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Discrimination between outcomes in instrumental learning: Effects of preexposure to the reinforcers

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In two experiments rats received instrumental training with two response levers, one response being reinforced by sucrose solution and the other by sucrose pellets. Prior to a test session, on which both levers were made available in the absence of reinforcement, the rats were given free access to one of the reinforcers, a procedure known to reduce its value. It was found that the rats responded at a lower rate on the lever that had produced the now-devalued reinforcer, but that this effect was substantial only in rats that had received preexposure to the two reinforcers before instrumental training was begun (Experiment 1). Experiment 2 demonstrated that this effect was obtained only when presentations of the two reinforcers were presented according to an intermixed schedule during preexposure. It is suggested that this result constitutes an instance of the perceptual learning effect in which intermixed preexposure to similar events enhances their discriminability.

Under some conditions, preexposure to two similar events appears to increase the ease with which they can be discriminated. The effect has typically been demonstrated in experiments that make use of conditioning procedures and in which the critical events are used as conditioned stimuli (CSs). For example, Symonds and Hall (1995) gave preexposure consisting of alternating trials on which rats were allowed to consume sucrose and saline solutions. They then established one of these flavours as a CS by pairing it with nausea. The rats showed evidence of an enhanced ability to discriminate between the flavours in that the conditioned aversion governed by the CS generalized rather poorly to the other flavour (see also, e.g., Honey & Hall, 1989; Mackintosh, Kaye, & Bennett, 1991; Mondragón & Hall, 2002; Symonds & Hall, 1997). This result is consistent with the proposal (e.g., Gibson, 1969; Mondragón & Hall, 2002) that exposure to a pair of stimuli, especially when it is arranged so as to promote

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comparison between them, will increase their discriminability. To accept this interpretation implies that the effects of such preexposure should be evident in any training procedure in which a discrimination between the two similar events is required. The aim of the work reported here was to confirm the generality of the preexposure effect by employing a test of the discriminability of the preexposed events that did not involve training either of them as a CS. In order to do this we made use of a task in which the subjects discriminated between two events used as reinforcers in an instrumental learning procedure.

Several studies of the associative structure underlying instrumental learning have made use of a procedure in which rats were trained to make two different responses, each of which yielded a different type of food as the reinforcer. The rats were then given free access to one of these food types until they were no longer willing to consume it. When returned to the instrumental training situation the rats were found to perform the two responses at different rates, with the response that had previously been reinforced by the food that was presented in the satiation phase being less frequent than the other (e.g., Balleine & Dickinson, 1998; Colwill & Rescorla, 1985; Dickinson, Campos, Varga, & Balleine, 1996; see also Balleine, 1992). This result has been taken to support the general view that instrumental training will establish an association between the response and the reinforcer, such that posttraining devaluation of the reinforcer can influence the vigour of the response (e.g., Adams & Dickinson, 1981). It further shows that rather specific information about the nature of the reinforcer is encoded during this training. For animals to be able to show selectivity in responding on test they must be able to discriminate between the two reinforcers; that is, the reinforcer representations must include information about features of the two food types that distinguish one from another.

The central aim of the present experiments was to investigate the effects of preexposure to the reinforcers on the reinforcer-specific satiation effect. In the main experiments to be reported here, we gave rats alternating preexposure trials with the two substances that were subsequently to be used as reinforcers for different responses in instrumental training. We then devalued one of these reinforcers by giving free access to it. We hoped to show that the selective effect of this devaluation procedure on instrumental responding would be greater in animals given this form of preexposure, allowing the conclusion that the discriminability of the two reinforcers had been enhanced.

We conducted two preliminary experiments designed to guide the choice of appropriate substances to use as the reinforcers in the critical experiment. In choosing the reinforcers for these experiments it seemed sensible to find two that were intrinsically difficult to discriminate in order to increase the likelihood of seeing an enhancement after preexposure to them. Successful demonstrations of the of reinforcer-specific satiation effect have made use of reinforcers that differ in several respects: Dickinson et al. (1996), for example, used food pellets and a solution of maltodextrin—substances that differ in texture, flavour, and perhaps also in motivational value. But the effect has also been obtained with reinforcers that are much more similar; for example, Balleine and Dickinson (1998) successfully demonstrated the devaluation effect using as reinforcers two solutions of polycose that differed only in their taste, salt having been added to one and lemon juice to the other. Four our experiment we chose two reinforcers that differed only in “texture”, in that one was a solution of sucrose and the other a sucrose pellet. Our intuition was that discrimination on this basis might be rather difficult, and our first preliminary experiment confirmed this to be so. We gave rats instrumental training with two response levers, one of which yielded the sucrose solution and the other sucrose pellets. Before the test session, the rats were prefed one of these reinforcers and were then given access to both levers. No reinforcers were presented on the test. The rate of response on the lever associated with the prefed reinforcer was very little lower than that on the other lever; that is, by this measure the rats showed no evidence of being able to discriminate sucrose pellets from sucrose solution. In addition, in consumption tests given after prefeeding, the rats were only marginally less willing to consume the prefed form of sucrose than the other form.

Although our experimental plans require the use of two reinforcers that are difficult to discriminate, we were concerned, given the results of this pilot experiment, that the two we had chosen might be impossible for rats to discriminate under any circumstances. Accordingly, in a second preliminary study, we conducted a simple test using Pavlovian conditioning procedures to determine whether rats could form a discrimination between sucrose solution and sucrose pellets. In this experiment the two forms of sucrose were used as CSs in the flavour aversion procedure. For one group of rats (group P) consumption of pellets was followed by a nausea-inducing injection of lithium chloride (LiCl); for a second group (group S), consumption of the solution was followed by the injection. Both groups were then tested with both forms of sucrose. It was found that both groups consumed less of the type of sucrose with which they had been conditioned than of the other type. Furthermore, group P drank more of the solution than did group S; similarly, group S ate more of the pellets than did group P. We may conclude that, under these conditions of training, a change in the value of one type of sucrose did not generalize fully to the other type. Whether this will be true under other conditions of testing, and when the change in value is induced by satiation rather than aversive conditioning, remains to be seen. But the present results show that such a discrimination is, at least, possible.

EXPERIMENT 1

The aim of this experiment was to assess the effect of preexposure to sucrose pellets and sucrose solution on a task requiring discrimination between these two substances when used as reinforcers. Subjects in the preexposed condition (group Pre) received initial training consisting of several sessions in operant chambers during which both types of sucrose reinforcer were delivered. (Studies of the perceptual learning effect using CSs indicate that preexposure is most effective when the two events to be discriminated are presented in an intermixed fashion during preexposure.) Subjects in the control group (group NP, for non-preexposed) received minimal experience of the reinforcers—just enough to ensure that they would learn to retrieve the reinforcer from the food tray or dipper when it was made available. Both groups then received instrumental training in which responses on one lever were reinforced with sucrose solution, and responses on the other lever were reinforced with pellets. Training in this stage was restricted to the minimum capable of establishing the two responses—since all animals necessarily receive experience of the two reinforcers during such training, to give extensive training would have allowed subjects in group NP to become familiar with the two reinforcers, reducing the likelihood of our finding an effect of preexposure.

Prior to the test session, all the animals were prefed with one or other of the reinforcers. They were then given access to both response levers. No reinforcers were delivered in this session. On the basis of our pilot work we anticipated that, for group NP, the rate of response on the lever that had previously produced the now-devalued reinforcer would not be much lower than the rate on the other lever. The question of interest was whether group Pre would show a more substantial effect.

Method

Subjects

The subjects were 16 male hooded Lister rats (from Harlan-UK), about 12 weeks old at the start of the experiment and with a mean ad libitum weight of 338 g (range: 290–355 g). They were housed in pairs, with free access to water, and were maintained at 80% of their ad libitum weights by a schedule of controlled feeding. The colony room was lit from 8 a.m. to 8 p.m., and experimental procedures occurred during the light portion of the cycle.

Apparatus

Preexposure, instrumental training, and testing were carried out in a set of four operant chambers (Med Associates, Vermont, USA). These chambers measured 30 cm × 24 x cm × 21 cm and were housed in sound-attenuating shells. The ceiling and the two longest sides of the chambers were made from clear polycarbonate, and the front and back walls were of stainless steel. The front wall of the box contained two retractable response levers, 11.5 cm apart, centre to centre. These levers were withdrawn during the preexposure phase of the experiment. Midway between the two levers was an aperture, 5 cm by 5 cm, that gave access to a food tray to which 45-mg Noyes sucrose pellets could be delivered, and, alongside the tray, was a liquid dipper with a cup capacity of .02 ml used to present sucrose solution (20% w/v). Illumination was provided by a 28-V 100-mA house light fitted high on the rear wall of the chamber.

Prefeeding prior to test sessions was carried out in a separate small room, different from the colony room and adjacent to that housing the operant chambers. This contained a rack of small cages (25 × 35 × 18 cm), made of white translucent plastic and with a wire mesh lid through which the spout of a drinking bottle could be inserted. Sucrose solution was presented in a 50-ml plastic centrifuge tube fitted with a stainless-steel, ball-bearing-tipped spout. Sucrose pellets were presented in a round glass dish, 4 cm deep and 10 cm in diameter.

Procedure

The rats were assigned at random to one of two equal-sized groups: group Pre, which received preexposure to the two forms of sucrose, and group NP, which received only minimal magazine training with the reinforcers. In preexposure, group Pre received six daily sessions during which 60 reinforcer presentations occurred according to a random time (RT) 20-s schedule, giving a session duration of approximately 20 min. Whether a given reinforcer was a pellet or sucrose solution was determined at random apart from the constraint that every session contained 30 of each. On each of the two final days of this phase, group NP received a 10-min session in which reinforcers were delivered according to an RT 60-s schedule. Half of the subjects received sucrose solution on the first of these sessions and pellets on the second; for the others this arrangement was reversed.

All subjects then received three daily 30-min sessions of lever-press training. On the first two of these sessions, a single lever was available, either the left then the right lever or vice versa, and the first 30 responses were reinforced according to a schedule of continuous reinforcement. The lever was then withdrawn from the chamber. For half the animals in each group, pressing the left lever led to the delivery of sucrose solution, and pressing the right led to a sucrose pellet, while for the remainder the reverse was true. On the third session, both levers were present and the appropriate reinforcers were delivered according to independent RI 20-s schedules.

The first test session occurred on the following day. Two hours prior to this session, all animals were transferred to the consumption cages where half of each group were given access to dishes containing 80 g of sucrose pellets, and half were given access to drinking tubes containing 40 ml of the sucrose solution. They were then transferred to the operant chambers for a 30-min session in which both levers were available. No reinforcers were delivered in this session. On the following day all received an instrumental retraining session with both levers present and reinforced, the procedure used being the same as that used on the third session of the initial lever-press training phase. This was followed, on the next day, by a further test session, identical to the first.

Results and discussion

No data were recorded during the preexposure phase. The instrumental training procedure was successful in establishing responding to the two levers in both groups, although group Pre responded at a higher rate than group NP. Almost all animals in both groups responded more readily for pellets than for the solution. The mean rates of response for group Pre during the third session of initial training were 10.28 responses per min (rpm) on the lever that yielded pellets, and 6.95 rpm on the lever that yielded sucrose solution. The equivalent scores for group NP were 6.62 rpm and 4.67 rpm. An analysis of variance confirmed there to be significant main effects both of group, $F(1, 14) = 8.91$, and of reinforcer-type, $F(1,14) = 16.85$. The interaction was not significant, $F(1, 14) = 1.15$.

During the prefeeding session prior to the first test session, the animals readily consumed the substance offered. The amount of sucrose solution consumed was consistently greater than the number of pellets, but there were no differences between the groups. The subjects in group Pre given access to pellets consumed a mean of 7.83 g; those given access to the solution consumed 19.59 g. The equivalent scores for group NP were 9.07 g and 19.02 g. An analysis of variance with type of sucrose reinforcer and group as the variables revealed only a significant effect of the former, $F(12, 12) = 49.5$ 1; other *F*s < 1. Levels of consumption were similar on the prefeeding session that preceded the second test session, but unfortunately an error on the part of experimenter resulted in the data being lost for this session.

The results of central interest come from the postsatiation test sessions. Figure 1 shows, for each group, the mean totals for responses made, in each session, on the lever associated with the devalued reinforcer and on the lever associated with the other reinforcer. These means are collapsed over the identity of the lever (left or right) and the nature of the devalued reinforcer (pellets or solution). As might be expected, on the basis of the response rates shown in the last session of instrumental acquisition, group Pre responded at a higher rate than group NP on Test 1. On Test 2, for which overall rates were lower, the difference between the groups was reduced, but was still present. On both tests, although more dramatically on the second, group Pre showed a discrimination between the two levers, responding less on that associated with the devalued reinforcer. Group NP responded at much the same rate on both levers.

Statistical analysis confirmed this description of the results. The response rates presented in the figure were subjected to a logarithmic transformation prior to an analysis of variance in which the variables were group (Pre or NP), session, and reinforcer type (valued or devalued). There was a significant main effect of group, $F(1, 14) = 5.63$ (here and elsewhere a rejection criterion of $p < .05$ was adopted), but not of session, $F(1, 14) = 2.38$, or of reinforcer value, $F(1, 14) = 2.33$. The interaction between group and reinforcer value was not significant, $F(1, 14) = 1.37$, nor was the interaction between group and session, $F(1, 14) = 2.03$. However, the

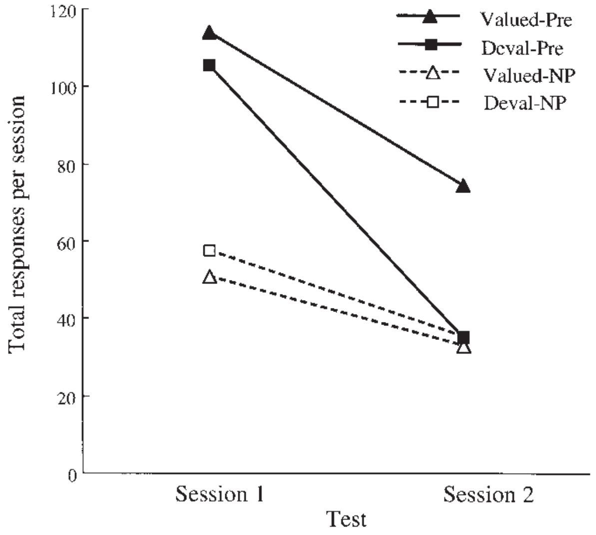

Figure 1. Experiment 1: Group mean response totals for the test sessions. Of the two levers available one had previously yielded a reinforcer that was still of value at the time of test; the other had yielded a reinforcer that had been devalued by prefeeding. Group Pre had been preexposed to the two reinforcers in an initial stage of training; group NP received no preexposure.

interaction between session and reinforcer value was significant, $F(1, 14) = 4.89$, as was the interaction between group, session, and reinforcer value, $F(1, 14) = 10.65$. In order to explore the source of this triple interaction, the data for the two groups were subjected to separate analyses. That for group NP revealed no significant effects (all Fs < 1). For group Pre the main effects of the session, $F(1, 7) = 4.39$, and of reinforcer value, $F(1, 7) = 4.31$, fell short of significance, but there was a significant interaction between these variables, $F(1, 7) = 12.16$. Analysis of simple main effects showed no significant effect of reinforcer value on the first test ($F < 1$), but a significant difference on the second test, $F(1, 7) = 12.94$.

It is worth noting that the selective effect of satiation (for group Pre) was substantially greater on the second test than on the first. This may simply reflect the fact that the second test session was given after an instrumental retraining session that allowed the animals further experience of intermixed presentations of the two reinforcers. The hypothesis being investigated holds that this experience should enhance the discriminability of the reinforcers (although it might be expected that this treatment would produce an effect in group NP also). Another possibility is prompted by the suggestion, made by Balleine and Dickinson (1998), that satiation on a given type of food not only devalues that food but also, by way of some contrast process, enhances the value of different foods that are encountered subsequently. In our procedure, all the rats, having been prefed one type of sucrose before the first test session, encountered the other type in the instrumental retraining session given on the following day. If the contrast mechanism postulated by Balleine and Dickinson operates in these circumstances, then performance on a second test session, given after prefeeding on the original type of sucrose, might be expected to show the effects both of the devaluation of the prefed sucrose and also of the enhanced value of the other type. Such an effect would only be possible, of course, in animals that were capable of discriminating the two types and thus, according to the hypothesis under investigation here, would not be expected in group NP.

The results shown in Figure 1 are what would be expected if preexposure to the two forms of sucrose facilitated discrimination between them. It is unfortunate, however, that the critical comparison supporting this conclusion must be made between groups that differ substantially in their absolute levels of responding. This leaves open the possibility that the results we take to be of prime interest might in fact be an artifact of our measurement procedure—it is possible that both groups are sensitive to the selective satiation procedure but that the effect is evident in behaviour only when relatively high rates of responding are occurring. Inspection of the figure does nothing to encourage this interpretation. It shows no sign of the selective satiation effect in group NP, and indeed this group responded at a somewhat higher rate on the lever associated with the devalued reinforcer than on the other lever. Nonetheless we thought it worthwhile to conduct a further experiment using a modified preexposure procedure designed to rule out this possible artifact.

EXPERIMENT 2

In studies of the effects of preexposure to events that are subsequently used as CSs, comparison has often been made, not between preexposed and nonpreexposed groups (as in Experiment 1), but between groups given different schedules of preexposure. In the experiments reported by Mondragón and Hall (2002), for example, all rats were given two sessions each day during preexposure during which they experienced the flavour stimuli subsequently used in the test phase. For group I (for intermixed) the flavours were presented in alternation, one in the morning session and one in the afternoon. Group B (for blocked), on the other hand, received a block of trials with one of the flavours followed by a block of trials with the other. It was found that an aversion conditioned to one of these flavours generalized less readily to the other in group I than in group B, supporting the proposal that the mechanism responsible for the perceptual learning effect operates more effectively when the relevant stimuli are experienced in alternation during preexposure. In the present experiment we made use of this comparison between intermixed and blocked preexposure procedures in a study of perceptual learning about USs.

The present experiment was modelled closely on Experiment 1, differing chiefly in the arrangement of the preexposure phase. During this phase, all animals received two sessions per day. For group I, sucrose pellets were presented in one of these sessions and sucrose solution in the other. Group B received a block of sessions with one reinforcer type followed by a block of sessions with the other. We hoped to find a selective effect of reinforcer devaluation in the instrumental test procedure in group I but not in group B. The use of the blocked procedure as a control condition is in general superior to the nonpreexposure condition of Experiment 1 as it ensures that the two groups being compared are equated in their experience of the reinforcers prior to instrumental training and testing. And specifically, we expected that it would result in a rate of responding on the test that would be comparable to that shown by group I. The relatively high rate shown by group Pre of Experiment 1 is likely to be a consequence of the fact that instrumental responding is more vigorous in a context that is well associated with reinforcement (group Pre had six sessions of preexposure in which reinforcers were presented in the context, whereas group NP was exposed to the context alone). The preexposure arrangement used in the present experiment ensures that groups I and B will have had equivalent experience of presentations of the two sucrose reinforcers in the training context.

Method

Subjects and apparatus

The subjects were 16 naive male hooded Lister rats with a mean ad lib weight of 330 g (range 300–355 g). The apparatus was the same as that described for Experiment 1.

Procedure

The rats were assigned at random to one of two equal-sized groups, which differed only in the treatment they received during the preexposure phase. During this phase, which lasted 4 days, group I received eight 40-min sessions, one each morning and one each afternoon. A total of 40 reinforcers were delivered in each session according to an RT 60-s schedule. The reinforcer presented (pellets or sucrose solution), alternated across sessions. For half the animals in this group this alternating sequence began with the presentation of pellets; for the remainder it began with presentation of the solution. Group B was treated identically except that one type of reinforcer was presented during the first block of four sessions and the other type during the second block of four sessions. Half the animals in group B received pellets during the first block and the solution during the second; for the remainder, this arrangement was reversed.

On the first of the three daily sessions of lever-press training, one lever was made available, and the rats were permitted to earn 30 reinforcers on a random ratio (RR) 3 schedule. For half the animals in each group this was the left lever, and for half it was the right lever; for half of these subgroups the reinforcer was pellets, and for half it was the solution. Session 2 was identical except that the other lever was present, and the other reinforcer was available. On Session 3, both levers were presented, and the rat earned 15 reinforcers of the appropriate type on each according to independent RR 5 schedules. The use of a ratio schedule in this experiment (an interval schedule was used in Experiment 1) was prompted by the suggestion (e.g., Dickinson, 1989) that instrumental responses trained in this way are more likely to show sensitivity to the effects of reinforcer devaluation.

Prior to the first test session half the animals in each group were given access to sucrose solution for 2 hr, and half were given access to pellets, as in Experiment 1. They were then given access to both levers without reinforcement in the operant chambers for 30 min. On the next day all received an instrumental retraining session, the procedure used being that described for Session 3 of initial lever-press training. On the following day they received a further test session, identical to the first except that prefeeding was given with the food type that was not presented prior to the first test.

Results and discussion

No data were recorded during the preexposure phase. Instrumental training successfully established responding on both levers. As in Experiment 1, there was evidence to suggest that pellets were more effective as a reinforcer than the sucrose solution. On Session 3 of lever-press training, when reinforcers were available on both levers, six of the eight rats in group B and all of the rats in group I completed the responding required on the pellet-reinforced lever before completing that required on the solution-reinforced lever.

During the prefeeding session that preceded the first test session, the subgroup of group B given pellets consumed 7.71 g; that given the solution consumed 20.16 g. The equivalent scores for group I were 8.62 g and 18.68 g. Thus the consumption of solution was greater than that of pellets, but there was no difference between the two groups. An analysis of variance showed there to be a significant difference in the scores for pellets and solution, *F*(1, 12) = 48.79, but no difference between the groups, and no significant interaction (*F*s < 1). The results for the second prefeeding session were closely similar: 8.58 g of pellets and 23.82 g of solution for group B; 10.39 g of pellets and 23.50 g of solution for group I. Again the difference between the two reinforcer types was significant, *F*(1, 12) = 192.63, but there was no significant difference between the groups (*F* < 1) and no significant interaction *F*(1, 12) = 2.09.

The critical results from the postsatiation test sessions are presented in Figure 2, which shows, for each session, group mean total responses on the lever associated with the devalued reinforcer and on the lever associated with the valued reinforcer. The results for group I match those of group Pre in Experiment 1. These animals showed a robust discrimination between the two levers, responding less on that associated with the devalued reinforcer, particularly on the second test session. Group B responded equally readily on both levers on Test 1; there was some sign, in the mean scores, of a preference for the valued lever on the second test session, but the effect was smaller than that seen in group I. The overall response rate in group B was closely similar to that shown by group I, being somewhat less than that shown by group I on the valued lever but rather higher than that shown by group I on the devalued lever. This is the pattern one would expect in animals that were unable to discriminate well between the two reinforcers.

Statistical analysis performed on log-transformed scores largely supported this description of the results. An analysis of variance, in which the variables were group (B or I), test session, and reinforcer type (valued or devalued), showed there to be no significant main effect of

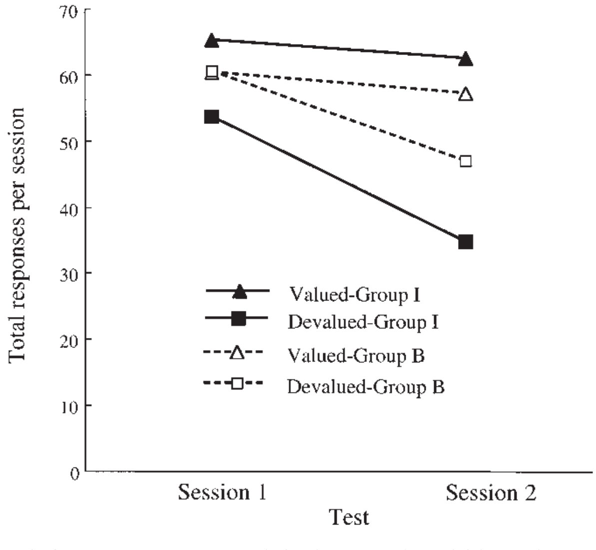

Figure 2. Experiment 2: Group mean response totals for the test sessions. Of the two levers available one had previously been yielded a reinforcer that was still of value at the time of test; the other had yielded a reinforcer that had been devalued by prefeeding. Group I had been preexposed to intermixed presentations of the two reinforcers in an initial stage of training; Group B received preexposure in which the two reinforcers were presented in separate blocks of sessions.

group ($F < 1$) or of session, $F(1, 14) = 2.70$. The main effect of reinforcer value approached significance, $F(1, 14) = 3.59$, $p < .1$. The interactions of group and session ($F < 1$) and of session and reinforcer value, $F(1, 14) = 1.39$, were not significant, nor was the triple interaction ($F < 1$). However, the interaction of group and reinforcer value approached the conventional level of significance, $F(1, 14) = 3.65$, $p < .08$. This interaction was explored by means of an analysis of simple effects. This revealed no significant effect of reinforcer value in group B ($F < 1$) but a significant effect in group I, $F(1, 14) = 7.25$.

Although the effect was not detected by this analysis, inspection of the details of the performance of individual animals showed that, as in Experiment 1, the difference between the groups was more substantial on the second test session than on the first. On Test 1, five of the eight subjects in group I had lower response rates on the lever associated with the devalued reinforcer than on the other lever; in group B, only two animals showed this pattern. A 2 × 2 analysis using Fisher's exact probability test revealed no significant difference. On Test 2, the performance of group B was little altered, with three animals of the eight animals having lower rates on the devalued lever. In group I, however, seven of the eight animals had a lower rate on the devalued lever (the remaining subject responding equally on both). Fisher's test showed there to be a significant difference on Test 2 ($p = .02$). Follow-up analyses using Wilcoxon's test showed no difference between the scores for the two levers in group B, $T(8) = 16.50$, but a significant difference between these scores for group I, $T(7) = 0$.

These results are consistent with those of Experiment 1 in showing that prior exposure to intermixed presentations of the two similar reinforcers is necessary for animals to show selective performance on a task that requires discrimination between them. In this experiment the control group, which was also given prior exposure to the reinforcers (but presented in separate blocks of sessions), responded at a relatively high rate on the test, presumably because the general level of responding in this situation is partly determined by an association between the experimental context and food. This outcome demonstrates that the effect seen in Experiment 1 was not simply an artifact of the low rate of response shown by the nonpreexposed control group in that experiment. It also confirms, for this test procedure, the importance of giving intermixed presentations of the events to be discriminated, a result amply demonstrated in studies of perceptual learning in which the critical events are CSs rather than USs (e.g., Symonds & Hall, 1995; Mondragón & Hall, 2002).

GENERAL DISCUSSION

Previous experiments have shown that rats trained to perform two different instrumental responses for two different reinforcers will show a reinforcer-specific satiety effect—prefeeding on one of the reinforcers will selectively reduce the rate of occurrence of the instrumental response that previously produced that reinforcer (with respect to the rate of occurrence of the other response). We have investigated this effect using reinforcers chosen to be very similar—sucrose pellets and sucrose solution. A reliable effect was obtained only in rats that were given extensive, intermixed, preexposure to the two types of sucrose that were to be used as reinforcers in instrumental training. This result is consistent with the proposal that preexposure, of the sort given here, enhances the discriminability of the preexposed events and confirms that the effect is not confined to the case in which the preexposed stimuli are used as CSs in a subsequent conditioning procedure.

We now turn to the implications of our results for interpretation of the mechanisms by which preexposure has its effects. Can theories that have been developed primarily on the basis of experiments in which the preexposed events are used as CSs be successfully applied to the present case?

The differentiation account of perceptual learning is comfortable with the results reported here. This account (Gibson, 1969; see also Mondragón & Hall, 2002) supposes that exposure to intermixed presentations of two similar stimuli will reduce the perceptual effectiveness of their common features and enhance that of their unique features. Two similar stimuli may be represented as being compounds, AX and BX, where X stands for features they hold in common (e.g., the sweet taste of the two forms of sucrose used in these experiments), and A and B stand for the unique features of the stimuli (e.g., fluid or solid, in this case). With appropriate preexposure the animal's ability to perceive X declines, and the unique feature of the event (i.e., A or B) dominates perception. Reduced generalization when the preexposed events are used as CSs follows readily from this analysis—conditioning with AX as the CS will establish a conditioned response only to the perceived element of the stimulus (i.e., to A), and there will be no basis for generalization to BX.

It will be apparent that these same processes will also play a role when the events are used as reinforcers in instrumental learning. In this training procedure the animal acquires an association between a response and its outcome. Again the animal will be able to learn only about those features of the events that are perceived. Nonpreexposed subjects will therefore form associations between one response and AX and the other response and BX; that is, the common features of the two forms of sucrose will be involved in both associations. Preexposed subjects, on the other hand, will (in the limiting case) form associations involving only A and B. There is room for discussion about the process by which the prefeeding manipulation has its effects (see below), but, under any interpretation, a selective effect is more likely when the animal can clearly discriminate between the two forms of reinforcer associated with the two responses. Accordingly, we may expect that the selective effect of prefeeding would be more powerful in animals given preexposure to the reinforcers.

The associative theory of perceptual learning proposed by McLaren and Mackintosh (2000; see also McLaren, Kaye, & Mackintosh, 1989), in its treatment of the role of latent inhibition, has something in common with differentiation theory. McLaren et al. have pointed out that latent inhibition can be expected to occur during preexposure to AX and BX. Although this will reduce the associability of all the various stimulus elements, the loss of associability suffered by the X element will be greater than that suffered by either of the unique elements—X is presented on all preexposure trials; A and B are each presented only half as often. Thus, like differentiation theory, this account allows that preexposure to AX and BX will have a special impact on the status of the common X element. The effect is not, however, on the general perceptual effectiveness of X (as the differentiation theory supposes), but on its level of associability.

The notion that preexposure has its effects primarily by way of latent inhibition can readily explain the enhancement of discrimination observed when the preexposed events are used as CSs. When animals receive conditioning with AX as the CS after such preexposure, the low associability of X will mean that associative strength will accrue mostly to the A element of the compound. Accordingly, generalization to BX, which depends on the strength acquired by X, will be restricted. It applies less readily, however, to the present results in which the preexposed events are used as reinforcers. On the face of things the associability of these events (i.e., the readiness with which they can come to function as CSs) will be irrelevant in this procedure.

The argument just advanced depends on the assumption that with the procedure used here, the rats displayed an ability to discriminate between the two reinforcers in a situation that did not involve the acquisition of associative strength by either of them (and was thus independent of any effects on associability that may have been produced by prior exposure to the events to be used as reinforcers). This assumption may, however, be open to question. According to some authors (e.g., Balleine, 1992; Balleine & Dickinson, 1998; Dickinson & Balleine, 1994) prefeeding may change the value of a reinforcer by a process of "incentive learning" in which experience of the state of satiation in the presence of certain sensory cues (e.g., the taste or texture of the reinforcer) causes the animal to assign a low incentive value to those cues. Balleine (2001) characterizes this form of learning as involving the formation of an association between the sensory properties of the reinforcer and the emotional feedback cues that derive from the change in the biological state of the animal produced by feeding to satiation. If we accept this analysis, it becomes possible to provide an account of the results of Experiment 1 in terms of latent inhibition. The animals not given preexposure might learn, during the prefeeding episode, about a feature of the reinforcer (its sweet taste) that is common to both forms of sucrose, in which case the prefeeding could not be expected to have a selective effect on instrumental responding. For preexposed animals, on the other hand, this feature, being common to the two reinforcers, will have suffered extensive latent inhibition during preexposure. These animals might, therefore, learn preferentially during prefeeding about a unique feature of the reinforcer (such as its texture), allowing a selective effect on test to be observed.

It may be noted, however, that although Balleine (2001) refers to the formation of an association with reference to incentive learning, he goes on to admit that the form of learning involved is not truly analogous to the predictive learning that occurs when a CS, by virtue of its association with a consequence, comes to signal the likely occurrence of that consequence. To the extent that latent inhibition refers to a property acquired by CSs in this latter form of learning, there is no reason to suppose that it necessarily exerts an influence in incentive learning. Interpretation of the results of Experiment 1 thus remains ambiguous. They are readily accommodated by the proposal that preexposure changes the perceptual effectiveness of the common and unique features of the preexposed stimuli by a mechanism that is independent of latent inhibition; alternatively they may indicate that the latent inhibition process plays a role in incentive learning just as it does in more orthodox forms of conditioning. There is less ambiguity, however, about the results of Experiment 2. In the first phase of this experiment, all animals were preexposed to both reinforcers, the two groups differing only in that one received intermixed and the other blocked presentations of the two types of sucrose. There is no reason to think the schedule of presentation will influence the development of latent inhibition; accordingly, if latent inhibition does influence incentive learning, it will do so to the same extent in the two groups and cannot be responsible for the difference between them observed in the test.

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