969). There is some evidence (from a rather different training procedure; see Bonardi, Honey, & Hall, 1990) that the ability of a CS to produce blocking is indeed enhanced when it is signaled by an appropriate conditional cue. Experiment 3 was designed to determine if the same holds true for a conditional cue established by the two-stage training procedure of Experiment 2. A positive result would allow us to conclude that the enhanced responding controlled by the cue in Group PRE of that experiment did indeed index a real enhancement in available associative strength.

The experiment used two groups of animals, Group SAME and Group DIFF (different). The design is summarized in Table 3. The first two stages of training were identical to those administered to Group PRE in Experiment 2. First, all subjects experienced preexposure of the target stimuli B and D. Then, all subjects were conditioned to

Table 3
Design of Experiment 3

Group	Preexposure	Stage 1	Stage 2	Test
SAME	Stimuli B and D	A → B → shock	A → BX → shock	X
		C → D → shock	C → DX → shock	
DIFF	Stimuli B and D	A → B → shock	C → BX → shock	X
		C → D → shock	A → DX → shock	

Note. DIFF = different.

these stimuli: B was always signaled by A and D by C during these sessions. In the third compound conditioning stage, B and D continued to be followed by shock, but both of these stimuli were accompanied, in simultaneous compound, by a third auditory stimulus, X. The way this was arranged differed in the two groups. For animals in Group SAME, B continued to be signaled by A and D by C, exactly as had been the case during the first stage of conditioning. In Group DIFF, this arrangement was reversed, so that B was signaled by C and D by A. Then, in the final test, the amount of fear displayed to X was examined.

The question of interest was the degree to which there would be blocking of fear conditioning to X. In the first stage of conditioning, we predicted that B would become associated with shock and that the B → shock association would come under the conditional control of the signaling stimulus, A. Thus, when animals in Group SAME entered the compound conditioning stage, the presence of A would ensure full retrieval, or use, of the B → shock association, so that the subsequent shock would be well predicted. This should be sufficient to ensure that X would acquire little associative strength—in other words, acquisition of the X → shock association would be blocked. In Group DIFF, on the other hand, B was preceded by the other signal, C, during the compound conditioning stage. The animals' ability to retrieve, or make use of, the B → shock association might therefore be expected to be poor in this group, making the subsequent shock somewhat surprising and, hence, allowing conditioning of X to occur. In other words, if our interpretation of the effect observed in Experiment 2 is correct, we would expect conditioning to X to be blocked in Group SAME but not in Group DIFF. However, if the effect witnessed in the previous experiment was an effect solely on performance to the target stimuli, rather than on their underlying associative strength, there would be no reason to predict such a difference in the blocking effect.

Method

Subjects

The subjects were 16 male Wistar rats that had previously undergone training in a flavor aversion study but were naive to the stimuli and procedures used here. They had a mean ad lib weight of 385 g (range = 332–443 g) and were maintained exactly as in Experiment 1.

Apparatus

The apparatus was the same as that used in Experiment 1 except in the following respects. The chambers were illuminated by a houselight (a 2.8-W jewel light operated at 24 V) that was situated above the food tray. A dark stimulus was produced by turning off this houselight and a light stimulus by turning on a 60-W striplight, operated at 220 V, that was situated above the ceiling of the chamber.

Procedure

All aspects of the procedure that are not specified here were the same as those of Experiment 1.

Lever-press training. Lever-press training was identical to that given in Experiment 1, except that all subjects received two, rather than six, sessions of VI 60-s training.

Preexposure. All subjects received 12 sessions of preexposure to B and D, which were identical to those experienced by Group PRE in the previous experiment. B was the tone and D the clicker for all animals.

Stage 1 conditioning. The conditioning sessions were identical to those in Experiment 2 except in the following respects: First, only one baseline recovery session was given, after the second conditioning session. Second, the shock level was 0.5 mA in all sessions.

Compound conditioning. This phase consisted of four sessions, each consisting of four trials. The animals were divided into two groups, Group SAME and Group DIFF, and both were given conditioning trials with a third auditory stimulus, X (the white noise), presented in simultaneous compound with B and with D. For Group SAME, the procedure was otherwise identical to that used in Stage 1. Animals in Group DIFF received trials identical to those given to Group SAME, except that each of the targets, B and D, was preceded by the "wrong" signal. In other words, B presentations were signaled by C rather than by A and D trials by A rather than by C.

Test. Two test sessions followed. Each consisted of four presentations of X, but was identical in other respects to those of Experiment 2.

Data treatment. Scores were pooled over the two auditory stimuli, B and D (the tone and the click) and also over the two counterbalanced visual stimuli A and C (the light and the dark). In the course of training, one of the Skinner boxes ceased to function; for this reason it was necessary to eliminate all the subjects that had been trained in that chamber, leaving 12 rats in the experiment, with 6 in each group.

Results and Discussion

No data were recorded during the preexposure sessions. Stage 1 of conditioning established suppression to all stimuli in both groups. During the last session of this stage, the mean suppression to B and D was .12 for Group SAME and .05 for Group DIFF. An ANOVA revealed that these scores did not differ, $F(1, 10) = 2.22$. Mean suppression to A and C in this last session was .15 for Group SAME and .08 for Group DIFF. An ANOVA revealed that these scores did not differ, $F(1, 10) = 2.28$. The mean rate of pre-CS responding during this session was 39.2 rpm for Group SAME and 37.0 rpm for Group DIFF; these rates did not differ ($F < 1$).

In the second compound conditioning stage, suppression

was maintained to B and D. The mean suppression scores for these stimuli in each of the four sessions were .09, .11, .11, and .11 for Group SAME and .10, .07, .07, and .04 for Group DIFF. An ANOVA with group (SAME or DIFF) and session as variables revealed no significant effects or interactions, largest $F(1, 10) = 3.53$. The mean rate of pre-CS responding, averaged over all these sessions, was 59.3 for Group SAME and 59.2 for Group DIFF. These rates did not differ ($F < 1$).

The group mean suppression ratios for X during the test are shown in Figure 3. Although these data were collected across the two test sessions, this variable did not interact with the main effect of group (see below), and so the data are presented collapsed across the two sessions. It is clear from the figure that animals in Group SAME showed less fear than those in Group DIFF. This description was supported by the results of an ANOVA with group (SAME or DIFF) and session as variables, which demonstrated that this difference between the groups was statistically significant, $F(1, 10) = 4.99$. The main effect of session was also significant, $F(1, 10) = 18.43$, reflecting the extinction that occurred over the course of testing. This variable did not interact with group, $F(1, 10) = 1.50$. The mean rate of pre-CS responding during these sessions was 56.4 rpm for Group SAME and 54.5 rpm for Group DIFF. These rates did not differ ($F < 1$).

General Discussion

These experiments were designed to examine the factors that determine when a cue signaling a CS-US pairing acts as an occasion setter, having conditional control over the effectiveness of the association formed in its presence. Rescorla (1988) suggested that the target CS that is reinforced in the presence of the signaling cue must possess inhibitory strength, whereas others (e.g., Bouton, 1993; Bouton & Bolles, 1985) have stressed the importance of ambiguity in the training history of the CS. The results reported here support the second of these hypotheses: In all three experiments, evidence for conditionality was obtained, provided that the target CS had been preexposed prior to the

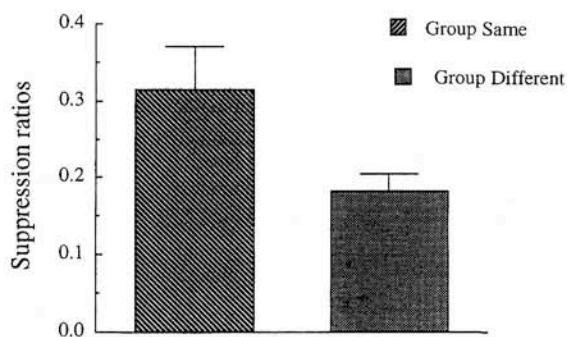


Figure 3. Group mean suppression ratios for Stimulus X during the test sessions of Experiment 3.

conditioning stage. In none of the experiments did the target CS possess any inhibitory strength.

One aspect of the results that deserves mention is the way in which ambiguity was produced. In these experiments, this was achieved by preexposing the target CS before it was paired with shock. The logic behind this technique was that in the first stage of training the animals would learn that the CS had no particular consequence and that this would conflict with the subsequently acquired information that the CS predicted shock. However, it should be acknowledged that this argument implicitly assumes a theory of latent inhibition, according to which the animal learns about the consequences of the CS during preexposure. This contrasts with the more traditional account that attributes latent inhibition to a loss of attention to the preexposed stimulus. These results may be taken as evidence supporting that class of theories positing that latent inhibition results from the formation of an association between the preexposed CS and the absence of any particular consequence (e.g., Hall, 1991; Swartzentruber & Bouton, 1992).

May we then conclude that an ambiguous target CS is both necessary and sufficient for the formation of a conditional cue? The results as we have presented them are clearly consistent with that conclusion, but there are some empirical and theoretical reasons for moderating this position. Bouton's (1993) formulation, for example, does not make such a strong claim. In discussing conditional control by contextual cues, he argues that, to some extent, all associations are dependent on context (or other accompanying cues); in the case of excitation, this dependence is weak, but present nonetheless. The role of stimulus ambiguity is supposedly to enhance the context dependence of the association by forcing the animal to encode the context to disambiguate the meaning of the CS. Bouton's (1993) theory, in other words, does not claim that ambiguity is necessary for conditionality, but rather that ambiguity enhances it.

Is there any reason why we should compromise and accept this weaker version of the original claim? Empirical evidence suggests that there is. It is widely believed that the conditional control exerted by discrete stimuli is not different from that commanded by experimental contexts, a belief that is supported by the documented parallels between the findings of studies using discrete occasion setters and those concerned with contexts (e.g., Bouton, 1994; Bouton & Swartzentruber, 1986). However, there is some dispute about whether context dependence can be established with unambiguous CSs, that is, after training in which the animal experiences only CS-US pairings in a given context. Although there are a number of studies claiming that it cannot be established in this way (e.g., Bouton & King, 1983; Bouton & Peck, 1989; Kaye, Preston, Szabo, Druiff, & Mackintosh, 1987; Lovibond, Preston, & Mackintosh, 1984), there are also a considerable number claiming that it can (e.g., Bonardi et al., 1990; Hall & Honey, 1989, 1990; Honey, Willis, & Hall, 1990). If the parallel between contexts and discrete conditional cues is appropriate, then these findings are problematic for the claim that ambiguity is necessary for conditional cue formation. It seems prudent to

accept, then, that even unambiguous stimuli can support the formation of conditional cues, but that the power of these cues is greatly enhanced if the stimulus has an ambiguous training history.

The weaker claim that ambiguity is not necessary for conditionality is also more easily reconciled with the study by Bonardi (1992), suggesting that discrete stimuli can become conditional cues when they accompany reinforcement of a novel CS. What remains to be resolved, however, is why Bonardi found conditionality with novel CSs in her experiments when none was found here. One explanation for this apparent contradiction may be found by closer examination of the procedures used in the two experiments. In the present studies, the signaling stimuli were relatively short and reliably preceded presentations of the target CS. In Bonardi's experiments, the signaling stimuli were much longer, and the shorter target CSs occurred unpredictably from time to time in their presence. It is reasonable to suppose that the former training procedure would be far more conducive to the formation of associations between the signaling and target stimuli, and, as we saw in Experiment 2, the existence of such associations can have the effect of opposing the expression of conditionality by permitting a negative priming effect to occur. Perhaps, then, in our experiments weak conditional learning did occur with the novel CSs but was overwhelmed by a superimposed negative priming effect and could only be observed when the target CS was ambiguous. In Bonardi's experiments, the negative priming effect was much smaller, so that even with a novel CS, conditionality could be observed.

One final point concerns the possibility of explaining the present results in terms of configural cues. It has been suggested (e.g., Pearce, 1987) that accurate performance on occasion-setting discriminations may reflect the fact that, during occasion-setting training, the animal forms a configure of the occasion setter and the target CS and associates this configure with reinforcement. Responding to the target CS in the absence of the occasion setter occurs only to the extent that there is some generalization to this stimulus from the reinforced configural cue. This account could perhaps explain our key finding that occasion setting is enhanced if the target stimulus has been preexposed. Consider, for example, Group PRE of Experiment 2. Compared with animals in Group CON, in which the CS had not been preexposed, animals in Group PRE responded more to the target CS on same trials, when it was signaled by its own conditional cue, than on different trials, when it was signaled by another stimulus. This result may be explained by assuming that preexposing the CS reduces its salience; according to Pearce's model, this would reduce the degree to which associative strength could generalize to the CS when it is presented in the absence of its conditional cue. In Experiment 2, this would have had the effect in Group PRE of reducing responding on different trials and, so, make it appear as though the conditional cue had acquired more control over responding in Group PRE than in Group CON—exactly the result that we observed. There are a number of reasons why we may reject this interpretation, however. The first relates to the plausibility of configural

learning with our preparation. Our conditioning procedure involved serial presentation of two 30-s stimuli (e.g., A followed by B). The configure in this case would thus have to consist of B accompanied by the trace of A, and one would have to assume that this trace persisted through much of B's presentation. It is not clear how plausible such an assumption might be. The second reason concerns the results of Group CON in Experiment 2, which actually responded more to the target CS when it was signaled by a conditional cue other than that with which it was trained. The model proposed by Pearce predicts that any degradation of the configure that was paired with reinforcement would produce a loss of conditioned responding, and, yet, here an increase in responding was observed. It is difficult to see how this pattern of results can be accommodated in the framework proposed by Pearce. If it cannot be supported, we may perhaps favor the interpretation presented above, that preexposure to a stimulus enhances the degree to which it may become the target of conditional control.

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1996 APA Convention *Call for Programs*

The *Call for Programs* for the 1996 APA annual convention appears in the September issue of the *APA Monitor*. The 1996 convention will be held in Toronto, Ontario, Canada, from August 9 through August 13. The deadline for receipt of program and presentation proposals is December 1, 1995. Additional copies of the *Call* are available from the APA Convention Office, effective in September. As a reminder, agreement to participate in the APA convention is now presumed to convey permission for the presentation to be audiotaped if selected for taping. Any speaker or participant who does not wish his or her presentation to be audiotaped must notify the person submitting the program either at the time the invitation is extended or before the December 1 deadline for proposal receipt.