

Acquired Equivalence Between Cues Trained With a Common Antecedent

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In Experiment 1, rats experienced 2 stimuli (A and N) each preceded by the same event (food) or by different events (food preceded 1 but not the other). N was then paired with shock, and the generalization of conditioned suppression to A was assessed. Generalization was more marked when A and N had been experienced along with a common antecedent. In Experiment 2, 3 stimuli (A, B, and N) were presented in initial training. For 1 group, A and N were preceded by food and B was not; for a 2nd group A alone was preceded by food. In each group, suppression generalized more readily from N to the stimulus that had received the same initial training as had been given to N. Experiment 3 found that generalization was not enhanced between stimuli when 1 had preceded food in initial training and 1 had followed it. These results demonstrate that stimuli that have shared a common antecedent will come to be treated as equivalent.

Honey and Hall (1989) demonstrated that the degree of generalization between a pair of cues can be enhanced by preliminary training designed to establish an association between each of the cues and some common consequence. In our experimental procedure, the subjects (rats) received initial training in which each of two auditory cues was presented prior to the delivery of food. One of these cues was then trained as a signal for shock (a conditioned stimulus [CS]) in the conditioned suppression procedure. The conditioned response (CR) of suppression was found to generalize particularly readily to the other cue.

We interpreted this effect as being an instance of acquired equivalence and offered an interpretation based on that originally proposed for the phenomenon by Miller and Dollard (1941; see also Hull, 1939; Miller, 1948). The initial phase of appetitive training, we argued, endowed each of the cues with the ability to activate associatively some central representation of food. This representation would thus be active during the phase of conditioned suppression training and might itself become associated with the aversive unconditioned stimulus (US). The test stimulus would also activate the food representation and would thus be capable of activating the US representation and of evoking the CR in the final test phase.

This explanation was specifically devised to account for the equivalence that stimuli acquire by virtue of having been experienced along with a common consequence. But acquired equivalence may be a more general phenomenon than is implied by this analysis. In particular, it may be possible

to generate equivalence using a "backward" version of the training procedure used by Honey and Hall (1989). Bonardi, Rey, Richmond, and Hall (in press) reported a study investigating the effects of certain forms of preliminary training on the generalization of autoshaped responding in pigeons. Generalization between two keylight stimuli was found to be enhanced when these stimuli (that trained as the CS and that used in the generalization test) had both been experienced in an initial phase of training preceded by a third keylight. This result was taken to indicate that stimuli might acquire equivalence not only by virtue of becoming linked to a common consequence but also because they have been experienced along with a common antecedent.

Bonardi et al. (in press) offered some speculations about the mechanisms by which a backward equivalence effect might be obtained and also pointed out that the existence of such an effect would have implications for the interpretation of a wider range of phenomena, including the mechanisms by which "equivalence classes" (Sidman, 1990) come to be established. These matters are taken up later in this article, but the main aim of Experiment 1 was to confirm the reliability and establish the generality of the backward equivalence effect. To this end we returned to the procedure used by Honey and Hall (1989) but adapted it so as to bear on the question of whether giving events a common antecedent can establish equivalence between them.

Experiment 1

The design of this experiment is shown in Table 1. There were two groups of subjects. Those in Group +A/+N received Stage 1 training that we thought would be effective in establishing equivalence. They received exposure to two auditory cues, A and N, each cue being preceded by the delivery of food. Control subjects in Group +A/-N also experienced these cues, but the cues did not share a common antecedent, only A being preceded by food. In Stage 2 for all subjects, N was established as a signal for shock using the

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Table 1
Experimental Designs

Group	Stage 1	Stage 2	Stage 3
Experiment 1			
+A/+N	f→A	N→sh	A&B
+A/-N	f→N	N→sh	A&B
	f→A		
	N		
Experiment 2			
+A/+N	f→A	N→sh	A&B
	f→N		
+A/-N	B	N→sh	A&B
	f→A		
	N		
	B		
Experiments 3A and 3B			
+A/N+ (3A)	f→A	N→sh	A&B
	N→f		
A+/+N (3B)	B	N→sh	A&B
	A→f		
	f→N		
	B		

Note. A, B, and N are auditory stimuli; f refers to the delivery of a food pellet; sh to electric shock. During Stage 1 in each experiment, all subjects in a given group experienced all the trial types shown for that group.

conditioned suppression procedure. The test stage, Stage 3, examined the degree to which Cue A controlled suppression in the two groups. Cue A had received identical Stage 1 training in the two groups, but if the treatment given to Group +A/+N established equivalence between A and N, then more generalization could be expected in this group. It is possible, of course, that a difference between the groups in their behavior toward A could also be generated by a difference between them in the readiness with which they acquired suppression to N in Stage 2. The design of the experiment required that the N cue be treated differently in the two groups in Stage 1, and this might have conceivably influenced Stage 2 conditioning. To control for this possibility, a further cue, B, was also presented in the test stage. Any difference between the groups in the associative strength governed by N would be revealed by differential generalization to B. We hoped, therefore, to observe in Stage 3 that Group +A/+N would show more suppression to A than would Group +A/-N but that there would be no differences between the groups in the suppression they showed to B.

Method

Subjects. The subjects were 16 male hooded Lister rats (mean ad lib weight: 358 g, range 320–405 g). They were maintained throughout the experiment at 80% of their ad lib weight by daily weighing and controlled feeding. The colony room in which they were housed had a daily light/dark cycle of 16/8 hr. Experimental sessions took place during the light phase of the cycle.

Apparatus. Four identical Skinner boxes (from Campden Instruments, Ltd.) were used. Each had a grid floor that could be electrified by means of a Grason-Stadler shock generator (Model 700). At floor level on the front wall of the box, an aperture, 6 cm high by 5 cm wide, gave access to a food tray to which 45-mg food pellets could be delivered. This aperture was covered by a transparent plastic flap, hinged at the top, which the rats learned to push aside to reach food pellets; the flap returned to its vertical resting position when the rat removed its snout from the tray. Movement of the flap operated a microswitch, and each closing of the switch was recorded as a single response. Operation of the flap constituted the baseline response in this experiment. The response levers with which the boxes were also equipped were withdrawn. A speaker fitted to the rear wall of the box could be used to present three auditory cues: a train of clicks at 10 Hz, a 2-kHz tone, and white noise. Each of these cues was presented at 80 dB(A), the intensity being measured immediately in front of the opening to the food tray. Dim background illumination was provided by a 3-W jewel light (operated at 16 V) mounted on the wall 15 cm above the food tray.

Procedure. Training consisted of daily 40-min sessions except in Stage 1 when sessions were given twice daily. On each of the first 2 days the subjects received magazine training in which food pellets were delivered according to a variable-time 60-s schedule. The rats learned to push aside the flap to retrieve the pellets. On the next day subjects were given a limited amount of preexposure to the stimuli to be used in later stages of training. There were two presentations each of the tone, of the clicker, and of white noise. The stimulus duration was 30 s and the interval between trials 5.5 min. This preexposure was intended to allow habituation of the unconditioned suppression that the stimuli tend to evoke when they are first presented.

Animals were then assigned at random to one of two equal-sized groups for the 12 sessions of Stage 1 training. All subjects received four 30-s trials per session, two presentations of N and two of Stimulus A. For half the subjects in each group A was the tone, and for half the subjects it was the clicker. For animals in Group +A/+N a food pellet was delivered 2 s before each stimulus presentation; for animals in Group +A/-N, food was delivered only before Stimulus A. The order in which trial types occurred was varied randomly from session to session. The interval between trials was 7.3 min, and the interval between the 2 sessions on a given day was approximately 4 hr.

Over the next two sessions all subjects received aversive conditioning with N as the CS. In each session there were three 30-s N trials in which the termination of the noise was followed immediately by a 0.5-s 0.4-mA shock. The first trial occurred after 10 min, and subsequent trials occurred at 10.5-min intervals. There followed three sessions in which pushing the magazine flap was trained as an instrumental response to establish a baseline of responding against which any suppression evoked by A and B could be assessed. On the first of these sessions every flap push was reinforced with the delivery of a food pellet until 70 pellets had been earned, at which point the rat was removed from the apparatus. On the next session responding was reinforced according to a variable interval (VI) 30-s schedule. During the third session a VI 60-s schedule was introduced, and this schedule was maintained throughout the rest of the experiment.

The next session constituted Test 1. There were three 30-s presentations of Stimulus A and three of Stimulus B, the intertrial interval being 5.5 min. For half the subjects in each group the order of trial presentation was ABBABA, and for half it was BAABAB. Responding was recorded separately for each stimulus presentation and during the 30-s stimulus-free period that preceded each trial. This allowed the calculation of a suppression ratio of the form

$x/(x + y)$, where x represents the number of responses during the stimulus and y the number during the prestimulus period.

Unfortunately, neither Stimulus A nor Stimulus B was effective in evoking suppression during Test 1 (see Results Section), presumably because the training given to N in Stage 2 did not endow this stimulus with sufficient associative strength. Accordingly, two further sessions of aversive conditioning with Stimulus N were given, identical to those given previously except that the baseline of food-reinforced instrumental responding was maintained. There followed two further test sessions. The first of these (Test 2) was identical to Test 1; Test 3 differed only in that the trial sequence was changed with B taking the position previously occupied by A and vice versa.

Results

The results of central interest are summarized in Figure 1, which presents for each group the performance shown on the six trials with A and the six trials with B (three trials with each stimulus in each of Tests 2 and 3). (For the results of Test 1, see below). It is evident that Stimulus A initially evoked suppression in both groups but did so more effec-

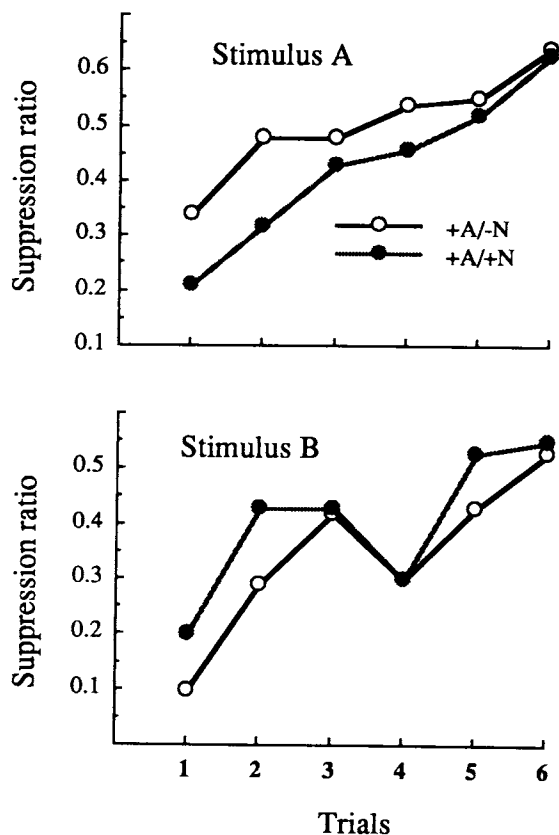


Figure 1. Experiment 1: Group mean suppression ratios for the test trials with Stimulus A (top panel) and Stimulus B (lower panel). (All subjects had experienced both A and N in Stage 1 training, A being preceded by food (+) for all, N being preceded by food in Group +A/+N. Stimulus B was novel on the test.)

tively in Group +A/+N than in Group +A/-N, a difference between the groups that was maintained until suppression was lost in both groups by the final trial of this extinction test. Stimulus B also evoked suppression that extinguished over the course of the test, but in this case the difference between the groups was less clearcut with Group +A/+N showing, if anything, less suppression than Group +A/-N. An analysis of variance was conducted on the data shown in Figure 1, the factors being group, stimulus type (A or B), and trials. An alpha level of $p = .05$ was used for this and all other statistical tests. This yielded a significant effect of trial, $F(5,70) = 21.28$, a significant effect of stimulus type, $F(1,14) = 11.57$, and a significant interaction between group and stimulus type, $F(1,14) = 6.74$. All other interactions were non-significant ($F_s < 1$).

To explore the theoretically important interaction between stimulus type and group, we conducted separate analyses comparing the performance of the two groups with respect to each of the stimuli. That for Stimulus A revealed a significant effect of trial, $F(5,70) = 7.89$, a significant difference between the groups, $F(1,14) = 5.41$, and no interaction between these factors ($F < 1$). The analysis for Stimulus B produced a significant effect only of trial, $F(5,70) = 11.19$; the effect of group ($F = 2.19$) and the interaction ($F < 1$) were not significant. The groups did not differ in their baseline responding during the tests. Rates recorded during the prestimulus periods of Tests 2 and 3 averaged 23.96 responses per minute (rpm) in Group +A/+N and 20.36 rpm in Group +A/-N ($F < 1$).

There was no reliable difference between the two groups in the ease with which they acquired suppression to the noise during the pair of on-baseline aversive conditioning sessions given immediately prior to Tests 2 and 3. Group mean suppression ratios, pooling over all three trials on each day, were, on the first day, .13 for group +A/+N and .22 for Group +A/-N. The equivalent scores for the final day of conditioning were .11 and .04. An analysis of variance with group and day as the factors revealed a nonsignificant change over days, $F(1,14) = 4.38$, no significant difference between the groups ($F < 1$), and no interaction ($F = 2.95$). The baseline response rates, pooling over all prestimulus periods, were 18.08 rpm in Group +A/+N and 22.58 rpm on Group +A/-N and did not differ significantly ($F < 1$).

As has already been noted, performance on Test 1 was uninformative in that neither A nor B produced reliable suppression of responding. The group mean suppression ratios for Stimulus A (pooling across all three trials) were .52 for Group +A/+N and .59 for Group +A/-N. Stimulus B evoked somewhat more suppression (the scores being .42 for Group +A/+N and .46 for Group +A/-N), but only 9 of the 16 subjects had suppression ratios to B of less than .5. An analysis of variance (ANOVA) was conducted on these scores, the factors being group and stimulus type. This revealed a significant main effect of stimulus type, $F(1,14) = 14.79$, but no effect of group and no interaction between the factors ($F_s < 1$). The effect of stimulus type presumably reflects the ability of the novel B stimulus to evoke unconditioned suppression.

Discussion

Generalization of conditioned suppression from one auditory cue (N) to another (A) was greater in Group +A/+N than in Group +A/-N. The groups differed in the prior training they had received with these two cues: Group +A/+N experienced both immediately preceded by food, whereas for Group +A/-N, only Stimulus A had been preceded by food. The difference between the groups did not appear to derive from a difference between them in the associative strength acquired by N. There was no reliable difference between the groups in the degree of suppression they showed to N during the aversive conditioning phase of Stage 2. In the final test, a novel cue (B) that had received no Stage 1 training was found to evoke equivalent levels of suppression in the two groups.

The results reported here constitute an exact parallel to the acquired equivalence effect demonstrated by Honey and Hall (1989). They differ only in that the equivalence between cues A and N in the earlier experiment was generated by initial training in which each of the cues was followed by the delivery of a food pellet, whereas in this experiment food preceded both A and N in Group +A/+N. These results may be taken to indicate, therefore, that equivalence can be established not only by giving stimuli common consequences but also by giving them common antecedents. They thus confirm the conclusion, based on a very different experimental procedure, reached by Bonardi et al. (in press).

Experiment 2

One aim of this experiment was to confirm the reliability of the essential finding of Experiment 1 by ruling out any possibility that the effect seen in Experiment 1 might be the direct result of a difference between the groups in the readiness with which they acquired conditioning to the noise in Stage 2. This was achieved by making use of the within-subjects design shown in Table 1. All subjects in Group +A/+N received Stage 1 training with all three of the critical stimuli, A, B, and N. As before, presentations of both A and N were preceded by food. Stimulus B was not. Thus, when it came to the Stage 3 test in which A and B were presented, these two stimuli had received the same amount of prior exposure and differed only in that A had shared a common antecedent with N, whereas B had not. The looked-for result, therefore, was for A to govern more generalized suppression than B. The source of this suppression would be generalization from the aversive conditioning given to N in Stage 2. The disadvantage of the between-subjects design of Experiment 1, where the two groups might possibly have differed in the readiness with which they conditioned to N, is thus eliminated by the present within-subjects design.

A second aim of Experiment 2 was to extend analysis to the other condition of training (Group +A/-N) shown in Table 1. In this condition, only Stimulus A was preceded by food in Stage 1. It might, therefore, be anticipated that N and B would show equivalence as these events will have experienced similar Stage 1 treatment. The test would then reveal more suppression to B than to A. Indeed, such a result might

be expected not only on the basis of acquired equivalence between N and B but also on the basis of an acquired distinctiveness effect; it could well be that the Stage 1 training in which the A and N cues are treated differently would be capable of enhancing their distinctiveness. A difference between A and B in the test would be the consequence not only of enhanced generalization between N and B but also of reduced generalization between N and A. It should be added that a similar argument can, of course, be advanced with respect to the results anticipated for the +A/+N group. That is, although we have described the experiment as providing a possible demonstration of acquired equivalence between A and N on the basis that both have been experienced preceded by food, the result would also be generated if the differing treatments given to N and B enhanced their distinctiveness. (See Honey & Hall, 1989, and Hall, 1991, for a discussion of the problems involved in attempting to distinguish between acquired equivalence and acquired distinctiveness.)

Method

The subjects were 16 naive male hooded rats maintained at 80% of their ad lib body weights (mean ad lib weight: 358 g, range: 330–390 g). The apparatus was that used in Experiment 1.

After 2 sessions of magazine training the animals were assigned to one or other of the Stage 1 training conditions, 8 in each. There were 12 daily Stage 1 sessions, each consisting of six trials: two presentations each of the stimuli A, B, and N. The intertrial interval was 5.5 min. Half of the subjects in each group received the tone as Stimulus A and the clicker as B, and half received the reverse arrangement. For animals in Group +A/+N, each presentation of A and N was preceded by a food pellet. For animals in Group +A/-N, food was presented only before A. Stimulus B was never preceded by food.

Over the next three sessions the instrumental baseline was established. There followed four sessions of Stage 2 training each of which contained three shock-reinforced N trials. All then received a single session in which responding was reinforced on a VI 60-s schedule so as to ensure that there would be a stable baseline of responding during the test. Stage 3 consisted of a single test session in which there were three presentations of A and three of B. Procedural details not described here were the same as those described for Experiment 1.

Results and Discussion

No data were collected during Stage 1. Stage 2 training established suppression to the noise in all subjects, the group mean suppression ratio on the last session of conditioning being .01.

Figure 2 shows, separately for the two groups, mean suppression ratios for the three test trials with each of the stimuli, A and B. It is apparent that both stimuli evoked suppression (at least on the early trials of the test) and that they did so to different extents in the two groups. Stimulus A evoked more suppression than did B in Group +A/+N, whereas in Group +A/-N Stimulus B evoked more suppression than did A. An ANOVA was conducted on the data summarized in Figure 2, the factors being group, stimulus type, and trial.

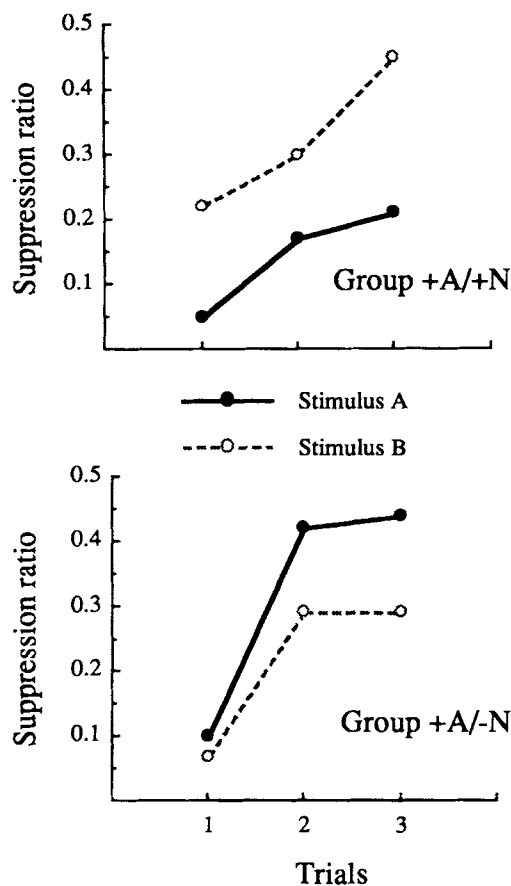


Figure 2. Experiment 2: Group mean suppression ratios for the test trials with Stimuli A and B. (All subjects had experienced A, B, and N in Stage 1 training. For Group +A/+N, A and N had both been preceded by food; for Group +A/-N, only A had been preceded by food in Stage 1.)

This showed there to be a significant effect of trial, $F(2,28) = 16.43$, and a significant interaction between group and stimulus type, $F(1,14) = 16.94$. No other effect or interaction was significant (all $F_s < 1$). An analysis of simple main effects was conducted to explore the source of the interaction between stimulus and group. This showed there to be a significant difference between the stimuli both in Group +A/+N, $F(1,14) = 13.51$, and in Group +A/-N, $F(1,14) = 4.60$. The baseline response rates (pooling over all prestimulus periods on the test session) were 15.42 rpm in Group +A/+N and 20.46 in Group +A/-N. These rates did not differ significantly, $F(1,14) = 2.01$.

The results for Group +A/+N confirm those obtained for the equivalent group in Experiment 1. They show that generalization occurs readily between two stimuli (A and N) that have been experienced along with a common antecedent in initial training. There is less generalization to a stimulus (B) that has not shared the antecedent with N, paralleling the results obtained from Group +A/-N in Experiment 1. The within-subjects design of the present experiment means that generalization to A and B has a common source (conditioning with N), eliminating the possibility inherent in the between-

groups design of Experiment 1 that differences in test performance might derive from differences in the associative strength acquired by N.

What remains possible, however, is that the suppression shown to A by Group +A/+N in this experiment might be a direct consequence of the training given in Stage 1. That is, initial training in which A is preceded by food might be enough in itself to generate suppression in the final test. The results of Group +A/-N help to rule out this possibility. For these subjects it is Stimulus B that shows a greater degree of suppression in the Stage 3 test, a stimulus that was not experienced preceded by food in Stage 1. The difference between Group +A/-N and Group +A/+N is that for the first of these N was not preceded by food in Stage 1. Taken together, therefore, the results for the two groups show that it is not the specific treatment given to A or B that determines test performance—what is critical, rather, is whether or not the treatment matches that given to N. Generalization is enhanced between stimuli that have received equivalent treatment; alternatively (or additionally), generalization may be restricted between stimuli that have received different treatments.

Experiments 3A and 3B

The results of Experiments 1 and 2 have been interpreted as demonstrating a phenomenon of “backward equivalence.” Previous studies of acquired equivalence (e.g., Honey & Hall, 1989) have concentrated on a “forward” training procedure in which equivalence is established between a pair of stimuli by giving them training in which they share a common consequence. The effectiveness of the backward procedure, in which equivalence is established between stimuli that have been experienced along with a common antecedent, appears to call for a general reconsideration of the mechanisms that have been supposed to underlie equivalence effects. Before attempting such a thing, however, it would be prudent to try to assess the possibility that the backward effects demonstrated in Experiments 1 and 2 might be a product of exactly the same processes as operated in the forward case. In particular, although we as experimenters arranged in Experiments 1 and 2 for the delivery of food to precede certain auditory cues, this is not necessarily how the events impinged on the rats. It takes time for a rat to collect and consume a food pellet, and we cannot be certain that the critical consequences of food presentation were completed before the presentation of the auditory cue. Thus, from the rat’s point of view our backward training procedure might conceivably have been functionally equivalent to the forward procedure used by Honey and Hall (1989).

The purpose of Experiment 3 was to investigate the relationship between the backward and forward training procedures. In Experiment 3A (see Table 1), the rats experienced a mixed procedure in Stage 1 with Stimulus A being preceded by food and Stimulus N being followed by food. If the forward and backward procedures are functionally equivalent, then generalization to A should be as substantial as that seen in Experiment 2 when both A and N followed food (or as that seen in the work of Honey & Hall, 1989, in which both A and

N preceded food). Experiment 3B was run separately but constitutes a parallel case and follows the same logic. It differs only that in this version of the experiment it was Stimulus A that received the forward training and Stimulus N the backward procedure (see Table 1).

Method

The subjects for Experiment 3A were 8 naive male hooded rats (mean ad lib weight: 295 g, range: 285–300 g). A further 16 subjects from the same stock served in Experiment 3B (mean ad lib weight: 345 g, range: 325–360 g). They were maintained as in Experiment 1. The apparatus was that used in Experiment 1.

Although run at separate times, Experiments 3A and 3B made use of almost exactly the same procedures. There were 2 sessions of magazine training followed by 12 sessions of Stage 1 training, 4 sessions of noise conditioning, and the test with A and B. The experiments differed only in that 2 sessions of baseline recovery ($VI = 60$ s) training were given following conditioning in Experiment 3B, whereas a single recovery session was sufficient in Experiment 3A. All subjects in Experiment 3A experienced the +A/N+ condition; that is, each presentation of A was preceded by the delivery of a food pellet and each presentation of N was followed by food. For the A+ / +N condition of Experiment 3B, the arrangement was reversed. On trials when food followed the cue, the operation of the feeder was initiated just as the cue terminated. All other procedural details were the same as those described for Experiment 2.

Results and Discussion

For Stage 1 of Experiment 3A a record was kept of magazine responding during each stimulus and of any responses that occurred during the 30-s period preceding the stimulus. (In the case of +A trials the prestimulus responding was recorded for the 30-s period preceding food delivery.) Response rates during the stimuli were corrected for background responding by subtracting from each the appropriate prestimulus score. The resulting mean rates for each trial type for the final session of Stage 1 were 3.63 rpm for Stimulus A, 12.25 rpm for N, and 2.63 rpm for B. An ANOVA showed there to be a significant difference among these scores, $F(2,14) = 21.11$, and subsequent pairwise comparisons using Duncan's test showed that responding to the N stimulus was significantly different from responding to either the A stimulus or the B stimulus. Rates to A and B did not differ ($p > .05$). Although the comparison is confounded with the nature of the stimulus (tone and clicker were counterbalanced as A and B, but Stimulus N was always white noise), these results suggest that Stage 1 training was effective in establishing N as a CS for food. Neither the stimulus that was preceded by food (A) nor that presented unaccompanied by food (B) evoked much responding.

Conditioned suppression was established to the noise during Stage 2. By the final session of this stage the group mean suppression ratio (pooling over all three trials) was .02. Figure 3 (top panel) shows the results of central theoretical interest, the suppression controlled by A and B on the test session. It is evident that both stimuli evoked suppression on the first of the (nonreinforced) test trials and that they did so to the same extent. There was no reliable difference between

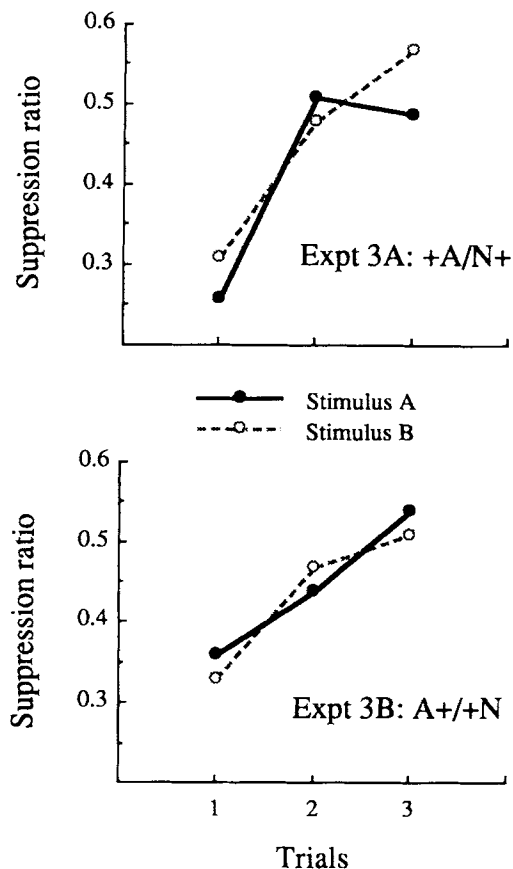


Figure 3. Experiment 3: Group mean suppression ratios for the test trials with stimuli A and B. (All subjects had experienced A, B, and N in Stage 1 training. For Group +A/N+, A had been preceded by food, and N had been followed by food in Stage 1; for Group A+ / +N the arrangement was reversed.)

the stimuli. An ANOVA conducted on the data shown in the figure showed only a significant effect of trial, $F(2,14) = 15.60$; the effect of group and the interaction were both non-significant ($F_s < 1$). Baseline responding was well maintained during the test, the mean rate during prestimulus periods being 32.21 rpm.

In Experiment 3B, Stage 1 training again established responding to the stimulus that preceded food (Stimulus A) but not to the stimulus (N) that followed food or to Stimulus B. The mean rates for the last day of Stage 1 (computed as for Experiment 3A) were 9.06 rpm to A, 1.81 rpm to N, and 0.13 rpm to B. An ANOVA showed there to be a significant difference among these scores, $F(2,30) = 8.72$. Pairwise comparisons (by Duncan's test) showed that the rate to A differed significantly from those to either of the other two stimuli, which did not themselves differ significantly ($p > .05$).

Stage 2 training established suppression to N, the group mean suppression ratio being .06 on the final day of this stage. The lower panel of Figure 3 shows the suppression controlled by A and B on the test trials. As in Experiment 3A, the stimuli did not differ. An ANOVA showed there to be a significant change over trials, $F(2,30) = 14.32$, but there was

no significant effect of stimulus type and no significant interaction ($F_s < 1$). Baseline responding was maintained during the test at 23.65 rpm.

The result of Experiments 3A and 3B demonstrate, as clearly as a null result can, that generalization between stimuli is not enhanced by prior training in which one of the stimuli has been followed by a given event and the other has been preceded by this same event. This was true both when it was the target stimulus that had preceded the common event during Stage 1 training (Experiment 3A) and when it was the stimulus to be used as the CS that had received this form of Stage 1 training (Experiment 3B). Thus training in which the critical stimuli share a common antecedent will establish equivalence between them (Experiments 1 and 2), as will training in which the stimuli share a common consequence (Honey & Hall, 1989); but the mixed form of training used in this experiment is ineffective in establishing equivalence.

The immediate implication of the results of the present experiment is that they rule out the possibility that the backward training procedure might, as experienced by the subject, be functionally equivalent to the forward procedure of Honey and Hall (1989). Their wider implications, for the interpretation of equivalence mechanisms more generally, are taken up next.

General Discussion

The results reported here confirm that the degree of generalization between stimuli can be influenced by the previous training that those stimuli have undergone; they also extend our knowledge of the sort of training that is capable of producing this effect. They show that a CR established to a stimulus that has previously been experienced preceded by a given event (the delivery of food) will generalize more readily to another stimulus that has also been experienced preceded by food than to a stimulus that has not been pre-trained in this way. We suggest that the preliminary training establishes equivalence between stimuli that have been treated in the same way, enhances the distinctiveness of stimuli that have been treated differently, or both.

Previous demonstrations of acquired equivalence and distinctiveness (e.g., Honey & Hall, 1989) have been concerned with the case in which the pretraining procedure involves manipulating the consequences of the target cues, and our theoretical interpretations have been devised to meet this case. Thus, Honey and Hall (1989) suggested that generalization will be enhanced between two cues, each of which has been followed by food in pretraining, by virtue of the fact that each will have formed an association with some representation of food. This representation will be able to acquire associative strength during the phase of training in which one of the stimuli is trained as the CS for the CR that is to be assessed in the generalization test. Its activation by the other stimulus on the test will allow that stimulus to evoke the CR to some degree. Clearly this analysis will require modification if it is to be applied to the present case in which the stimuli appear to acquire equivalence by virtue of having had a common antecedent.

One possibility, considered by Bonardi et al. (in press), emerges if we allow that backward conditioning procedures might permit the formation of excitatory associations. In the present context this would mean that the two stimuli that were experienced following food in initial training in Experiments 1 and 2 would acquire the ability to activate the food representation when presented in subsequent stages of training. This representation would then be able to mediate generalization in just the same way as has been postulated for the case of forward equivalence training. One difficulty for this interpretation is the sparseness of the evidence that might be thought to show the reality of backward excitatory conditioning. But perhaps more critical are the results of Experiment 3. If backward equivalence is a consequence of the operation of essentially the same mechanism as that responsible for forward equivalence, then the mixed procedure used in Experiment 3 should also be effective in establishing equivalence. Both the stimulus that had preceded food in initial training and the stimulus that had been followed by food should be able to activate a food representation that would be able to mediate generalization between them. But no evidence of acquired equivalence was obtained in Experiment 3.

A second suggestion considered by Bonardi et al. (in press) offers an explanation for the backward equivalence effect but assumes only forward excitatory conditioning. In the procedure used here, the presentation of food could become a CS associated with both A and N in the +A/+N conditions. As a result, the representation of A would be associatively activated on +N trials as would the representation of N on +A trials. Associations might then be formed between A and N during the initial phase of training, in spite of the fact that the two events themselves are not presented together. Should such associations be formed, a CR subsequently trained to one of them can be expected to generalize to the other in the way evidenced by more orthodox demonstrations of sensory preconditioning (see Honey & Hall, 1991, for a fuller discussion of the relationship between equivalence effects and sensory preconditioning).

The foregoing explanation of the backward equivalence effect requires us to accept that establishing one event (food in this case) as a signal for each of two others (A and N) permits the formation of excitatory associations between A and N. This possibility is explicitly rejected by the associative account of the formation of stimulus representations proposed by McLaren, Kaye, and Mackintosh (1989). McLaren et al. argued that training in which two events are separately signaled by the same CS will establish inhibitory links between these events because the presentation of one of them will be correlated with the omission of the other. In our experiments, A could come to inhibit activation of the N representation and vice versa; far from enhancing generalization between these stimuli, the training given to them should have actually restricted it. Our finding that the backward procedure is capable of establishing equivalence between A and N means either that the analysis offered by McLaren et al. is faulty in some respect or that some other process is operating in these experiments that is capable of obscuring the effects

of any inhibitory associations that may be formed between the target stimuli.

The notion that inhibitor associations might form between A and N in our training procedure remains only a hypothesis at this stage. There is good reason to suppose, however, that this procedure might establish each of the stimuli as an inhibitor for food—the effectiveness of backward pairings in generating inhibition has been well documented (see, e.g., Wagner & Larew, 1985). Such inhibitory learning could form the basis of the equivalence effect demonstrated in our experiments. If A and N both become inhibitors for food, then the central state that each will evoke (frustration, say) might be able to mediate generalization between them. Aversive conditioning with N would also establish the state of frustration as a signal for shock and thus allow A, which also evokes this state, to elicit the CR of suppression on the test. The analysis is the exact parallel of that offered for forward equivalence but with the state of frustration rather than that produced by the activation of a food representation acting as the mediating event. It should be acknowledged, however, that this account applies rather less plausibly to the backward equivalence effect demonstrated by Bonardi et al. (in press) in which the common antecedent presented in the first stage of training was an event without motivational significance.

It remains to be determined which, if any, of these interpretations of backward equivalence is correct. But the reality of the effect seems to be established by these experiments, and it is of some interest to ask whether the processes presumed to be responsible for it could perhaps play a role in other circumstances, in particular in the conditional discrimination tasks that have been used by Sidman (1990) and others in demonstrating the emergence of equivalence classes.

Consider, first, the study of conditional discrimination learning in pigeons reported recently by Zentall et al. (1992). The essence of the experimental design was as follows. Birds were initially trained on conditional discriminations in which they were required to choose Stimulus X rather than Y given Sample Cue A and also to choose P rather than Q given the same cue, A. As training proceeded, the birds came, as a consequence of their own responding, to experience a series of presentations of A prior to X and of A prior to P. The formal parallel between this and the procedure used in Stage 1 of our Experiments 1 and 2 is evident. We might expect, therefore, that X and P would be rendered equivalent by virtue of their common antecedent, and the test stage of the experiment by Zentall et al. provides evidence for this. Some of their subjects were given a “full” reversal (i.e., they now had to choose Y rather than X and Q rather than P after presentations of A); the remaining subjects experienced a “partial” reversal (Nakagawa, 1986) in which only one of the subtasks was reversed. Performance in the full reversal condition was found to be superior, that is, it proved advantageous to require the animals to continue to treat in the same way the two cues between which equivalence might have been established during initial training.

The experiment by Zentall et al. (1992) is of particular interest as their training procedure constitutes an exact parallel to the example cited by Sidman (1990) as constituting the “basic experiment” on equivalence class formation. Sid-

man, too, suggested that equivalence can be established between X and P by training on the pair of conditional discriminations described above. It still needs to be shown, however, that one or other of the associative mechanisms that we have proposed as possible explanations for our own results could explain the outcome of the test procedure used by Sidman; the form of equivalence of interest to Sidman would be evidenced if subjects tended to choose X (rather than Y) when given X's supposed equivalent, P, as the conditional cue. An explanation can be devised that accords with one of those suggested by Bonardi et al. (in press) for their backward equivalence effect if it is allowed that initial training on the conditional task will establish an A–P association. (We have already pointed out that, as subjects come to solve such a conditional task, their own behavior ensures that they experience A and then P in close succession.) Once this association has been formed, one consequence will be that the representation of P will be activated associatively by Stimulus A on training trials when the choice is between X and Y, and X is reinforced. To this extent, therefore, the subject will have had some experience of being rewarded for choosing X in the presence of some of the central consequences of Stimulus P. Such training could well be enough to ensure appropriate performance on test trials with X and Y when P itself is presented as the conditional cue.

The analysis just outlined is offered essentially as an exercise in determining whether or not our associative explanations could apply, in principle, to the outcome of conditional discrimination tasks. We have no direct evidence that might help establish the validity of the analysis. And indeed, the observation (e.g., D'Amato, Salmon, Loukas, & Tomie, 1985) that experiments with nonhuman subjects modeled on those performed with humans have frequently failed to reveal evidence of equivalence class formation may be used to argue against the suggestion that basic mechanisms of associative learning (that are presumably common to all subjects) are responsible for the effects seen in humans. However, the force of this objection depends on the assumption that the procedures used for animals and for humans have been truly comparable, and this matter is open to debate (see Zentall et al., 1992).

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