The Role of Mediated Conditioning in Acquired Equivalence

Jasper Ward-Robinson and Geoffrey Hall

University of York, York, U.K.

In Experiment 1 rats received initial training in which delivery of a sucrose pellet was signalled by an auditory cue. This cue was then paired with shock in a second phase of training. In a test the rats showed an unwillingness to perform an instrumental response that yielded the sucrose pellet. This was interpreted as indicating that the associatively activated representation of the pellet had acquired aversive properties during the shock-reinforced stage of training. Experiment 2 replicated this *mediated conditioning* effect making use of a Phase 1 training procedure, modelled on that used by Honey and Hall (1989) to demonstrate acquired equivalence of cues, in which two auditory cues were each used to signal sucrose pellets. A further test revealed that this training resulted in enhanced generalization between these two cues. It was argued that this effect is mediated by the conditioned aversive properties of the common associate of the two auditory cues.

In their demonstration of the acquired equivalence effect, Honey and Hall (1989) made use of the following basic procedure: In a first phase of training rats were presented with two auditory stimuli, A and B, which were trained as signals for a common outcome, for example the delivery of a food pellet. In a second phase, A was paired with shock, and a conditioned response (CR), the suppression of free-operant responding, was established. A final test phase established that this CR generalized readily to B. It was concluded that the common training history shared by A and B had rendered them functionally equivalent so that the CR subsequently established to one would be elicited by the other (cf. Miller & Dollard, 1941).

The explanation offered for the acquired equivalence effect by Miller and Dollard (1941, see also Hull, 1939) supposes that the enhanced generalization that occurs between two cues that share a training history is mediated by the conditioned properties of their common associate. Honey and Hall (1989) applied this general notion to their own results as follows. They suggested that an association formed between Stimulus A and food in the

first phase of training would allow the activation of a representation of food during the second phase of shock-reinforced training with A. This representation would therefore become associated with the shock and acquire the capacity to evoke the CR. As Stimulus B would also have formed an association with food during the first phase of training it would be able to activate the food representation on test, and thus it too would be able to elicit the CR to some extent.

A critical feature of this proposed explanation for acquired equivalence is its assumption that the associatively activated representation of an event can enter into further associations. Evidence to support this assumption comes from studies demonstrating what has been called backward sensory preconditioning (Ward-Robinson & Hall, 1996) or representation-mediated conditioning (Holland, 1981). The general procedure for such an experiment follows that of standard, sequential, sensory preconditioning (e.g. Prewitt, 1967; Rizley & Rescorla, 1972) in which two neutral stimuli are paired (X→A) before a CR is trained to the second element by pairing A with a reinforcer. This allows the other stimulus, X, which has not been paired with the reinforcer, to evoke the CR. The backward form of this procedure is identical except that the order of the two stimuli is reversed during the first phase of training—that is, A→X trials are given. The ability of X to evoke the CR in this case has been interpreted as showing that X, which is activated associatively by A during Phase 2 of the procedure, is able to enter into a direct association with the reinforcer presented during that stage (Hall, 1996; Holland, 1990; but see also Cole, Barnet, & Miller, 1995).

The explanation for acquired equivalence offered by Honey and Hall (1989) assumes that the process demonstrated by the mediated conditioning effect operates during their training procedure. In particular it requires that an association be formed between the associatively activated representation of food and the shock reinforcer. It has often been thought, however, that associations between such stimuli are not readily formed (e.g. Garcia & Koelling, 1966). Moreover, Holland (1981, Experiment 3) failed to find a mediated conditioning effect using precisely these classes of stimuli. In his experiment, rats were first presented with pairings of (for example) a tone and a flavoured sucrose pellet before, in a second training phase, the tone was shock-reinforced. A final test phase revealed no evidence of mediated conditioning in that these subjects were found to consume sucrose pellets as readily as did control subjects that did not experience tone–sucrose or tone–shock pairings.

Although Holland's (1981) results are not encouraging, we thought it worthwhile to pursue the possibility that his failure to obtain a mediated conditioning effect might be a consequence simply of the insensitivity of the test procedure that was used. This consisted of a consumption test in which the subjects were given access to a large number of sucrose pellets, and the number eaten was recorded. We thought it possible that, during the course of this test, the crucial pellet→shock association might have extinguished, reducing the likelihood of observing the mediated conditioning effect (rats consumed more than 75 pellets during the course of the test). Accordingly we attempted to devise a test procedure in which the rats received relatively few pellets during testing. In addition, rather than using a consumption test, we made use of an instrumental procedure in which the rats were required to earn the pellets by lever-pressing—Jackson and Delprato (1974) have provided some evidence to suggest that appetitive instrumental responding is

particularly sensitive to disruption by signals associated with aversive events. In Experiment 1 we attempted to replicate the essential features of Holland's (1981) experiment in the hope of finding evidence of mediated conditioning with pellet and shock stimuli using this modified and, we hoped, more sensitive test procedure. In Experiment 2 we sought evidence for the effect in rats trained with the procedure used by Honey and Hall (1989) to generate the acquired equivalence effect.

EXPERIMENT 1

The design of Experiment 1 is summarized in the upper panel of Table 1. There were two groups of subjects that differed only in the training given in Phase 1. During this phase, groups A+/B− received presentations of two auditory stimuli. Each presentation of Stimulus A was reinforced by the delivery of a distinctively flavoured sucrose pellet; Stimulus B was presented as often as Stimulus A, but was never reinforced. During Phase 2, Stimulus A was paired with a shock reinforcer. It was anticipated that, following the Phase 1 training given to group A+/B−, the presentation of Stimulus A would be capable of activating a representation of the sucrose pellet and that this representation would therefore be active during the presentations of the shock in Phase 2. The question of interest was whether such a pairing would allow associative learning to occur about the relationship between the sucrose pellet (or its representation) and the shock reinforcer. This was examined by allowing rats to earn these pellets by pressing a lever (the mediated conditioning test)—evidence of learning about the pellet–shock relationship would be

TABLE 1
Experimental Designs

Experiment	Group	Phase 1	Phase 2	Acquired Equivalence Test	Mediated Conditioning Test
1	A+/B−	A→+ B−			
	A−/B+	A− B→+	A→shock		Lever→+
2	A+/B+/C−	A→+ B→+ C−			
	A−/B−/C+	A− B− C→+	A→shock	B versus C	Lever→+

Note: A, B and C refer to auditory stimuli, which either signalled delivery of a grape-flavoured sucrose pellet, →+, or were nonreinforced, −. Stimulus A was paired with a shock reinforcer during Phase 2. The effect of this training on rat's willingness to earn grape-flavoured sucrose pellets by lever pressing was assessed during the Mediated Conditioning Test. Experiment 2 included an additional Acquired Equivalence Test which examined the ability of Stimuli B and C to suppress a different instrumental response.

provided if rats were reluctant to perform this instrumental response. Comparison was made against a control group, group A−/B+, for whom Stimulus B rather than Stimulus A was paired with the sucrose pellet during Phase 1. Both groups therefore received similar exposure to the stimuli, but only group A+/B− could be expected to experience pairings of the associatively activated representation of the sucrose pellets and the shock.

Method

Subjects

The subjects were 16 naive male hooded (Lister) rats with a mean free-feeding weight of 308 g (range: 300–315 g). They were maintained at 80% of their free-feeding weights by being fed a measured amount of food after each session. They were housed in pairs in a colony room illuminated from 0800–2000 h.

Apparatus

The apparatus consisted of four Skinner boxes, measuring 24.5 cm long × 23.0 cm wide × 20.5 cm high, supplied by Campden Instruments Ltd. (Loughborough, England). The boxes were constructed from aluminium except for the door and roof, which were made, respectively, from clear and opaque Perspex. Each box was housed in a sound- and light-attenuating shell equipped with an exhaust fan serving to ventilate the chamber and generate a background noise level of 65 dB. The boxes were equipped with a recessed food tray to which standard 45-mg food pellets (Noyes Formula A/I), and grape-flavoured sucrose pellets (Noyes Formula F) could be delivered. Access to this tray was by means of a rectangular aperture, 6 cm high and 5 cm wide. A transparent plastic flap of the same dimensions was attached by a hinge to the top of this aperture. Pushing against this flap actuated a microswitch, and this was recorded as a response. A retractable response lever was positioned on either side of the magazine 5.0 cm above the floor. The floors of the boxes were made from 16 stainless steel rods 0.5 cm in diameter and spaced 1.0 cm apart. A 0.5-mA, 0.5-sec shock could be passed through the bars by Campden Instruments Ltd. shock generators (Model 521C) and shock scramblers (Model 521S). The boxes were equipped with a loudspeaker, which was used to present a 2-kHz tone and a noise, each at around 75–82 dB (Scale A) when measured against background noise produced by the exhaust fan. Dim illumination was provided by a 1.5-cm diameter, 2.8-W jewel light (rated for 24 V but operated at 15 V) mounted 14.5 cm above the base of the magazine tray. Events were controlled and recorded by a BBC microcomputer (Model B) using a version of BASIC.

During the mediated conditioning test, in which the rats were required to earn pellets by lever pressing, the hinged plastic flap that guarded the food tray was removed. (There is reason to think that eliminating the flap-pushing requirement might make the lever-press response more sensitive to the effects of changes in the value of the reinforcer; see Balleine, Garner, Gonzalez, & Dickinson, 1995.) In order to prevent pellets from spilling out of the tray, a strip of aluminium was inserted along the lower edge of the aperture, forming a lip 18 mm high. The rats could readily reach over this lip to retrieve a pellet.

Procedure

Preliminary Training.   In order to attenuate any possible neophobic reaction, each rat was per- mitted to consume five of the grape-flavoured pellets in the home cage. The rats were next given two sessions of magazine training in which standard food pellets were delivered according to a variable

time (VT) 60-sec schedule. The response levers were retracted. Sessions occurred daily, and, except where indicated, all sessions were 40 min in duration. On the following day, the rats were given a further five grape-flavoured sucrose pellets in their home cages.

Phase 1 Training. Rats were randomly assigned to either group A+/B− or group A−/B+ (see Table 1) and were given appetitive conditioning during the 12 daily sessions of Phase 1. In each of these sessions 30-sec noise and tone stimuli were presented in a random sequence with the constraint that each stimulus occurred twice. For half of the rats in each of the groups the noise served as Stimulus A, and the tone served as Stimulus B; for the remaining rats the roles of these stimuli were reversed. Trials were separated by a mean intertrial interval (ITI) of 456 sec (range: 182–730 sec). For group A+/B−, a grape-flavoured sucrose pellet was delivered on termination of Stimulus A, whereas Stimulus B was nonreinforced; group A−/B+ received reinforcement following Stimulus B, and Stimulus A was nonreinforced. Magazine responding was recorded during stimulus presentations and during the 30-sec stimulus-free period that preceded each trial.

Phase 2 Training. Over the following three daily sessions, Stimulus A was presented three times per session, but no pellets were delivered. For rats in both groups, a shock was given on the termination of Stimulus A. The ITI was a fixed 555 sec. To reduce any general fear of the apparatus resulting from this phase of training, two sessions of context extinction were followed in which rats received no programmed stimuli.

Mediated Conditioning Test. For this single test session, the plastic flap that covered the food tray was removed, and the lever to the left of the magazine was extended into the box. Each depression of the lever resulted in the delivery of a grape-flavoured sucrose pellet until 11 pellets had been earned. At this point the session was terminated. The first response started a timer, and the latency of each of the subsequent 10 responses was recorded.

Results and Discussion

During initial magazine training, the rats learned to retrieve and consume the standard food pellets. Some rats failed to consume all of the sucrose pellets delivered in Phase 1 but this occurred only in the first few sessions of the phase. Conditioning was evident in the development of a tendency to approach the food tray during the auditory cue that preceded pellet delivery. On the final session of Phase 1 training rats in both groups responded more during reinforced than during nonreinforced trials. Rats in group A+/B− responded at a mean rate of 21 and 5 responses per min during Stimuli A and B, respectively; for group A−/B+ the corresponding data were 3 and 20 responses per min. An analysis of variance performed on these data revealed a main effect of stimulus type (i.e. reinforced vs. nonreinforced), $F(1, 14) = 24.50$. Neither the main effect of the group factor nor its interaction with stimulus reached significance, both $Fs < 1$. (In this and all subsequent analyses a criterion of $p < .05$ was adopted.)

No data were recorded during the shock-conditioning trials of Phase 2 or from the context extinction sessions that followed. The data of central interest are those of the mediated conditioning test, which are summarized in Figure 1. The top panel shows the group mean latency for each of the 10 responses recorded. It is evident that rats' latencies declined over the course of testing as would be expected of animals learning a new
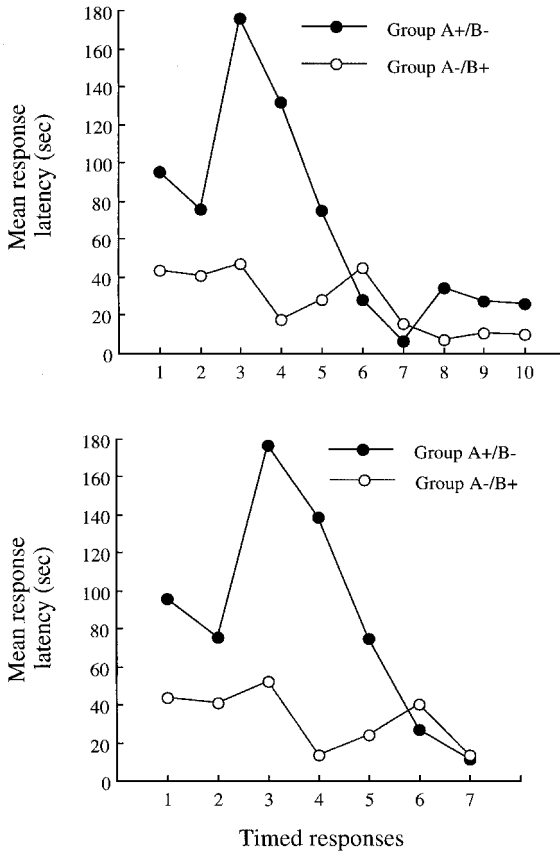
FIG. 1.   Experiment 1: Mean latency data from the test for mediated conditioning. Scores represent the interval between successive responses after the first reponse. In the top panel scores from all 10 recorded responses are presented. In the bottom panel the scores are for the first 7 response latencies that were 0.2 sec or longer.

instrumental response. However, it is also evident that, especially early in the test, the interresponse latencies recorded for group A+/B− tended to be longer than those of group A−/B+. This is consistent with the suggestion that for group A+/B− the grape-flavoured sucrose pellet had acquired aversive properties, which, to some extent, were able to interfere with its efficacy as an instrumental reinforcer. The data summarized in Figure 1 were subjected to an analysis of variance with group and response numbers as factors. This analysis revealed no main effects or interactions, largest $F(9, 126) = 1.93$, $.1 > p > .05$, for the effect of response number.

   A closer inspection of the data revealed that some of the latencies recorded were no greater than a fraction of a second. It is not possible that a pellet earned by the first of two very closely spaced responses could be retrieved before the occurrence of the second, and thus such latencies can give no information about the effectiveness of the reinforcer but simply add "noise" to the mean scores depicted in the figure. Accordingly the test data

were recomputed with any response latencies of less than 0.2 sec being excluded from consideration. This meant excluding some scores for two animals in each of the groups. In group A+/B−, one rat had two latencies of less than 0.2 sec, and another had three such latencies. For each of the two subjects in group A−/B+, one score was excluded. The lower panel of Figure 1 shows group mean latencies for the first seven responses for which all animals were able contribute scores. An analysis of variance on the log transform of these data, with trial number and group as the variables revealed a significant effect of group, $F(1, 14) = 5.55$. Neither the effect of response number nor the interaction was significant ($Fs < 2$).

We have suggested that pairing the associatively activated representation of a stimulus with a reinforcer might be sufficient to condition a response to that stimulus, in much the same way as the direct pairing of those events can do so (cf. Holland, 1981; Rescorla & Freberg, 1978; Ward-Robinson & Hall, 1996). The results of the present experiment lend support to this general notion and to the more specific suggestion that a food pellet may be devalued by the pairing of its associatively activated representation with a shock reinforcer. It is perhaps surprising that we have been able to detect shock-devalued flavour aversion in this preparation given that, in several widely cited papers, rats have been shown to be unable to form an association between a gustatory CS and a shock reinforcer even when these events are paired directly (e.g. Domjan & Wilson, 1972). It is therefore necessary to ask why such learning was observed in the current experiment. One possibility is prompted by the suggestion, put forward by Krane and Wagner (1975), that taste–shock pairings rats fail to generate a CR because the gustatory CS tends to persist beyond the termination of the shock reinforcer, thereby producing some inhibitory learning that acts to obscure excitatory learning (e.g. Siegel & Domjan, 1971). According to this view, learning about gustatory CSs and shock reinforcers should be evident if this persistence of the CS can be prevented. If we can assume that the associatively activated representation of a gustatory CS is likely to be less long-lasting than the CS itself, then the procedure used in the present experiment should generate only minimal inhibitory learning and therefore allow excitatory learning to show through on the test.

The findings of the current experiment are also surprising in that Holland (1981, Experiment 3) failed to produce mediated conditioning using a procedure that was similar to ours in all respects apart from the nature of the test. Indeed, in our own preliminary experiments that made use of a free-access consumption test of the sort used by Holland we were similarly unsuccessful in finding evidence for mediated conditioning. Although we cannot be certain on the basis of a cross-experiment comparison we conclude that the mediated conditioning effect is of no great size and requires a particularly sensitive test, of the sort used here, to show itself. However, although the effect is not powerful, it remains the case that, at least in some circumstances, mediated conditioning can be demonstrated using pellets as target stimuli and shock reinforcement.

EXPERIMENT 2

Experiment 1 confirmed the reality of the mediated conditioning effect and thus lends support to the suggestion that the formation of an association between shock and the associately activated representation of a pellet might be responsible for the acquired

equivalence effect of Honey and Hall (1989). There are, however, many differences between the procedure used to demonstrate acquired equivalence and that used in Experiment 1. Accordingly, in this experiment, we attempted to demonstrate the mediated conditioning effect in animals given training that exactly followed the procedures used by Honey and Hall. In addition, we conducted, for these same animals, a test of acquired equivalence in the hope of showing that the two effects co-occur.

In Experiment 2, the design of which is summarized in the lower panel of Table 1, rats were given trials with three stimuli, A, B, and C, during Phase 1. For animals in group A+/B+/C−, Stimuli A and B were reinforced by the delivery of a grape-flavoured sucrose pellet, and Stimulus C was nonreinforced. For other animals (group A−/B−/C+), Stimulus C was reinforced by the delivery of a grape-flavoured sucrose pellet, and A and B were nonreinforced. It was anticipated that Stimuli A and B would acquire equivalence as a result of their common training history. This was tested by training a fear-CR to Stimulus A (Phase 2) and examining the generalized responding governed by Stimulus B relative to that governed by Stimulus C (the acquired equivalence test). If the results reported by Honey and Hall (1989) can be replicated, there should be more generalization to B than to C.

The hypothesis under test is that this enhanced generalization to B is mediated by the acquisition of aversive properties by the associate of A that is activated during Phase 2 training. For group A+/B+/C− this will be the associatively activated representation of the sucrose pellet; for group A−/B−/C+, Honey and Hall (1989) suggest that it will be the state that is engendered by the omission of a pellet. In order to test this notion we gave the animals a further test (labelled Mediated Conditioning Test in Table 1), in which they were allowed to earn by lever pressing the flavoured sucrose pellets that were given in the first phase of training. If the hypothesis is correct we would expect to find that animals in group A+/B+/C− would show an unwillingness to respond for the grape-flavoured sucrose pellet because its representation will have occurred along with shock in Phase 2. The performance of this group can be conveniently assessed by comparison with group A−/B−/C+, for whom no such pairing will have occurred.

Method

Subjects and Apparatus

The subjects were 32 experimentally naive male hooded (Lister) rats with a mean free-feeding weight of 366 g (range: 315–425 g). The apparatus was that used in Experiment 1 but a further auditory stimulus, a 10-Hz click train, was used in addition to the tone and noise.

Procedure

Any procedural details not specified here were the same as those described for Experiment 1.

Preliminary Training.   All rats were given two sessions of magazine training in which standard food pellets were delivered according to a VT 60-sec schedule. Because pilot work indicated an initial reluctance to consume flavoured sucrose pellets, a third session of magazine training was given in which sucrose pellets were delivered according to a VT 300-sec schedule. To limit unconditioned

suppression during subsequent appetitive training, rats were also given a fourth pretraining session containing two presentations each of the tone, noise, and clicker stimuli during a single session. Stimulus presentations were separated by intervals of 322 sec. No pellets were given in this session.

Phase 1 Training.   Over the 12 sessions of this phase, rats received presentations of the tone, noise, and clicker, each being presented twice per session. Except for this constraint, the sequence of these stimuli was random over the sessions. The first trial occurred 322 sec after the beginning of the session, and trials were separated by an ITI of the same duration thereafter. For group A+/B+/C−, the noise served as Stimulus A and was reinforced by the delivery of a grape-flavoured sucrose pellet. For half of the rats in this group the tone, serving as Stimulus B, was similarly reinforced, whereas the clicker (Stimulus C) was not. The roles of the tone and clicker were reversed for the remaining rats. The treatment of group A−/B−/C+ differed from that of group A+/B+/C− only in that Stimuli A and B were not reinforced whereas Stimulus C was.

Phase 2 Training.   The training given in this phase was designed to condition a fear response to Stimulus A. Two sessions were given in each of which Stimulus A was presented and shock re-inforced three times. No pellets were delivered during Phase 2.

Test Phase.   There were two tests, one for the acquired equivalence effect and one for mediated conditioning. Half of the rats received the tests in this order; half received the reverse order. Counter-balanced subgroups were represented equally in each case.

The acquired equivalence test was carried out to measure the amount of generalized fear responding governed by Stimuli B and C. To this end, an instrumental baseline was established using standard food pellets (rather than the sucrose pellets used earlier) as reinforcers. Rats earned pellets by pushing the plastic panel in front of the food tray. During the first session of baseline training 25 pellets were earned on a continuous reinforcement schedule. Responding was reinforced according to a variable interval (VI) 30-sec schedule in the second session and a VI-60 schedule in the third and fourth sessions. During the following session, in which the VI-60 schedule of reinforcement remained operational, animals received three trials each of Stimulus B and of Stimulus C. Half of each counterbalanced subgroup received the sequence BCCBCB, the remainder received the sequence CBBCBC. The first trial occurred 322 sec after the beginning of the session, and trials were separated by an ITI of the same duration thereafter. Responses were recorded separately for each trial and for the 30-sec period that preceded each trial.

The mediated conditioning test was designed to detect group differences in preference for the grape-flavoured sucrose pellets. The rats first received two sessions intended to extinguish the instrumental response of pressing the magazine panel; this treatment was omitted for the rats who received mediated conditioning testing before acquired equivalence testing. In the first of these sessions the rats were placed in the box and no events were programmed to occur. The second extinction session was the same, except that the magazine panel was removed from the box and replaced with the metal lip designed to prevent the loss of pellets from the tray. In the single test session that followed, the two groups' readiness to respond for grape-flavoured sucrose pellets was examined. The lever to the left of the magazine was extended throughout this test. Each depression of the lever resulted in the delivery of a grape-flavoured sucrose pellet until 11 pellets had been earned. The first response started a timer thus allowing the recording of the latencies of the sub-sequent 10 responses.

Results and Discussion

Phase 1 appetitive training was successful in conditioning magazine responding to those stimuli paired with sucrose pellet delivery. For group A+/B+/C−, on the final session of training, the mean response rates were 13.0, 11.7, and 5.6 responses per min (rpm) during A, B, and C, respectively. A one-way analysis of variance was performed on these data and revealed a reliable main effect of stimulus, $F(2, 30) = 8.80$. A Tukey (HSD) test revealed that responding during Stimulus C was reliably lower than that during either A or B and that responding during A and B did not differ reliably. The corresponding data for group A−/B−/C+ were 4.9, 0.2, and 7.9 rpm for A, B, and C, respectively; again the rate of responding was greater during the reinforced stimulus, C, than during the nonreinforced stimuli, A and B. A one-way analysis of variance revealed a significant difference among these scores, $F(2, 30) = 7.65$. Further analysis using Tukey's test showed that responding during C differed from that during B. No other differences were reliable.

For each trial of the acquired equivalence test, a suppression ratio was calculated of the form $a/(a + b)$ where a represents the number of responses emitted during the stimulus and b the responses emitted during the prestimulus period. The data for group A+/B+/C− are summarized in Figure 2a and those for group A−/B−/C+ in Figure 2b. For the first of these groups, it is clear that B elicited more suppression than C. An analysis of variance conducted on these data with stimulus (B vs. C) and trial as variables revealed main effects of stimulus, $F(1, 15) = 11.96$, and of trial, $F(2, 30) = 3.44$. These factors did not interact, $F(2, 30) = 2.15$. The data for group A−/B−/C+ were more variable, but by the final test trial a substantial difference, with B eliciting more suppression than C, emerged. This difference proved to be statistically reliable. An analysis of variance revealed a main effect of trial, $F(2, 30) = 6.47$, no main effect of stimulus, $F(1, 15) = 2.75$, but a significant interaction between these variables, $F(2, 30) = 4.20$. An analysis of simple main effects revealed the source of the interaction to be the stimulus difference on test trial three, $F(1, 15) = 7.70$. The differences observed on the other test trials were not statistically reliable, smallest $p > .10$ (Trial 1). The prestimulus response rates from this test are summarized in Table 2. An analysis of variance performed on the data for group A+/B+/C− with stimulus and trial as the variables produced no reliable effects or interactions (all Fs < 1). The corresponding analysis of the group A−/B−/C+ data produced only a reliable interaction between stimulus and trial factors, $F(2, 30) = 4.30$. This was further examined using a test of simple main effects; however, none of the differences in responding on B and C trials was found to be reliable (smallest $p > .10$). The results of this test replicate those of the study on which it was based (Honey & Hall, 1989, Experiment 3), demonstrating better generalization from Stimulus A to Stimulus B—an event with which it shared a common training history—than to Stimulus C.

Data from the mediated conditioning test are summarized in Figure 3, which shows, separately for each group, the mean interval between successive responses after the first. One rat from each of the groups failed to respond in 40 min, at which point the session was terminated; these animals therefore contributed no data to this test. As would be expected of rats learning a new instrumental action, response latencies decreased over the course of testing. A more important feature of the data is that, early in testing, group A+/B+/C− produced relatively long latencies. An analysis of variance with group and
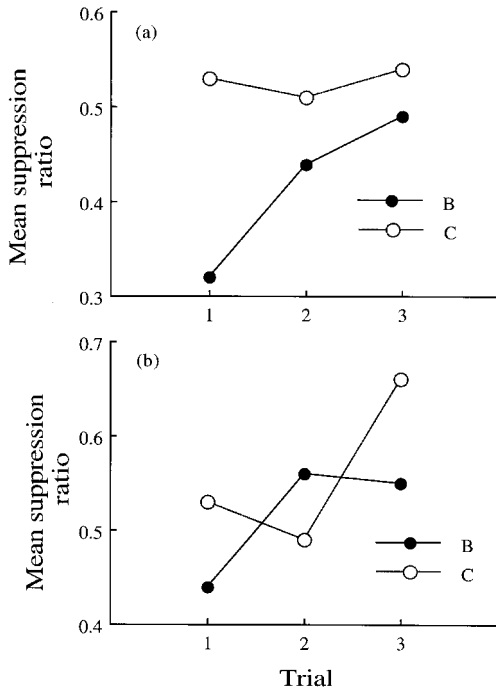
FIG. 2.   Experiment 2: Group mean suppression ratios for each trial of the acquired equivalence test for Stimuli B and C. Panel (a) shows the results for group A+/B+/C−; Panel (b) for group A−/B−/C+. Stimulus B had received the same Phase 1 treatment as Stimulus A; Stimulus C had received different treatment in Phase 1.

TABLE 2
Experiment 2: Acquired Equivalence Test:
Mean Prestimulus Response Rates

	Stimulus B			*Stimulus C*		
Group	*Trial 1*	*Trial 2*	*Trial 3*	*Trial 1*	*Trial 2*	*Trial 3*
A+/B+/C−	23.5	24.0	27.5	25.6	24.3	22.9
A−/B−/C+	23.0	18.9	18.8	20.9	23.9	15.8

Note: Rates are expressed as responses per min.

response number as factors confirmed this description of the data, revealing a main effect of response number, $F(9, 252) = 4.32$, no main effect of group, $F < 1$, but a reliable interaction between these two variables, $F(9, 292) = 2.00$. An analysis of simple main effects revealed the source of the interaction to be a group difference on Responses 2 and 3, $Fs(1, 9) = 8.01$ and 7.63, respectively. No other simple main effects were reliable, $Fs < 1$. This group difference in response latency indicates that the sucrose pellet was a less effective reinforcer for group A+/B+/C− than it was for group A−/B−/C+, a result
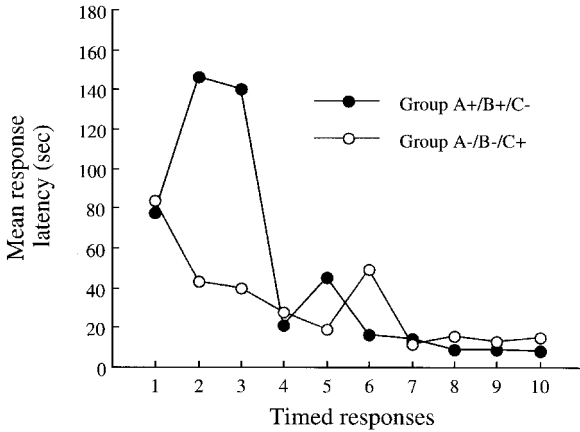
FIG. 3.   Experiment 2: Mean latency data from the test for mediated conditioning. Scores represent the interval between successive responses after the first response.

that would be expected if the pairing of A with shock in Phase 2 endowed A's associate (sucrose for group A+/B+/C−) with aversive properties.

Before accepting these results as an instance of mediated conditioning, other possible explanations should be considered. First, the Phase 1 treatment given to the two groups in this experiment means that they differed in their experience of the grape-flavoured sucrose pellets: Group A+/B+/C− received twice as many of the pellets as did group A−/B−/ C+ during this phase. As it is known that animals' consumption of novel flavours can change with experience, the possibility is raised that the extra experience of the sucrose pellets in the former group was in some way responsible for their slow responding during testing. This account of the results seems unlikely, however, given that preference for a flavour is typically found to increase rather than decrease with experience (e.g. Domjan, 1977). A second feature of the Phase 1 procedure used in this experiment was that group A−/B−/C+ received nonreinforced preexposure to Stimulus A, whereas, for group A+/ B+/C−, A was followed by a reinforcer during this stage. It is possible that this difference might have influenced the rate at which A acquired associative strength in Phase 2 of training and, as a consequence, might have produced a difference between the groups in the extent to which conditioning occurred to contextual stimuli. The results of the mediated conditioning test could thus reflect a difference between the groups in their fear of the apparatus. We have no information about conditioning to A, but a direct measure of contextual fear is provided by the baseline response rates measured during acquired equivalence testing. As we have already noted, there was no difference between the groups on these scores (see Table 2). The absence of a difference between the groups in their prestimulus rates suggests that there was, in fact, no marked difference between them in the degree of contextual conditioning. We conclude, therefore, that the difference between the groups in their performance in the instrumental test phase of this experiment is best regarded as being a further example of the mediated conditioning effect example of Experiment 1. And in this case the effect has been shown in animals given a training regime that has been demonstrated also to be effective in establishing acquired equivalence.

GENERAL DISCUSSION

The experiments presented here were aimed at examining Honey and Hall's (1989) suggestion that the acquired equivalence demonstrated in their experiments was mediated by the formation of an association between the associatively activated representation of food and a shock reinforcer. Experiment 1 provided evidence that shock reinforcement of a CS that had previously been used to signal the delivery of a distinctively flavoured food pellet would result in a devaluation of that pellet. Rats given this training showed a reluctance to perform an instrumental response rewarded by delivery of such pellets. This result may be regarded as a form of mediated condition in which, after pretraining with a pair of stimuli, A→X, reinforcement of A is found to endow X with associative strength (e.g. Ward-Robinson & Hall, 1996).

Experiment 2 examined acquired equivalence directly and confirmed that the fear responding generalizing from a shock-reinforced stimulus, A, to two other stimuli was greater to one (Stimulus B) with which it shared a training history than to a control stimulus (C). For the case in which A and B shared the common history of having signalled the delivery of a grape-flavoured sucrose pellet, it was argued that the enhanced generalization was mediated by aversive properties acquired by the pellet (by virtue of the mediated conditioning effect) during the phase of shock reinforcement of Stimulus A. A further test phase in this experiment confirmed that animals given this form of training showed some reluctance to lever press for grape-flavoured sucrose pellets. The simple co-occurrence of two phenomena cannot prove the existence of a causal link between them, but these results are what would be expected if the acquired equivalence effect were mediated by the mediated conditioning effect.

We have concentrated so far on the version of acquired equivalence demonstrated by Honey and Hall (1989), but it is appropriate to examine the possible role of mediated conditioning in other acquired equivalence procedures. Some instances of acquired equivalence, particularly those employing classical conditioning procedures, can be readily explained in these terms. Consider, for example, the acquired equivalence demonstration of Bonardi, Rey, Richmond, and Hall (1993). Pigeons were trained initially with four serial compound keylight stimuli, A–X, B–X, C–Y, and D–Y; this treatment was expected to generate acquired equivalence between A and B and between C and D. A was re-inforced with access to food in a second stage of training, and in the final test phase Stimulus B was found to elicit more keypeck responding than Stimulus D. This result is what would be expected if the phase of reinforcement with Stimulus A endowed X with excitatory strength by way of the mediated conditioning process.

A form of this analysis may also be extended to some demonstrations of acquired equivalence using instrumental training procedures. Consider, for example, an experi-ment reported by Urcuioli, Zentall, Jackson-Smith, and Steirn (1989), which used a symbolic matching-to-sample procedure. In the first phase, pigeons' choice of Compar-ison W was reinforced with access to food following presentation of Sample A and Sample B; choice of the alternative comparison, X, was reinforced following presentation of two other samples, C and D. (We might formalize this discrimination as AW+, BW+, CX+, DX+.) After the pigeons had mastered this problem, they were required to choose between two new comparison stimuli, Y and Z, following presentation of the old samples,

A and C; choice of Comparison Y was reinforced following Sample A, and choice of Z was reinforced following Sample C (formally, AY+, CZ+). If the A and B (and C and D) samples had acquired equivalence as a result of their similar training as samples for the same comparison, then B should be able to control choice of Y over Z. To test this, Urcuioli et al. trained some pigeons on this discrimination and found their performance to be superior to a group for whom the reverse choice was reinforced. This pattern of results can be understood by assuming that a representation of Comparison W (activated by the presentation of Sample A) was able to gain discriminative control over the choice of Comparison Y during the second distrimination. Thus, the final discrimination involving the matching of Comparison B to Sample Y will be relatively easy, as B will be able to activate associatively a representation of Comparison W.

It remains to be seen whether an associative analysis of this sort can be successfully applied to other demonstrations of the acquired equivalence effect (e.g. see Hall, 1996), but the evidence provided by the experiments presented here goes some way toward supporting the account offered by Honey and Hall (1989) for their version of the effect. It also encourages the view that other instances might be explicable in similar terms, thus contesting the suggestion that acquired equivalence might need to be regarded as a separate psychological process in its own right.

REFERENCES

Balleine, B.W., Garner, C., Gonzalez, F., & Dickinson, A. (1995). Motivational control of heterogeneous instrumental chains. *Journal of Experimental Psychology: Animal Behavior Processes*, *21*, 203–217.

Bonardi, C., Rey, V., Richmond, M., & Hall, G. (1993). Acquired equivalence of cues in pigeon autoshaping: Effects of training with common consequences and with common antecedents. *Animal Learning & Behavior*, *21*, 369–376.

Cole, R.P., Barnet, R.C., & Miller, R.R. (1995). Temporal encoding in trace conditioning. *Animal Learning & Behavior*, *23*, 144–153.

Domjan, M. (1977). Attenuation and enhancement of neophobia for edible substances. In L.M. Barker, M.R. Best, & M. Domjan (Eds.), *Learning mechanisms in food selection* (pp. 151–179). Waco, TX: Baylor University Press.

Domjan, M., & Wilson, N.E. (1972). Specificity of cue to consequence in aversion learning in the rat. *Psychonomic Science*, *26*, 143–145.

Garcia, J., & Koelling, R.A. (1966). Relation of cue to consequence in avoidance learning. *Psychonomic Science*, *4*, 123–124.

Hall, G. (1996). Learning about associatively activated stimulus representations: Implications for acquired equivalence and perceptual learning. *Animal Learning & Behavior*, *24*, 233–255.

Holland, P.C. (1981). Acquisition of representation-mediated conditioned food aversions. *Learning and Motivation*, *12*, 1–18.

Holland, P.C. (1990). Event representation in Pavlovian conditioning: Image and action. *Cognition*, *37*, 105–131.

Honey, R.C., & Hall, G. (1989). The acquired equivalence and distinctiveness of cues. *Journal of Experimental Psychology: Animal Behavior Processes*, *15*, 338–346.

Hull, C.L. (1939). The problem of stimulus equivalence in behavior theory. *Psychological Review*, *46*, 9–30.

Jackson, D.E., & Delprato, D.J. (1974). Aversive CSs suppress lever pressing for food but not the eating of free food. *Learning and Motivation*, *5*, 448–458.

Krane, R.V., & Wagner, A.R. (1975). Taste aversion learning with a delayed shock US: Implications for

the "Generality of the laws of learning". *Journal of Comparative and Physiological Psychology*, *88*, 882–889.

Miller, N.E., & Dollard, J. (1941). *Social learning and imitation*. New Haven, CT: Yale University Press.

Prewitt, E.P. (1967). Number of preconditioning trials in sensory preconditioning using CER training. *Journal of Comparative and Physiological Psychology*, *64*, 360–362.

Rescorla, R.A., & Freberg, L. (1978). The extinction of within-compound flavor associations. *Learning and Motivation*, *9*, 411–427.

Rizley, R.C., & Rescorla, R.A. (1972). Associations in second-order conditioning and sensory preconditioning. *Journal of Comparative and Physiological Psychology*, *81*, 1–11.

Siegel, S., & Domjan, M. (1971). Backward conditioning as an inhibitory procedure. *Learning and Motivation*, *2*, 1–11.

Urcuioli, P.J., Zentall, T.R., Jackson-Smith, P., & Steirn, J.N. (1989). Evidence for common coding in many-to-one matching: Retention, intertrial interference, and transfer. *Journal of Experimental Psychology: Animal Behavior Processes*, *15*, 264–273.

Ward-Robinson, J., & Hall, G. (1996). Backward sensory preconditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, *22*, 395–404.

Rôle de la médiation par le conditionnement dans l'équivalence acquise

Dans l'expérience 1, des rats sont soumis à un entraînement préalable, au cours duquel la délivrance d'une pastille de sucrose est signalée par un stimulus auditif. Dans une seconde phase, ce stimulus est associé avec un choc électrique. Au cours d'une phase ultérieure de test, les rats refusent d'effectuer une réponse instrumentale pour obtenir la pastille de sucrose. L'interprétation que nous donnons de ce résultat est que la représentation ainsi activée de la pastille a acquis des propriétés aversives au cours de la phase d'entraînement avec les chocs. Dans l'expérience 2, nous avons reproduit cet effet de médiation par le conditionnement. Pour ce faire, nous avons utilisé une procédure d'entraînement en Phase 1, calquée sur celle utilisée par Honey et Hall (1989) afin de démontrer l'équivalence acquise par des stimuli. Dans cette procédure, deux stimuli auditifs signalent chacun la délivrance de pastilles de sucrose. Un test ultérieur montre que cet entraînement produit une augmentation de la généralisation entre ces deux stimuli. Ceci suggère que cet effet est médié par les propriétés aversives conditionnées du dénominateur commun à ces deux stimuli auditifs.

El papel del condicionamiento mediado en la equivalencia adquirida

En el Experimento 1, unas ratas recibieron inicialmente un entrenamiento en el que una clave auditiva señalaba la administración de una bolita de sacarosa. En una segunda fase de entrenamiento, esta clave se emparejó con una descarga. En una prueba, las ratas mostraron una mala disposición a ejecutar una respuesta instrumental que daba lugar a la bolita de sacarosa. Esto se interpretó como indicativo de que la representación de la bolita activada asociativamente había adquirido propiedades aversivas durante la fase de entrenamiento con la descarga como reforzador. El Experimento 2 replicó este efecto de *condicionamiento*

mediado empleando un procedimiento de entrenamiento de Fase-1, siguiendo el modelo que usaron Honey y Hall (1989) para demostrar la equivalencia adquirida de las claves, en el que cada una de dos claves auditivas señalaba las bolitas de sacarosa. Una prueba posterior reveló que este entrenamiento dió como resultado un incremento de la generalización entre estas dos claves. Se argumenta que este efecto está mediado por las propiedades aversivas condicionadas del asociado común de las dos claves auditivas.