VARIATIONS IN THE SENSITIVITY OF INSTRUMENTAL RESPONDING TO REINFORCER DEVALUATION

CHRISTOPHER D. ADAMS

Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, England

In five experiments hungry rats were trained to make a lever press response for a sucrose reinforcer. That sucrose was subsequently devalued by conditioning a food-aversion to it, and the ability of the rats to integrate knowledge about the instrumental contingency with that gained from aversion training was assessed in an extinction test. Experiment I showed successful integration following limited but not extended instrumental training. Experiment II suggested that the crucial factor was the spacing of training; successful integration was seen after massed but not distributed training. The third experiment implicated distributed experience with the reinforcer, rather than distributed response practice, in failures of integration. Experiment IV showed that if the distribution of food-aversion learning was dissimilar to that of instrumental training then a failure of integration could result; this finding was able to account for the distribution of training effects seen in previous studies, but not the effect of extended training. Experiment V replicated the extended training effect seen in Experiment I, and provided evidence that this may reflect the degree of exposure to the reinforcer rather than the extent of response practice.

Introduction

Over the past few years a number of papers have reported experiments examining the effects on instrumental responding of post-conditioning manipulations of the value of the reinforcer. The aim of these studies (Adams and Dickinson, 1981*b*; Rozeboom, 1958) has generally been to elucidate the nature of the associative structure set up by an instrumental conditioning procedure. In an attempt to determine whether this structure involves a representation of the reinforcer, studies have investigated whether or not changes in the value of the reinforcer can lead to changes in instrumental behaviour, without further experience with a reinforcement contingency. Typically, these studies have established an instrumental response, such as maze running or lever pressing, reinforced with food. The value or significance of the reinforcer is then modified in some way, and the capacity of the animal to integrate the knowledge acquired during the instrumental conditioning experience with the changed value of the goal is assessed in a nonreinforced extinction test. Thus successful integration, indicated by an appropriate change in responding during the extinction test, may be taken as evidence that the asso-

ciative structure established during instrumental conditioning does encode information about the reinforcer.

A number of early studies, in the absence of a potent means of devaluing the primary reinforcer, manipulated the value of stimuli correlated with the reinforcer, such as goal box stimuli. Following such manipulations, changes in instrumental behaviour have been observed in some experiments (Miller, 1935; Tolman and Gleitman, 1949), but not in others (Rozeboom, 1957; Tolman, 1933). In recent years techniques which directly manipulate the value of the primary reinforcer have been developed, notably food-aversion conditioning to the reinforcer. Using this technique, some studies have reported successful integration of the representational structure established during instrumental training with the changed reinforcer value (Adams and Dickinson, 1981a; Chen and Amsel, 1980), whereas in other experiments responding appeared to be independent, or autonomous, of the current value of the reinforcer (Adams, 1980; Chen and Amsel, 1980; Holman, 1975; Morrison and Collyer, 1974; Wilson, Sherman and Holman, 1981).

An attempt to analyse these diverse outcomes suggests that a multitude of factors are of importance in determining the sensitivity to reinforcer devaluation. Chen and Amsel (1980) found that instrumental behaviour is autonomous of changes in the significance of the goal following partial reinforcement, but not following consistent reinforcement. Similarly, Adams (1980), Holman (1975), Morrison and Collyer (1974) and Wilson et al. (1981) have found that food-aversion induced devaluation of the reinforcer failed to affect lever pressing reinforced according to a variable interval (VI) schedule. It is clear, however, that successful integration can occur following partially reinforced training. Adams and Dickinson (1981a) observed that illness induced reinforcer devaluation depressed subsequent instrumental responding following reinforcement on a variable ratio (VR) schedule. The purpose of the present study was to investigate some of the factors that determine the susceptibility of instrumental performance to reinforcer devaluation brought about by establishing a lithium chloride (LiCl) induced aversion to the reinforcer.

Experiment I

In addition to the nature of the reinforcement schedule under which the response is established, a traditional view (Kimble and Perlmuter, 1970) is that behavioural autonomy may result from extended practice of the response. Consequently, the first experiment investigated the effects of two different levels of instrumental training, and to maintain control over the number of responses and reinforcers, used a continuous reinforcement (CRF) schedule for all groups. Two groups of hungry rats were magazine trained, and then required to make a limited number of lever press responses, each of which was reinforced (Groups 100-P and 100-U). A further two groups were given extended reinforced lever press training, following magazine training (Groups 500-P and 500-U). Adams (1980) established that a food-aversion to the reinforcer conditioned in the operant chamber was effective in attenuating the rewarding properties of the reinforcer. Consequently, following instrumental training, the reinforcer was devalued for half the animals (Groups 500-P and 100-P), by pairing its consumption in the operant chamber with

LiCl-induced illness. The value of the reinforcer was maintained for the other animals in the unpaired condition (Groups 500-U and 100-U). After aversion training, the animals were given an integration test, in which the level of responding in extinction was measured. If the animals can integrate knowledge about the instrumental contingency with that gained from aversion training, we should expect to observe less responding during the integration test in the paired than in the unpaired condition. Furthermore, this difference would be smaller in the extended training condition if such training decreases sensitivity to reinforcer devaluation. Finally, the effectiveness of aversion training in devaluing the reinforcer for the paired groups was assessed by measuring reacquisition of responding after reinstating the CRF schedule.

Method

Subjects

The subjects were 48 naive male hooded Lister rats with a mean free-feeding weight of 363 g (range: 320 to 420 g). Before training they are reduced to 80% of their free-feeding weights and were maintained at this level by being fed a restricted amount of food after each daily session.

Apparatus

The subjects were tested in squads of four in four operant chambers ($25 \times 20 \times 20$ cm). The walls and roof were constructed from aluminium, except for one Perspex side-wall. The floors were composed from 0·5 cm stainless steel rods spaced 1 cm apart. The operant chambers were enclosed within a sound attenuating chest; masking noise was provided by a ventilator fan.

A Campden Instruments retractable rat lever was mounted on one wall of each operant chamber adjacent to a recessed food magazine covered by a hinged panel. Forty-five-milligramme Noyes sucrose pellets could be delivered into each of the magazines. Illumination was provided by a 3 W bulb mounted in the centre of the roof of each chamber.

Procedure

At the start of the experiment the subjects were randomly assigned to the four groups. On the first day of baseline training the levers remained retracted and single sucrose pellets were delivered on a variable time (VT) 60 s schedule throughout the 30-min session. The subsequent sessions started with the insertion of the lever and ended with its withdrawal. In the second session each of 50 lever press responses were reinforced by a single sucrose pellet. The subjects in Groups 500-P and 500-U then received an additional nine daily sessions in each of which 50 lever press responses were consistently reinforced. Subjects in Groups 100-P and 100-U received only one further session of instrumental training. During this session each of 50 responses was reinforced. Groups 100-P and 100-U began their instrumental training on the ninth day of training for Groups 500-P and 500-U, so that all subjects completed baseline training on the same day.

Food-aversion training was carried out in the operant chambers with the levers retracted over a number of 2 day cycles. On the first day of each cycle Groups 500-P and 100-P were allowed 15 min access to 50 sucrose pellets which had been placed in the magazine,prior to being given an intraperitoneal (i.p.) injection of 13 ml/kg body weight 0·15 M LiCl and returned to their home cages. Their consumption was determined by counting the number of uneaten pellets. Animals in Groups 500-U and 100-U were placed in the operant chamber for 15 min without any sucrose pellets prior to receiving an identical LiCl injection. On the second day of each cycle subjects in Groups 500-U and 100-U were allowed 15 min access to the number of sucrose pellets consumed on the previous day by a randomly matched subject from the appropriate paired group. They were then given an i.p. injection

of 13 ml/kg body weight 0·15 M saline. Groups 500–P and 100–P were simply placed in the operant chamber for 15 min without any sucrose pellets prior to receiving a saline injection.

Food-aversion training was continued until all animals in the paired groups evidenced complete, or almost complete suppression of sucrose pellet consumption. For animals in Group 500–P this entailed five 2 day cycles of food-aversion training, whereas those in Group 100–P needed only three 2 day cycles.

Twenty-four hours after the last session of food-aversion training all subjects were given a single 20 min extinction test, in which lever presses did not operate the pellet dispenser. On the next day, re-acquisition of lever pressing for sucrose pellets was tested in a 10 min session in which each lever press was reinforced. The extinction and re-acquisition tests started and terminated with the insertion and withdrawal of the lever. During the re-acquisition test responses were recorded in 5 min blocks, and in addition, the number of sucrose pellets earned and the number consumed by each subject was determined.

Results

In this and all subsequent experiments, the absolute and relative response rate scores were subjected to a square root transformation to increase the homogeneity of the variance factor prior to statistical analysis. These data were initially analysed by an analysis of variance with the factors representing the different instrumental training conditions (training) and the two food-aversion conditioning treatments (devaluation). Significant interactions between these factors were evaluated by planned comparisons between the scores of the paired and unpaired groups within each instrumental training condition. One subject in Group 100–U died, and the results are based on the remaining 11 rats in this group.

In the last session of baseline training the mean lever press response rates for Groups 500–P, 500–U, 100–P and 100–U were 10·5, 12·2, 7·5 and 7·0 responses per minute respectively. Analysis of variance revealed a significant effect of the training factor $(F_{(1,43)}=29\cdot60, P<0\cdot01)$, but there was no main effect of devaluation $(F<1)$, and no significant Training×Devaluation interaction $(F_{(1,43)}=1\cdot79, P>0\cdot05)$. Thus, after baseline training, the paired and unpaired groups at each training level did not differ.

Sucrose consumption declined steadily for Groups 500–P and 100–P during the food-aversion training. During their fifth conditioning trial no animal in Group 500–P ate any sucrose pellets, whereas all subjects in Group 500–U continued to eat all the sucrose pellets. In their third conditioning trial, animals in Group 100–P ate a mean of 3% of the sucrose pellets. All subjects in Group 100–U continued to eat all available sucrose throughout this stage. That animals in Group 500–P required five sucrose–LiCl pairings to completely suppress sucrose pellet consumption, whereas Group 100–P needed only three such pairings, probably reflects the greater exposure to the reinforcer experienced by Group 500–P during baseline training.

In order to minimise the effects of individual differences in baseline response rates within groups, the extinction and reacquisition scores for each subject were expressed as a ratio of that subject's response rate on the last day of baseline training.

The mean extinction ratio scores for each group are presented in Figure 1. Animals in the low training condition, averted from the reinforcer, Group 100–P,

showed considerably less responding in extinction than the corresponding unpaired condition, Group 100–U; thus, in contrast to most previous studies of the effect of reinforcer devaluation on free-operant responding, this experiment provides a clear demonstration that instrumental lever pressing can be sensitive to post-conditioning devaluation of the reinforcer. By contrast, there was no evidence of integration for the extended training condition; if anything, Group 500–P responded more in extinction than Group 500–U.
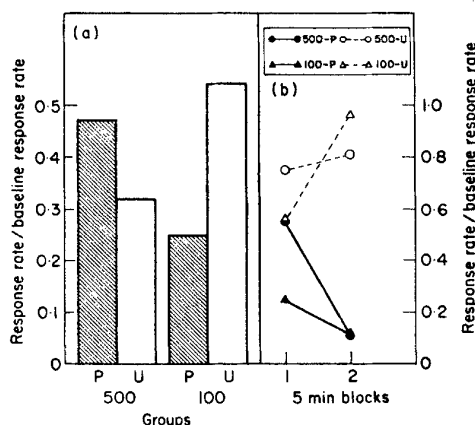

FIGURE 1. Mean relative response rates during the extinction test (a) and the re-acquisition test (b) (in 5 min blocks) of all groups in Experiment I.

An analysis of variance with training and devaluation as factors, supports this observation. The effects of training ($F<1$) and devaluation ($F(1,43)=1\cdot61$, $P>0\cdot05$) were not significant, but the Training$\times$Devaluation interaction ($F(1,43)=11\cdot63$, $P<0\cdot01$) was highly significant. Individual comparisons revealed a significant difference between Groups 100–P and 100–U ($t(43)=3\cdot30$, $P<0\cdot05$), but no difference between Groups 500–P and 500–U ($t(43)=1\cdot51$, $P>0\cdot05$).

The reacquisition scores are illustrated in Figure 1. For both Groups 500–P and 100–P reinstatement of the CRF schedule failed to maintain responding, whereas Groups 500–U and 100–U rapidly recovered their baseline response rates. This is reflected by a main effect of devaluation ($F(1,43)=95\cdot62$, $P<0\cdot01$) and a significant Devaluation $\times$ Block interaction ($F(1,43)=37\cdot72$, $P<0\cdot01$). By contrast with the extinction test, the devaluation factor affected animals in each of the instrumental training conditions similarly, and there was no Training $\times$ Devaluation interaction ($F(1,43)=1\cdot56$, $P>0\cdot05$). Group 500–P responded more than Group 100–P during the first block of the reacquisition test, but as both these groups showed negligible responding during the second 5 min block this probably reflects carry over from the extinction test, and accounts for the significant Training$\times$ Block interaction ($F(1,43)=12\cdot29$, $P<0\cdot01$). The main effects of training and block were not significant ($F(1,43)<3\cdot99$, $P>0\cdot05$ in each case).

During the reacquisition session none of the animals in Groups 500–P and 100–P

ate any sucrose pellets, whereas every subject in Groups 500–U and 100–U consumed all sucrose earned.

Discussion

The results of Experiment I suggest that the sensitivity of instrumental performance to food-aversion induced devaluation of the reinforcer can be attenuated by extended instrumental training. Thus, after 100 consistently reinforced responses, devaluation of the reinforcer was reflected by a reduction in responding during the integration test, whereas after 500 reinforced responses performance was unaffected by reinforcer devaluation. This is true despite the evidence from the reacquisition test that the devalued reinforcer was as ineffective in sustaining responding for Group 500–P as for Group 100–P.

Although one of the aims of the first experiment was to investigate the effect of extended training on the sensitivity of instrumental responding to reinforcer devaluation, and despite the finding that a high level of training appeared to result in behavioural autonomy, it would be rash to conclude that the level of training was the critical factor responsible for the difference between groups. Unfortunately, the effect of training in the experiment confounded a number of factors, any one, or any combination of which may have been sufficient to produce a change in the nature of the control exerted by the value of the reinforcer over emission of the response. The most clear-cut obstacle to interpretation stems from the CRF schedule used to establish lever pressing. This, of necessity, confounds the number of responses with the number of reinforcers experienced by rats in the two training conditions. Furthermore, Groups 500–P and 500–U received 10 days of instrumental training whereas Groups 100–P and 100–U received only 2 days. The results of a study by Adams and Dickinson (1981a), in which rats trained to make a total of 500 lever press responses for a total of 100 reinforcers showed a clear reinforcer devaluation effect on extinction responding, suggest that the number of responses itself may not have been the important factor. However, the design employed by Adams and Dickinson (1981a) and that of the first experiment are not strictly comparable, and consequently, the second experiment attempts both to replicate the findings of Experiment I, and to investigate some of the factors confounded in the previous experiment.

Experiment II

In addition to the two instrumental training conditions employed in the first study, Experiment II included two further baseline training conditions, in which rats were given lever press training reinforced on a variable ratio (VR) schedule. This reinforcement schedule permitted some dissociation of the number of responses and the number of reinforcers, so that these animals made the same number of responses as the extended training condition of Experiment I, yet received only the number of reinforces earned by animals in the limited training condition. For one of the additional conditions, the instrumental training was massed into two sessions, and was thus comparable to Groups 100–P and 100–U. The other new training condition involved instrumental practice distributed over 10 sessions, as it

was for Groups 500–P and 500–U. For half the subjects in each of the four baseline training conditions the reinforcer was subsequently devalued, and for the other half its value was maintained, prior to extinction and reacquisition tests. Thus, Experiment II investigated the importance of the number of responses made, the number of reinforcers earned, and the distribution, or number of days, of instrumental training, in determining the sensitivity of extinction performance to post-conditioning reinforcer devaluation.

Method

Subjects and apparatus

The subjects were 64 male hooded Lister rats with a mean free-feeding weight of 340 g (range: 250 to 431 g). They were reduced to and maintained at 80% of their free-feeding weights as for Experiment I. The apparatus was that used in Experiment I.

Procedure

At the start of the experiment the subjects were randomly assigned to eight groups. Magazine training for all groups was identical to that given in Experiment I, consisting of a 30 min session during which sucrose pellets were delivered on a VT 60 s schedule. Groups 500–P, 500–U, 100–P and 100–U then received the same training given to those groups in Experiment I. This consisted of 10 daily sessions in which each of 50 responses were reinforced for Groups 500–P and 500–U, and two such sessions for Groups 100–P and 100–U. Both Groups M–P and M–U (massed-paired and -unpaired) and Groups D–P and D–U (distributed-paired and -unpaired) were required to make a total of 500 responses for a total of 100 responses. Thus, they made the same number of responses as Groups 500–P and 500–U, and yet they received only the number of reinforcers as Groups 100–P and 100–U. Following magazine training animals in both of these training conditions received a single session in which each of 50 responses were reinforced. For Groups M–P and M–U this was followed by one further session in which they were required to make 450 responses reinforced on a VR 9 schedule, and so animals in this training condition received the same number of days on instrumental training as Groups 100–P and 100–U. By contrast, following initial response acquisition, subjects in Groups D–P and D–U received nine daily sessions in each of which 50 responses were reinforced on a VR 9 schedule, and thus these groups experienced the same number of days of training as Groups 500–P and 500–U. As in Experiment I the start of training for each group was staggered so that instrumental training finished on the same day for all subjects.

Food-aversion training to the sucrose pellets was similar to that in Experiment I. Groups 500–P, 100–P, M–P and D–P received pairings of sucrose pellets with i.p. LiCl injections, alternated with days on which they were simply placed in the operant chamber for 15 min and then injected with saline. Groups 500–U, 100–U, M–U and D–U received pairings of sucrose pellets with saline injections alternated with days on which they were injected with LiCl following 15 min placements in the operant chamber. Groups 100–P, M–P and D–P required three sucrose–LiCl pairings to attain the criterion of completely suppressed sucrose consumption, and Group 500–P required four such pairings.

The test sessions were identical to those of the first experiment. They consisted of a 20-min session in which lever pressing was extinguished, followed by a 10 min reacquisition session in which each response was reinforced by the delivery of a sucrose pellet.

Results and discussion

The experiment was analysed as a $2 \times 2 \times 2$ factorial design, where the factors were the reinforcement schedule (CRF or VR 9), the distribution, or number of days, of instrumental training (2 or 10), and the food-aversion treatment (paired or unpaired).

In the last session of baseline training the mean lever press response rates for Groups 500-P, 500-U, 100-P, 100-U, D-P, D-U, M-P and M-U were 12·0, 11·9, 6·0, 5·6, 17·4, 17·2, 12·9 and 12·1 responses per minute, respectively. Those groups experiencing the CRF schedule during baseline training responded less than those trained on the VR 9 schedule ($F(1,56)=32\cdot30$, $P<0\cdot01$), and rats for which the training was distributed over 10 sessions responded more than those for which it was massed into two sessions ($F(1,56)=26\cdot81$, $P<0\cdot01$). However, within each of the four instrumental training conditions, the paired and unpaired groups did not differ ($F<1$).

Sucrose pellet consumption declined steadily for all paired group subjects, so that for Groups 100-P, M-P and D-P no animal ate any sucrose during the third cycle, and for Group 500-P no subject ate any sucrose on the fourth pairing. All unpaired group subjects continued to eat all available sucrose.

As in Experiment I, in order to minimise individual differences in baseline response rates, the extinction and reacquisition scores are expressed as a ratio of each subject's response rate on the last day of baseline training.
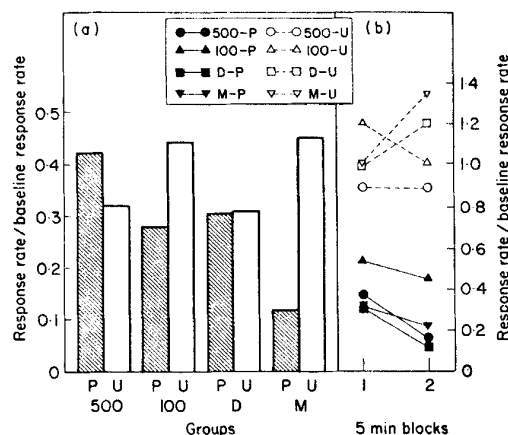

FIGURE 2. Mean relative response rates during the extinction test (a) and the re-acquisition test (b) (in 5 min blocks) of all groups in Experiment II.

The extinction ratio scores for each group are presented in Figure 2. The results of Experiment I are replicated in that Group 100-P showed less extinction responding than Group 100-U, whereas Group 500-P responded slightly more than Group 500-U. The most interesting results came from the extinction perform-ance of the two novel training conditions, for which instrumental training was reinforced on a VR 9 schedule. If this training was distributed over 10 sessions, then extinction responding appeared to be insensitive to reinforcer devaluation. However, if this training was massed into only two sessions, then there was clear evidence of successful integration, with less responding in Group M-P than Group M-U. The interaction of the distribution of training with reinforcer devaluation following training on the VR schedule, can be extended to account for the per-

formance of animals trained on the CRF schedule, and overall this interaction proved highly significant ($F(1,56)=8·87$, $P<0·01$), whereas the three-way interaction was not significant ($F<1$). There was a significant main effect of devaluation ($F(1,56)=4·22$, $P<0·05$), but the effects of days ($F<1$), reinforcement schedule ($F(1,56)=2·39$, $P>0·05$), the Schedule × Devaluation ($F(1,56)=1·56$, $P>0·05$), and Days × Schedule interactions ($F<1$) were not significant. Individual comparisons showed significantly less responding in Groups 100-P than 100-U ($t(56)=1·69$, $P<0·05$ one tailed) and in Groups M–P than M–U ($t(56)= 3·38$, $P<0·05$), but no significant difference between Groups 500-P and 500-U ($t(56)=0·84$, $P>0·05$) and between Groups D–P and D–U ($t(56)=0·09$, $P>0·05$).

The re-acquisition scores are presented in Figure 2, and show that responding was not maintained by the sucrose reinforcer in any of the paired groups, regardless of whether or not they evidenced response suppression during the extinction test. All the unpaired groups showed a rapid recovery to baseline response rates. Analysis of variance supported these observations with a highly significant main effect of devaluation ($F(1,56)=133·23$, $P<0·01$), and Devaluation × Block interaction ($F(1,56)=16·98$, $P<0·01$).

In summary, the results of Experiment II replicated the reinforcer devaluation effect seen in the first experiment and, in addition, established that extinction performance of an instrumental response established under a partial reinforcement schedule, in this case a VR 9 schedule, can also be sensitive to post-training devaluation of the reinforcer. Furthermore, Experiment II demonstrated that two of the factors possibly responsible for the loss of sensitivity of extinction responding to reinforcer devaluation in Group 500-P of the previous study, were not themselves sufficient to cause the onset of behavioural autonomy: The depressed extinction responding of Group M–P compared to M–U shows that simple extended response practice does not result in behavioural autonomy. Similarly, the insensitivity of extinction performance of Group D–P to reinforcer devaluation shows that receiving 500, as opposed to 50, reinforcements is not a necessary condition for behavioural autonomy. Rather, Experiment II suggests that spaced distribution, or a large number of days, of training may be an important determinant of behavioural autonomy, both in Group D–P and in Group 500-P. However, this experiment still confounds the distribution of reinforced response practice with the distribution of the reinforcer itself. In other words, if an animal received instrumental training over 10 days, then both the distribution of response output and that of reinforcement would be similar, and the distribution of either of these events could have contributed to the onset of behavioural autonomy.

Experiment III

Experiment III sought to unconfound the distributions of the response output and reinforcement presentation, and to provide a replication of the distribution of training effect. Four groups essentially replicated Groups M–P, M–U, D–P and D–U of the last experiment, and can be considered to have received massed presentation of the reinforcer during magazine training, in that they received a single session in which 50 sucrose pellets were delivered, followed by either massed

(Groups M–P and M–U), or distributed (Groups D–P and D–U) response practice. Two new groups received distributed magazine training, during which they received a total of 50 pellets but distributed over nine daily sessions, followed by massed response practice (Groups DM–P and DM–U), prior to reinforcer devaluation. Thus, evidence of a reinforcer devaluation effect in the extinction test for Group DM–P would suggest that the distribution of response practice is of prime importance, whereas the absence of such an effect would point to the importance of the temporal distribution of the reinforcer.

Method

Subjects and apparatus

The subjects were 96 male hooded Lister rats with a mean free-feeding weight of 314 g (range: 284 to 345 g). They were reduced to and maintained at 80% of their free-feeding weights as for Experiment I. The apparatus was that used in Experiment I.

Procedure

At the start of the experiment the subjects were randomly allocated to the six groups. For the subjects in Groups M–P, M–U, D–P and D–U, magazine training consisted of a single 40 min session in which 50 sucrose pellets were delivered on a VT schedule. Groups DM–P and DM–U received nine daily sessions of magazine training. The sessions were initially 15 min in duration, and were reduced by stages to 5 min duration. In each session either five or six sucrose pellets were programmed on a VT schedule, so that a total of 50 pellets were presented over the 9 days of training. All subjects then received a single session in which each of 50 lever press responses were consistently reinforced. Groups M–P, M–U, DM–P and DM–U then experienced one further session in which 450 responses were reinforced on a VR 9 schedule. Groups D–P and D–U received nine daily sessions in each of which 50 responses were reinforced on a VR 9 schedule.

Food-aversion training was identical to that of the last experiment. The paired groups received pairings of sucrose pellets with LiCl injections, whereas the unpaired groups experienced injections of saline following access to sucrose pellets. On alternate days animals in the paired and unpaired groups were injected with saline and LiCl, respectively, following a period of exposure to the operant chamber with no food. Food-aversion conditioning was continued until sucrose pellet consumption was completely suppressed in all the paired groups. This required three cycles of aversion training.

The test sessions were similar to those of the previous experiments. They consisted of a 20 min extinction test followed, the next day, by a 10 min reacquisition test in which the VR 9 reinforcement schedule was reinstated.

Results

In the last session of baseline training the mean lever press response rates for Groups M–P, M–U, D–P, D–U, DM–P and DM–U were 20·2, 20·6, 26·5, 26·3, 19·1 and 19·3 responses per minute, respectively. The groups receiving massed practice did not differ from one another, but showed less responding in the last session of instrumental training than the groups receiving distributed response practice, as was reflected by a main effect of training condition ($F(2,90)=6·32$, $P<0·01$). However, within each training condition, the paired and unpaired groups did not differ, and the main effect of devaluation and Training × Devaluation interaction were not significant ($Fs<1$).

The course of food-aversion learning was similar to that observed in previous

experiments with all paired group subjects showing complete suppression of sucrose consumption during the third sucrose–LiCl pairing. All unpaired group animals continued to eat all sucrose presented.

The results of the extinction test, which are presented in Figure 3, replicated the distribution of training effect found in the previous study. Although Group D–P was slightly more suppressed in extinction than Group D–U, the difference between the paired and unpaired groups in the distributed training condition was not as large as that in the massed training condition between Groups M–P and M–U. The most interesting finding was that Group DM–P showed a level of extinction responding comparable to that of Group DM–U.
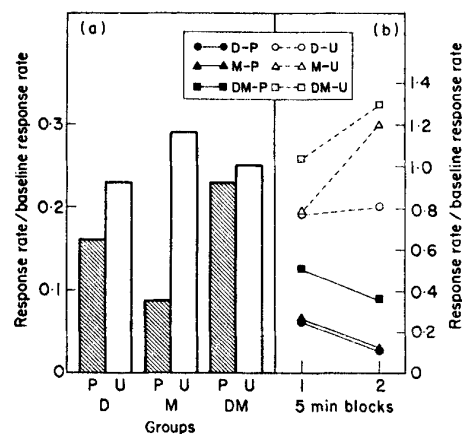

FIGURE 3. Mean relative response rates during the extinction test (a) and the reacquisition test (b) (in 5 min blocks) of all groups in Experiment III.

This pattern of results is supported by an analysis of variance, which showed a significant Training × Devaluation interaction $((F(2,90)=4\cdot19,\ P<0\cdot05)$, and a main effect of devaluation $(F(1,90)=14\cdot72,\ P<0\cdot01)$. The main effect of training was not significant $(F(2,90)=1\cdot24,\ P>0\cdot05)$. Planned t-tests confirmed that extinction responding in Group M–P was suppressed compared to Group M–U $(t(90)=4\cdot53,\ P<0\cdot05)$, and that there were no differences between Groups D–P and D–U $(t(90)=1\cdot53,\ P>0\cdot05)$ and Groups DM–P and DM–U $(t(90)=0\cdot59,\ P>0\cdot05)$.

The re-acquisition ratio scores for each group are presented in Figure 3. As in the previous experiments, there was no suggestion that the differences in the sensitivity of the baseline training conditions to reinforcer devaluation seen in the extinction test was due to differences in the strength of the sucrose aversion established in the various paired groups. For all three paired groups the sucrose reinforcer failed to maintain responding, whereas all unpaired groups recovered towards their baseline rates. There were significant main effects of devaluation $(F(1,90)=113\cdot4,\ P<0\cdot01)$ and training $(F(2,90)=5\cdot55,\ P<0\cdot01)$, and a significant Devaluation × Block interaction $(F(1,90)=56\cdot2,\ P<0\cdot01)$.

During the re-acquisition test every animal in all three paired groups left all earned sucrose uneaten, whereas all unpaired group subjects consumed all available sucrose.

Discussion

The findings of the first three experiments can be summarised as follows. Rats allowed to make 100 consistently reinforced lever press responses showed suppressed responding in extinction following reinforcer devaluation, whereas rats allowed to make 500 reinforced responses showed no effect of reinforcer devaluation. If the subjects were allowed to make a total of 500 responses, but for a total of only 100 reinforcers available on a VR schedule, then a reinforcer devaluation effect was seen if that training was massed into two sessions, but not if training was distributed over 10 sessions. This latter effect may be responsible for differences in the sensitivity of extinction performance to reinforcement devaluation seen in the CRF experiments, as the 100 response condition involved 2 days of instrumental training and the 500 response condition involved 10 days of training. The third experiment further demonstrates that the distribution of training is of importance, but suggests that it is the temporal distribution of the reinforcer, rather than the distribution of responding, that brings about a loss of sensitivity to reinforcer devaluation.

Bearing in mind this last result, one possible explanation of these findings might be that the aversion conditioned to the sucrose during food-aversion training generalised more completely to the sucrose pellets used as the instrumental reinforcer when experience of the instrumental reinforcer was massed than when it was distributed. A simple notion of generalisation decrement is rendered implausible by the massive suppression of responding seen in all paired groups during the reacquisition test, regardless of whether or not a devaluation effect was demonstrated in extinction. However, it could still be argued that the extinction test represents a more sensitive measure of food-aversion generalisation than does the reacquisition test. If this is accepted, a possible basis for the failure of the food-aversion to transfer to the instrumental reinforcer previously presented in a distributed manner, may be the nature of the food-aversion training stage. In all the experiments presented so far, paired food-aversion training consisted of 15-min access to 50 sucrose pellets followed by a LiCl injection. Both in terms of number of sucrose pellets presented each session, and duration of the session, this procedure can be said to be more similar to massed instrumental training than to distributed training.

Experiment IV

Experiment IV sought to test this explanation directly. Animals received either massed or distributed instrumental training, followed by either massed or distributed food-aversion training. An explanation of the effect of reinforcer spacing in terms of a failure of the sucrose-aversion to generalise fully to sucrose as an instrumental reinforcer, predicts that extinction responding should reveal an interaction between the distribution of the reinforcer in the instrumental and food-aversion stages.

Method

Subjects and apparatus

The subjects were 64 male hooded Lister rats with a mean free-feeding weight of 432 g (range: 360 to 475 g). They were reduced to and maintained at 80% of their free-feeding weights as for Experiment I. The apparatus was that used for Experiment I.

Procedure

At the beginning of the experiment the animals were randomly assigned to 8 groups. The animals in Groups M–MP, M–MU, M–DP and M–DU all received massed instrumental training identical to that given to Groups M–P and M–U in Experiment II. This consisted of a single session each of magazine training and consistently reinforced lever pressing, followed by one further session in which 450 responses were reinforced on a VR 9 schedule. Groups D–MP, D–MU, D–DP and D–DU received distributed instrumental training identical to that given to the previous Groups D–P and D–U, consisting of nine sessions, in each of which 50 responses were reinforced on a VR 9 schedule, following magazine training and initial response acquisition.

An aversion to the sucrose reinforcer was established for the paired group subjects over a number of two-day cycles in a manner similar to the previous experiments. However, the number of pellets presented in these sessions and the duration of the sessions were varied. For animals in Groups M–MP, M–MU, D–MP and D–MU the food-aversion training was massed. The sessions were 30 min in duration and 50 sucrose pellets were presented. By contrast, animals in Groups M–DP, M–DU, D–DP and D–DU received distributed food-aversion training. The session length was 5 min and only six sucrose pellets were presented, which is approximately the same length of session and number of pellets per session experienced during distributed instrumental training. On these days paired groups received LiCl and unpaired groups saline injections. On alternate days the paired animals were injected with saline following placement in the operant chamber for the appropriate period of time, and the unpaired groups were injected with LiCl. Food-aversion conditioning was continued until all subjects in each paired group evidenced complete suppression of sucrose consumption.

The test sessions were identical to those of Experiment III. They consisted of a 20 min extinction session, followed by a 10 min re-acquisition session in which a VR 9 reinforcement schedule was in effect.

Results and discussion

In the last session of baseline training the mean response rates for Groups M–MP, M–MU, M–DP, M–DU, D–MP, D–MU, D–DP and D–DU were 19·1, 13·7, 14·5, 12·8, 38·5, 28·3, 28·7 and 27·7 responses per minute, respectively. Groups experiencing distributed instrumental training responded more than those receiving massed instrumental training ($F(1,56)=56·42$, $P<0·1$), and the paired group animals responded slightly more than the unpaired groups ($F(1,56)=4·23, P>0·05$). This latter difference was not very large and its effect on the interpretation of the test sessions was minimized by expressing each animal's extinction and re-acquisition score as a ratio of its baseline training score.

The establishment of an aversion to the sucrose in Groups M–MP and D–MP proceeded as in the previous experiments, with all subjects in these two groups showing complete suppression of sucrose consumption after three sucrose–LiCl pairings. Animals experiencing distributed food-aversion training (Groups M–DP and D–DP) required five sucrose–LiCl pairings before sucrose consumption was completely suppressed. The retarded acquisition of an aversion to sucrose in these latter groups probably reflects the reduced salience of 6, vs. 50, sucrose

pellets presented on each conditioning trial.   Every subject in each of the unpaired groups continued to eat all sucrose presented.
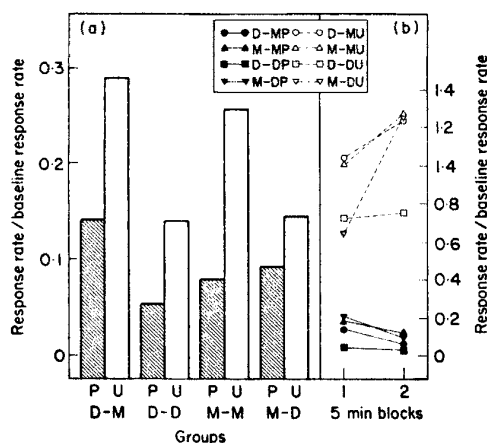

FIGURE 4.   Mean relative response rates during the extinction test (a) and the reacqusition test (b) (in 5 min blocks) of all groups in Experiment IV.

The mean extinction ratios for each group are presented in Figure 4.   Generally the extinction ratios of animals experiencing massed food-aversion training were higher than those experiencing distributed aversion training ($F(1,56)=15\cdot6$, $P>0\cdot01$).   This probably reflects greater aversive conditioning to the operant chamber for the latter groups, which received more food-aversion conditioning trials, since these trials also involved pairings of the operant chamber with large volume i.p. injections.

The groups which received massed instrumental training showed a greater sensitivity of extinction responding to reinforcer devaluation if food-aversion conditioning was also massed, rather than distributed.   Planned t-tests confirmed this observation, Group M–MP responded significantly less than Group M–MU ($t(56)=3\cdot99$, $P<0\cdot05$), while Groups M–DP and M–DU did not differ ($t(56)= 1\cdot19$), $P>0\cdot05$).   In the case of groups that received distributed instrumental training, there was clear evidence of a reinforcer devaluation effect after distributed aversion training, but extinction responding was equally sensitive to reinforcer devaluation established by massed food-aversion training.   Planned t-tests showed significantly less responding in Group D–DP than D–DU ($t(56)=2\cdot54$, $P<0\cdot05$), and in Group D–MP than D–MU ($t(56)=2\cdot95$, $P<0\cdot05$).   The large devaluation effect in Group D–MP was somewhat unexpected, and represents a failure to fully replicate the results of the previous two experiments.   Overall analysis of variance revealed a significant main effect of devaluation ($F(1,56)=28\cdot45$, $P<0\cdot01$), whereas the interaction between the distribution of instrumental conditioning, food-aversion training, and devaluation was nonsignificant ($F(1,56)=1\cdot43$, $P>0\cdot05$).

The mean reacquisition scores for each group are shown in Figure 4.   As in the previous experiments, all those groups with an aversion to the reinforcer showed

profound suppression of responding during the reacquisition session, whereas all unpaired groups showed a rapid and complete recovery to baseline response rates. The main effect of devaluation ($F(1,56)=99\cdot84$, $P<0\cdot01$) and the Devaluation $\times$ Block interactions were highly significant ($F(1,56)=43\cdot18$, $P<0\cdot01$). No animal in any of the paired groups ate any of the sucrose pellets earned during this stage, whereas all unpaired group animals consumed all earned sucrose.

The results of Experiment IV suggest that the distribution of training effect seen in the previous experiments may require some reinterpretation. For the first time, extinction responding following massed instrumental training was insensitive to reinforcer devaluation, but only if aversion training was distributed (Group M–DP); if aversion training was massed (Group M–MP) a clear reinforcer devaluation effect was observed. It should be acknowledged that this interaction may be due, in part, to the difference between the two unpaired groups (Groups M–MU and M–DU), and that a significant depression of extinction responding in Group M–DP may have been obscured by a floor effect. However, this account is rendered less likely by the observation of a significant depression of extinction responding seen in Group D–DP even though the mean extinction ratio for the unpaired control for this condition, Group D–DU, was no greater than that for Group M–DU. Successful integration was shown by Group D–DP, which received distributed instrumental training followed by distributed food-aversion earning, but the group receiving distributed instrumental training evidenced successful integration even when the aversion training was massed (Group D–MP). This result is at odds with the results of the two previous experiments, in which groups with an identical training history did not evidence a significant devaluation effect. In the light of this discrepancy it is worth acknowledging that the difference in the present experiment between the extinction test performance of Groups D–MP and D–MU may well be a type 1 error. In addition it should be noted that Experiment III represented a more powerful test of the effect of reinforcer devaluation on extinction performance in this condition than the present study, because it contributed more observations to this contrast. Consequently, it would seem that a failure of integration may occur if the same number of pellets are not received in both the instrumental training and aversion training sessions, and this account can provide a satisfactory, if unexpected, explanation for all the distribution of training effects seen in Experiments II and III.

However, such an explanation is less readily applied to the failures of integration reported in Experiments I and II, where extended training of responding on a CRF schedule led to a loss of the devaluation effect seen during the extinction test. In these experiments, the food-aversion training was roughly similar to instrumental training for both Groups 500–P and 100–P. During instrumental training both groups received 50 sucrose pellets each session, and the sessions were on average less than 10 min in length for both groups. This compares with food-aversion training which consisted of 15-min sessions in which 50 sucrose pellets were presented. Thus, although failure of integration following extended CRF training initially appeared to be an instance of a more general distribution of training effect, the results of the present experiment suggest that this explanation is not viable.

Experiment V

Experiment V reexamined the issue of extended training and sensitivity to post-conditioning reinforcer devaluation. In particular, it investigated whether behavioural autonomy results from extended response practice or extended exposure to the reinforcer. Rather than employing the CRF schedule of Experiments I and II, a VR schedule was used to generate more robust extinction responding, and to eliminate some of the individual variability associated with the CRF schedule. A low training condition (Groups L–P and L–U) consisted of one session in which 500 responses were reinforced on a VR 10 schedule, so providing 50 response–reinforcer pairings. A high training condition (Groups H–P and H–U) consisted of 10 such sessions, and so provided 500 response–reinforcer pairings. Unlike Experiment I which staggered the start of the high and low training conditions, Experiment V gave initial magazine training and response acquisition to all groups on the same day. The high training groups then continued with daily sessions whereas the low training groups remained in their home-cages for 9 days before their final training session. Two further groups (Groups Y–P and Y–U) addressed the question of whether any differential sensitivity to reinforcer devaluation seen should be attributed to increased exposure to the reinforcer, or whether it reflected an increased number of response–reinforcer pairings. After initial response acquisition, each subject in Groups Y–P and Y–U was yoked to a subject from Groups H–P and H–U, and in the following nine sessions received free-sucrose pellets with the response lever retracted. They then received one session in which they were required to make 500 responses on a VR 10 reinforcement schedule. Consequently Groups Y–P and Y–U received equivalent exposure to the sucrose reinforcer as Groups H–P and H–U, yet only experienced the number of response-reinforcer pairings of Groups L–P and L–U.

Food-aversion training consisted of 20-min sessions in which animals had access to 50 sucrose pellets and as such was comparable to the instrumental training sessions of all 6 groups.

Method

Subjects and apparatus

The subjects were 48 male hooded Lister rats with a mean free-feeding weight of 302 g (range: 274 to 340 g). They were reduced to and maintained at 80% of their free-feeding weights as for Experiment I. The apparatus was that used for Experiment I.

Procedure

At the start of the experiment the animals were randomly allocated to the 6 groups. All subjects then received one session of magazine training, in which 30 sucrose pellets were delivered on a VT 60 s schedule, followed, the next day, by a session in which 50 responses were consistently reinforced. Groups L–P and L–U received no training for the next 9 days, remaining in their home-cages. Each subject in Groups Y–P and Y–U was randomly "yoked" to a subject in Groups H–P and H–U for the following nine sessions, in each of which Groups H–P and H–U were required to make 500 responses reinforced on a VR 10 schedule. During this period, each Group Y–P and Y–U subject was presented with the same number and temporal distribution of sucrose pellets as their "yoked" high training group counterpart. For Groups Y–P and Y–U the response lever was retracted during this

stage. In the final session of instrumental training subjects from all groups were required to make 500 responses on a VR 10 schedule.

Food-aversion training was similar to the previous experiments except that the sessions were 20 min in duration. All paired groups required three sucrose–LiCl pairings to ensure complete suppression of sucrose consumption.

The test sessions were identical to those of the last two experiments, consisting of a 20 min extinction session, followed, the next day, by a 10 min reacquisition test.

Results and discussion

One subject in Group L–U died during food-aversion training and all the results are based on the seven remaining subjects in this group.

During the final session of baseline training the mean response rates for Groups H–P, H–U, L–P, L–U, Y–P and Y–U were 38·4, 42·5, 14·2, 13·8, 13·4 and 13·3 responses per minute, respectively. The high training condition led to faster response rates than the low training and yoked conditions, which did not differ from one another. Consequently, there was a significant main effect of training conditions ($F(2,41)=55·41$, $P<0·01$); however, the paired and unpaired groups within each training condition did not differ and there was no effect of devaluation, or interaction between these factors ($Fs<1$).

An aversion to the sucrose was readily established for the three paired groups, which all showed complete suppression of sucrose pellet consumption on the third conditioning cycle. All subjects in each of the unpaired groups continued to eat all sucrose presented throughout aversion training.
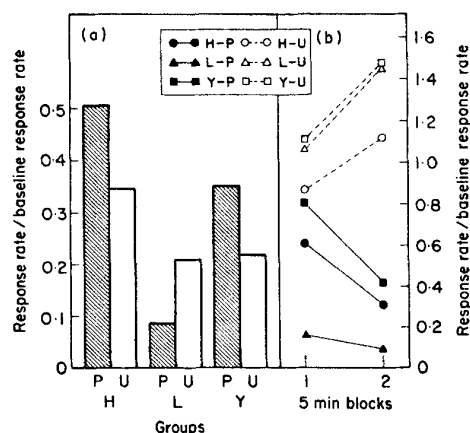

FIGURE 5. Mean relative response rates during the extinction test (a) and the reacquisition test (b) (in 5 min blocks) of all groups in Experiment V.

Figure 5 presents the mean extinction ratios for each group. Considering the high and low training conditions, there was clear evidence of a loss of sensitivity of the extinction test to reinforcer devaluation with extended training. This provides a systematic replication of the results of Experiments I and II. The additional groups, Y–P and Y–U, showed no effect of reinforcer devaluation, which suggests that the failure of integration seen on moving from the low to the high training

conditions is, at least in part, a result of increased exposure to the reinforcer. There was an interaction of Training with Devaluation ($F(2,41)=3\cdot24$, $P<0\cdot05$) and a significant main effect of training ($F(2,41)=8\cdot97$, $P<0\cdot01$). The main effect of devaluation was not significant ($F<1$). Planned t-tests showed Group L–P to be significantly more suppressed than Group L–U ($t(41)=1\cdot94$, $P<0\cdot05$ one tailed) and confirmed that there were no significant differences between Groups H–P and H–U ($t(41)=1\cdot02$, $P>0\cdot05$) and Group Y–P and Y–U ($t(41)=1\cdot32$, $P>0\cdot05$).

The mean reacquisition ratio scores of each group are shown in Figure 5. In all three paired groups the sucrose reinforcer failed to maintain responding during the reacquisition test, leading to a highly significant main effect of devaluation ($F(1,41)=99\cdot96$, $P<0\cdot01$), and there was a significant Devaluation×Block interaction ($F(1,41)=49\cdot62$, $P<0\cdot01$). Groups H–P and Y–P responded more than Group L–P during the first 5 min block, as reflected in a main effect of training condition ($F(2,41)=11\cdot35$, $P<0\cdot01$) and Training×Devaluation interaction ($F(2,41)=12\cdot35$, $P<0\cdot01$); however, their response rates declined markedly by the second block, suggesting that the initial difference was a carry-over from the extinction test. All unpaired groups rapidly recovered their baseline response rates.

No member of any of the paired groups ate any of the sucrose earned during the reacquisition test, while all unpaired animals consumed all sucrose delivered in this stage.

General discussion

In summary, the present experiments provide evidence suggesting that extended instrumental training can lead to the onset of behavioural autonomy, and that this, in some instances, may reflect the degree of exposure to the reinforcer, rather than the extent of response practice. Experiments II and III implicated the distribution of instrumental training as a factor influencing the loss of sensitivity of extinction responding to reinforcer devaluation. However, Experiment IV suggested that this effect reflected a failure in generalisation of reinforcer devaluation from aversion conditioning to the extinction test.

The present findings, together with those of Adams and Dickinson (1981a) and Chen and Amsel (1980), provide a substantial body of evidence for successful integration following instrumental training, in that illness-induced devaluation of the reinforcer depressed subsequent extinction responding. Successful integration can be taken as evidence that exposure to an instrumental conditioning procedure may set up a representation which encodes the reinforcer. Two distinct classes of theories are consistent with successful integration, and differ in the way in which the reinforcer is represented, and consequently, in how the reinforcer devaluation effect is mediated. One class of theories is based upon the formation of an act–outcome, or response–reinforcer expectancy (Adams and Dickinson, 1981b; Asratyan, 1974; Bolles, 1972; Irwin, 1971; Mackintosh and Dickinson, 1979; Mowrer, 1960; Tolman, 1932), and as such maintains that the reinforcer devaluation effect depends directly upon the response–reinforcer relationship experienced by the animal. The other class of theories comprises the two-process models

(Rescorla and Solomon, 1967; Trapold and Overmier, 1972), which argue that a potential Pavlovian relationship, between stimuli correlated with responding and the reinforcer, mediates the reinforcer devaluation effect. It may not be possible to distinguish empirically between these two general accounts, although Adams and Dickinson (1981a) have gone some way to demonstrating that successful integration depends, at least in part, upon the response–reinforcer relationship.

The present experiments have identified two major factors that may be involved in failures to demonstrate successful integration. Firstly, the results of Experiment IV suggest that a failure of integration may occur if the animal experiences a different number of pellets in the food-aversion conditioning sessions than it did during instrumental training sessions. A possible explanation of this finding is that the representations of the reinforcer established under massed and distributed training conditions differed in some way. An essential pre-requisite of successful integration is that the knowledge structure controlling the instrumental response and that encoding information about the changed value of the reinforcer should contain a common term; specifically a representation of the reinforcer. Thus, if experience with massed and distributed presentations of the reinforcer established representations of that reinforcer that differed in some way, then the two knowledge structures may have no term in common and could, therefore, not be combined in a way that would modulate responding appropriately.

The other main factor implicated in the onset of behavioural autonomy, is the extent of instrumental training. The final study suggested that this depends upon the amount of exposure to the reinforcer rather than the number of response emissions, or response–reinforcer pairings experienced. Both two-process models and response–reinforcer expectancy theories can provide a number of possible mechanisms for the onset of behavioural autonomy following extended instrumental training. The results of Experiment V, which suggested that increased exposure to the reinforcer was a sufficient condition for behavioural autonomy, may reflect a change in the nature of the representation of the reinforcer. For instance, after a limited amount of training the reinforcer may be represented both by its affective value and its stimulus characteristics. Following extended training, the representation may predominantly encode only the affective value; in terms of an expectancy model, the animal knows that responding leads to something pleasant, but not specifically what the reinforcer is. As food–aversion conditioning devalues only the stimulus attributes of the reinforcer, a reinforcer devaluation effect would only be expected if those attributes were encoded. A related analysis could start from the observation that second-order Pavlovian conditioning can be insensitive to reinforcer devaluation (Holland and Rescorla, 1975; Holland and Straub, 1979). Rescorla (1977) has suggested that instrumental conditioning should show a similar insensitivity to the extent that it depends upon analogous processes. Onset of behavioural autonomy, following extended exposure to the reinforcer, could then depend upon an increased role for second-order reinforcement, possibly by stimuli which regularly accompany presentation of the primary reinforcer, such as the sound of the pellet dispenser.

It must be acknowledged, however, that the failures of integration following extended training may simply reflect a less potent aversion to the reinforcer.

Although this is a real possibility, it is rendered somewhat unlikely for a number of reasons. Firstly, the design of the food-aversion conditioning stage, whereby a criterion of complete suppression of sucrose pellet consumption had to be achieved by each animal, and once that had been achieved, aversion training ceased for that group, should have ensured equivalent strength aversions in all paired groups, irrespective of their previous experience. In fact, Mikulka and Klein (1977) employed a similar criterion in a study of food-aversion conditioning following varying degrees of exposure to the to-be-conditioned food, which, as in the present studies, entailed giving some groups more food–LiCl pairings than others. Mikulka and Klein went on to demonstrate that food-aversions acquired under such conditions extinguished at the same rate regardless of the degree of pre-exposure to the food, and the consequent number of food–LiCl pairings. Thus, it seems improbable that in the limited instrumental training conditions employed in Experiments I and V a floor effect masked a more potent aversion to the sucrose reinforcer than was established in the extended training conditions. Secondly, and most compelling, is that for all the paired groups, including those which had previously received extended instrumental training, the devalued reinforcer failed to maintain responding during the reacquisition test. Although it could be argued that in the paired conditions a floor effect obscured a greater suppression of reacquisition performance following limited instrumental training than after extended training, there was, nonetheless, a profound devaluation of the reinforcer following extended instrumental training.

Having identified two conditions that may result in behavioural autonomy, it is worth considering whether the application of these factors can explain past failures of integration following instrumental lever pressing and illness induced reinforcer devaluation. The experiments by Holman (1975), Morrison and Collyer (1974) and Wilson et al. (1981) devalued the reinforcer in the animals' home-cages, rather than in the operant chamber, and only Wilson et al. demonstrated suppression of reacquisition responding. Chen and Amsel's (1980) continuously reinforced and partially reinforced conditions differed in the number of reinforcements presented each session. Consequently, the food-aversion established in the home-cage may have transferred more fully to the extinction test following continuously reinforced training than after partially reinforced training. Thus, it is possible that these failures of integration may indeed be considered as failures of generalisation. However, in the study reported by Adams (1980), following instrumental training reinforced on a VI 60 s schedule, food-aversion conditioning was not only established in the operant chamber, but also the reinforcer was delivered on a VT 60 s schedule during this stage. Thus, aversion conditioning was as similar as is possible to instrumental training, and this, together with the failure of the devalued reinforcer to maintain re-acquisition responding, suggests that this failure of integration was due to factors other than poor generalisation of the aversion to extinction. Analysis of Adams' (1980) results in terms of extended training is still hard pressed to explain this failure of integration. The animals in Adams' VI study received a total of 200 reinforcers during instrumental training, whereas in Experiment V of the present study, the low training condition received 130 and the high training condition 580 reinforcers. Thus, although the rats in Adams' (1980)

experiment did have more experience with the reinforcer during instrumental training than the low training condition, this difference was not very great. It would appear, therefore, that another factor that may determine the sensitivity of extinction responding to post-conditioning devaluation of the reinforcer, may be the nature of the instrumental training schedule, in that extinction responding following training on a VI schedule is less sensitive to reinforcer devaluation than responding following training on a VR or CRF schedule. Unfortunately, no direct comparison between ratio and interval schedules, which could eliminate non-schedule differences, has yet been made within this paradigm.

The present results add to a growing body of evidence that instrumental learning can be sensitive to conditioned changes in the value of the reinforcer, and identify a number of factors that may lead to a loss of this sensitivity. Some authors (Adams and Dickinson, 1981b; Bolles, 1972; Dickinson, 1980) have suggested that such failures of integration may reflect a transition in the associative structure controlling response emission, from a response–reinforcer expectancy to a stimulus–response habit. While this may be the case, it is clear that changes in the representation of the reinforcer may produce a failure of integration independently of any change in the associative structure, and that considerable caution should be exercised when interpreting failures of integration.

References

ADAMS, C. D. (1980). Post–conditioning devaluation of an instrumental reinforcer has no effect on extinction performance. *Quarterly Journal of Experimental Psychology*, 32, 447-58.

ADAMS, C. D. and DICKINSON, A. (1981a). Instrumental responding following reinforcer devaluation. *Quarterly Journal of Experimental Psychology*, 33B, 109-21.

ADAMS, C. D. and DICKINSON, A. (1981b). Actions and habits: Variations in associative representations during instrumental learning. In SPEAR, N. E. and MILLER, R. R. (Eds), *Information Processing in Animals: Memory Mechanisms*. Hillsdale, N.J.: Erlbaum.

ASRATYAN, E. A. (1974). Conditioned reflex theory and motivational behaviour. *Acta Neurobiologiae Experimentalis*, 34, 15-31.

BOLLES, R. C. (1972). Reinforcement, expectancy, and learning. *Psychological Review*, 79, 394-409.

CHEN, J.-S. and AMSEL, A. (1980). Recall (versus recognition) of taste and immunization against aversive taste anticipations based on illness. *Science*, 209, 851-3.

DICKINSON, A. (1980). *Contemporary Animal Learning Theory*. Cambridge: Cambridge University Press.

HOLLAND, P. C. and RESCORLA, R. A. (1975). The effect of two ways of devaluing the unconditioned stimulus after first- and second-order conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, 1, 355-63.

HOLLAND, P. C. and STRAUB, J. J. (1979). Differential effects of two ways of devaluing the unconditioned stimulus after Pavlovian appetitive conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, 5, 67-78.

HOLMAN, E. W. (1975). Some conditions for dissociation of consummatory and instrumental behavior in rats. *Learning and Motivation*, 6, 358-66.

IRWIN, F. W. (1971).   *Intentional Behavior and Motivation: A Cognitive Theory*.   Philadelphia: Lippincott.

KIMBLE, G. A. and PERLMUTER, L. C. (1970).   The problem of volition.   *Psychological Review*, **77**, 361–84.

MACKINTOSH, N. J. and DICKINSON, A. (1979).   Instrumental (Type II) conditioning: In DICKINSON, A. and BOAKES, R. A. (Eds), *Mechanisms of Learning and Motivation*. Hillsdale, N.J.: Earlbaum.

MIKULKA, P. J. and KLEIN, S. D. (1977).   The effect of CS familiarisation and extinction procedures on the resistance to extinction of a taste-aversion.   *Behavioral Biology*, **19**, 518–22.

MILLER, N. E. (1935).   A reply to 'sign-gestalt or conditioned reflex'.   *Psychological Review*, **42**, 280–92.

MORRISON, G. R. and COLLYER, R. (1974).   Taste-mediated aversion to an exteroceptive stimulus following LiCl poisoning.   *Journal of Comparative and Physiological Psychology*, **86**, 51–5.

MOWRER, O. H. (1960).   *Learning Theory and Behavior*.   New York: Wiley.

RESCORLA, R. A. (1977).   Pavlovian second-order conditioning: Some implications for instrumental behavior.   In DAVIS, H, and HURWITZ, H. M. B. (Eds), *Operant-Pavlovian Interactions*.   Hillsdale, N.J.: Erlbaum.

RESCORLA, R. A. and SOLOMON, R. L. (1967).   Two-process learning theory: Relationships between Pavlovian conditioning and instrumental learning.   *Psychological Review*, **74**, 151–82.

ROZEBOOM, W. W. (1957).   Secondary extinction of lever-pressing behavior in the albino rat.   *Journal of Experimental Psychology*, **54**, 280–7.

ROZEBOOM, W. W. (1958).   "What is learned?"—an empirical enigma.   *Psychological Review*, **65**, 22–33.

TOLMAN, E. C. (1932).   *Purposive Behavior in Man and Animals*.   New York: Century.

TOLMAN, E. C. (1933).   Sign–gestalt or conditioned reflex?   *Psychological Review*, **40**, 246–55.

TOLMAN, E. C. and GLEITMAN, H. (1949).   Studies in learning and motivation. I. Equal reinforcements in both end-boxes followed by shock in one.   *Journal of Experimental Psychology*, **39**, 810–9.

TRAPOLD, M. A. and OVERMIER, J. B. (1972).   The second learning process in instrumental learning.   In BLACK, A. H. and PROKASY, W. F. (Eds), *Classical Conditioning. II. Current Research and Theory*.   New York: Appleton–Century–Crofts.

WILSON, C. L., SHERMAN, J. E. and HOLMAN, E. W. (1981).   An aversion to the reinforcer differentially affects conditioned reinforcement and instrumental responding.   *Journal of Experimental Psychology: Animal Behavior Processes*, **7**, 165–74.