

Instrumental responding following reinforcer devaluation

Christopher D. Adams & Anthony Dickinson

To cite this article: Christopher D. Adams & Anthony Dickinson (1981) Instrumental responding following reinforcer devaluation, *The Quarterly Journal of Experimental Psychology*, 33:2, 109-121, DOI: [10.1080/14640748108400816](https://doi.org/10.1080/14640748108400816)

To link to this article: <https://doi.org/10.1080/14640748108400816>



Published online: 29 May 2007.



Submit your article to this journal [↗](#)



Article views: 1098



Citing articles: 282 View citing articles [↗](#)

INSTRUMENTAL RESPONDING FOLLOWING REINFORCER DEVALUATION

CHRISTOPHER D. ADAMS AND ANTHONY DICKINSON

*The Psychological Laboratory, University of Cambridge, Downing Street,
Cambridge CB2 3EB, England*

In two experiments, hungry rats were given instrumental lever-press training for an appetitive reinforcer and, in addition, were exposed to another type of food which was not contingent on lever pressing. In the first experiment, exposure to each type of food was on separate days, whereas in the second experiment rats were exposed to each type of food in strict alternation within each session. Subsequently, a food aversion was conditioned to the reinforcer for the experimental group and to the non-contingent food for the control group. In both experiments, animals with an aversion to the reinforcer responded less in an extinction test than animals with an aversion to the non-contingent food. Subsequent reacquisition tests confirmed that the aversion to the non-contingent food in the control group was of comparable strength with that to the reinforcer in the experimental group. The results were discussed in terms of whether the reinforcer is encoded in the associative structure set up by exposure to an instrumental contingency.

Introduction

Whether or not animals know about the consequences of their actions has been a matter of persistent theoretical dispute in discussions of instrumental learning. Simple stimulus-response (S-R) habit theories deny such knowledge by assuming that instrumental performance reflects an underlying associative structure in which a representation of the stimulus context during conditioning is connected directly to the response generating mechanism. An alternative view is to assume that some aspect of the reinforcer is incorporated in the associative knowledge controlling instrumental behaviour (e.g. Asratyan, 1974; Bolles, 1972; Irwin, 1971; Mackintosh and Dickinson, 1979; Mowrer, 1960; Trapold and Overmier, 1972). The distinction between these two general classes of theories can be addressed empirically by studying the effects of post-conditioning changes in the value of the reinforcer (Rozeboom, 1958). Thus, when the reinforcer is devalued following instrumental conditioning, we should expect responding to be depressed in a subsequent extinction test if the reinforcer is encoded in the associative structure controlling performance. In contrast, simple S-R theory, by precluding any knowledge about the consequences of an action, would anticipate that instrumental performance,

once established, should be autonomous of the current value of the goal and hence unaffected by post-conditioning devaluation of the reinforcer.

The significance of this post-conditioning devaluation test has long been recognised, and early studies, some successful (Miller, 1935; Tolman and Gleitman, 1949) and others not (Rozeboom, 1957; Tolman, 1933) attempted to demonstrate that aversive conditioning to cues incidentally associated with the presentation of a positive reinforcer, such as a goal box or magazine stimulus, depressed the performance of a previously established instrumental response. However, as the devaluation procedures employed in these studies sought to change the affective significance of cues incidentally associated with the positive reinforcer during training, rather than the value of the reinforcer itself, they do not address directly the question of whether the reinforcer is encoded in the associative representation set up by instrumental conditioning.

The subsequent discovery of food-aversion conditioning (Garcia, Kimeldorf and Koelling, 1955) provided a technique by which the affective significance of the reinforcer itself could be changed. Following instrumental training with a particular food, an aversion can be established to that food by pairing its consumption with an injection of lithium chloride (LiCl). If instrumental performance is controlled by knowledge about the consequences of the action, the animal should be less ready to perform this action following food-aversion training. Although Chen and Amsel (1980) have recently reported just such a devaluation effect following instrumental training in a runway, this finding appears to be the exception rather than the rule. All previous studies employing a free-operant procedure found that instrumental responding in extinction is completely unaffected by prior aversion training to the reinforcer (Adams, 1980; Holman, 1975; Morrison and Collyer, 1974). The present experiments represent a further attempt to observe a devaluation effect with a free-operant procedure.

Experiment I

In the first study two groups of rats were trained to lever press for a particular food prior to aversion training. Adams (1980) established that the reinforcing properties of a food could be attenuated when aversion training was administered in the operant chamber. He gave animals a series of exposures to the operant chamber in the absence of the lever, half of which were followed by an injection of LiCl and half by an injection of saline. The animals were allowed to consume the reinforcer in the operant chamber prior to the LiCl injection in the paired condition and prior to the saline injection in the unpaired condition to produce a selective aversion to the reinforcer in the paired group. Although such a procedure equates the number of pairings of the apparatus or contextual cues and the LiCl injections in the paired and unpaired conditions, recent evidence suggests that it may not result in a similar level of aversive conditioning to the contextual cues. A number of studies have shown that a stronger aversion may be established to an exteroceptive cue if it is paired with LiCl in conjunction with a distinctively flavoured food (Clarke, Westbrook and Irwin, 1979; Galef and Osborne, 1978; Lett, 1980; Rusiniak, Hankins, Garcia and Brett, 1979). Consequently, if the

paired group were to respond less in a subsequent extinction test, this effect could reflect a difference in the strength of aversive conditioning to the contextual cues rather than a consequence of reinforcer devaluation. Such a possibility is strengthened by Morrison and Collyer's (1974) observation that when thirsty rats are injected with LiCl after lever pressing for a solution in the presence of a continuous light, the light comes to suppress responding only if the reinforcer solution is distinctively flavoured. This suggests that consumption of a flavoured substance may be capable of mediating LiCl-induced aversive conditioning to the contextual cues, so that these cues can themselves suppress instrumental performance, and thus produce an apparent reinforcer devaluation effect. As we were only interested in detecting a reinforcer devaluation effect that was mediated directly by the instrumental contingency, we attempted to equate any contextual conditioning in the paired and unpaired groups during the food-aversion training. Therefore in the present experiment, by using two distinctively flavoured types of food pellet, animals in both the paired, experimental, condition and the unpaired, control, condition consumed food pellets prior to injections of LiCl. For animals in the paired group the pellets were of the type previously used to reinforce lever pressing, whereas for animals in the unpaired group the pellets had not previously served as a reinforcer. On the alternate days, the paired group was exposed to non-contingent pellets and the unpaired group to reinforcer pellets prior to being injected with saline. In order to equate initial exposure to the two types of food pellets, the animals were able to consume an equivalent quantity of the non-contingent pellets on alternate days during instrumental training.

Method

Subjects

The subjects were 32 experimentally naive male hooded Lister rats with a mean free-feeding weight of 411 g (range: 345–500 g). Before training they were gradually 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 × 20 × 20 cm). The walls and roof were constructed from aluminium, except for one perspex side-wall. The floor was composed from 0.5-cm stainless-steel rods spaced 1 cm apart. The operant chambers were enclosed in 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, and adjacent to each lever was a recessed food magazine covered by a hinged perspex panel. Forty-five-mg Noyes sucrose pellets could be delivered into the magazines of two of the chambers, and 45-mg Campden Instruments mixed-composition food pellets into the magazines of the other two chambers. Illumination was provided by a 3-W bulb mounted in the centre of the roof of each chamber.

Procedure

Baseline training. This stage consisted of three daily sessions of instrumental training reinforced by one type of pellet, alternated with three daily sessions in which the animals were allowed access to an equivalent number of non-contingent pellets of the other type. For 16 subjects the instrumental reinforcer was sucrose and the non-contingent pellets were mixed-composition food pellets, whereas for the other 16 subjects this relationship was

reversed. The order of instrumental and non-contingent sessions was counterbalanced within each group of 16 subjects.

On the first day of instrumental training the levers remained retracted for magazine training and the reinforcer was delivered on a variable-time (VT) 60-s schedule throughout the 30-min session. The subsequent instrumental sessions started with the insertion of the lever and ended with its withdrawal. Each of 50 lever presses were reinforced in the second instrumental session, whereas during the final session lever presses were reinforced on a variable ratio (VR) 9 schedule. This session ended when subjects had made 450 responses, thereby earning 50 reinforcements.

The three non-contingent sessions were of 30-, 20- and 50-min duration respectively, and thus approximately of a duration equivalent to the corresponding instrumental session. On these three days the levers were always retracted and 30, 50 and 50 of the non-contingent pellets respectively were placed in the magazine prior to the start of each session.

Food-aversion training. After completion of baseline training the subjects were allocated to two groups ($N=16$). For half the subjects in each group the reinforcer was sucrose and the non-contingent pellets mixed-composition food, and for the other half the reinforcer was mixed-composition food and the non-contingent pellets sucrose. This stage was carried out in the operant chambers, with the levers retracted, over three two-day cycles. On the first day of each cycle Group P (paired) were allowed 15-min access to 50 reinforcer pellets which had been placed in the magazine. They were then given an intraperitoneal (ip) 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 pellets uneaten. Group U (unpaired) received identical treatment except that they had access to 50 pellets of the non-contingent type prior to the LiCl injection. On day 2 of each cycle each subject was allowed access to pellets of the opposite type to that consumed on day one of that cycle before being given an ip injection of 13-ml/kg 0.15 M saline. The magazine was preloaded with the number of pellets consumed on the first day of the cycle unless this was less than 20 when the animals were allowed to consume 20 of the appropriate pellets. For Group P the pellets were of the non-contingent type, whereas Group U received the pellets which had previously served as the reinforcer.

Extinction and reacquisition. 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 reacquisition of lever pressing for the original reinforcer was tested in a 20-min session, during which the animals were able to earn the reinforcer programmed on a VR-9 schedule. On the final day reacquisition of lever pressing for the non-contingent pellets, programmed on a VR-9 schedule, was tested in a 20-min session. The extinction and reacquisition sessions started and terminated with the insertion and withdrawal of the lever, and responses were recorded in 5-min blocks. In addition, for the reacquisition tests the number of pellets earned and number consumed by each subject was determined.

Results and discussion

In the last session of instrumental baseline training the mean lever press response rates for Groups P and U were 16.8 and 17.8 responses per minute respectively. An analysis of variance revealed neither a significant effect of groups ($F<1$) nor a significant effect of whether the reinforcer was sucrose or food ($F<1$). All subjects rapidly acquired a discriminated aversion to the pellets paired with LiCl. During the last food-aversion cycle, no subject in Group P consumed any reinforcer pellets but each consumed at least 17 of the 20 non-contingent pellets presented. In contrast, no subject in Group U consumed any non-contingent pellets but each consumed at least 18 of the 20 reinforcer pellets presented.

As there was no significant effect of whether the reinforcer was sucrose or food

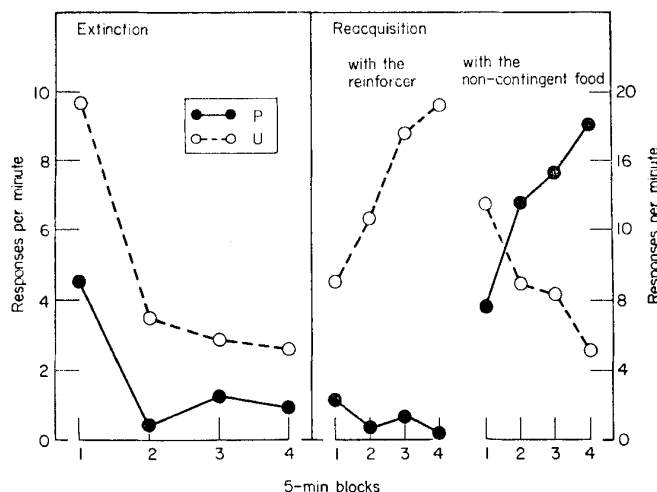


FIGURE 1. Experiment I: mean response rates in 5-min blocks of Groups P and U during extinction and reacquisition sessions. P: paired; U: unpaired.

on responding during the extinction and reacquisition sessions [$F(1,28)=1.4$, $P>0.10$] and no significant interactions involving this factor, the performance of animals receiving the sucrose and mixed-composition food as the reinforcer have been combined in Figure 1. In contrast to all previous studies of the effect of reinforcer devaluation on free-operant responding, the group with an aversion to the reinforcer, Group P, showed less responding in extinction than the unpaired group, Group U. There was a significant effect of groups [$F(1,28)=7.3$, $P<0.05$], but no significant Group \times Block interaction [$F(3,84)=2.6$, $P>0.05$].

The reacquisition performance shows that the food-aversion procedure was successful in selectively attenuating the reinforcing properties of the original instrumental reinforcer in Group P and the non-contingent food in Group U. In the first session, during which the original reinforcer was contingent on lever pressing, Group P showed no increase in the rate of responding, whereas Group U showed a rapid increase over successive 5-min blocks. This difference is supported by a significant effect of groups [$F(1,28)=35.2$, $P<0.01$] and blocks [$F(3,84)=8.6$, $P<0.01$] and a significant Group \times Block interaction [$F(3,84)=14.9$, $P<0.01$]. During the second reacquisition session responses were reinforced with the originally non-contingent food, and whereas Group P showed a marked increase in responding, the response rates declined in Group U. There was a significant Group \times Block interaction [$F(3,84)=24.2$, $P<0.01$], although the effects of groups [$F(1,28)=3.0$, $P>0.05$] and blocks ($F<1$) were not significant. During reacquisition with the reinforcer, no subjects in Group P consumed any of the reinforcer pellets earned, whereas every subject in Group U consumed all pellets earned. In contrast, during the second reacquisition session, all the animals in Group P consumed all pellets, whereas no Group U subject consumed any pellets.

Experiment II

Although the first study demonstrates that instrumental performance can be affected by devaluation of the reinforcer, it does not show that this effect is mediated by the instrumental contingency between the response and reinforcer. This point can be illustrated by considering Miller's (1935) original explanation of the devaluation effect, an account subsequently endorsed by Chen and Amsel (1980) in explaining the action of food-aversion training on runway performance. Miller pointed out that an instrumental training procedure not only arranges a response-reinforcer contingency, but also a potential Pavlovian relationship between the contextual stimuli and the reinforcer. As a result these stimuli may become capable of activating, in contemporary terminology, some representation of the reinforcer which might then interact with performance of the instrumental response. The devaluation procedure, by altering the significance of the reinforcer, may well change the Pavlovian responses elicited by the contextual stimuli and hence their capacity to modulate instrumental responding. There are good reasons for taking this argument seriously. Holland and his colleagues (Holland and Rescorla, 1975; Holland and Straub, 1979) have shown that appetitive Pavlovian responses can be changed by post-conditioning aversion training to the reinforcer.

One way of evaluating this account is to ensure that the contextual stimuli are equally associated with two potential Pavlovian reinforcers, one of which acts as an instrumental reinforcer while the other occurs in a non-contingent relationship to the instrumental response. If the devaluation effect depends upon the instrumental contingency, devaluation of the reinforcer should depress responding more than the equivalent devaluation of the non-contingent food. On the other hand, as the instrumental reinforcer and non-contingent food bear the same Pavlovian relationship to the contextual stimuli, establishing an aversion to either of these foods should have similar consequences for instrumental performance if a Pavlovian mechanism mediates the devaluation effect. Experiment I went some way to meeting the requirements of such a design in that the same number of reinforcers and non-contingent food pellets were consumed in the presence of the contextual cues prior to food-aversion training. Even so, it could be reasonably argued that the reinforcer and non-contingent food brought about different levels of Pavlovian conditioning to the contextual stimuli as the temporal distribution of the two types of food pellets in the presence of these cues differed. The distribution of the reinforcer was determined by the animals' response pattern, whereas they had massed free-access to the non-contingent food from the start of the session. Furthermore, although many of the cues provided by the operant chamber were equally correlated with the non-contingent food and reinforcer, one important local feature, the lever itself, was only present on instrumental training sessions and thus positively correlated with the reinforcer but negatively correlated with the non-contingent food. To the extent that Pavlovian conditioning to the lever may have controlled extinction performance, the results of the first study could be attributed to changes in the Pavlovian responses elicited by the lever as a consequence of reinforcer devaluation. Experiment I also confounded a second potential function of the reinforcer with its role in the instrumental contingency. The

reinforcer may have acquired discriminative control over lever pressing in that instrumental responding was only reinforced during sessions in which contingent, but not non-contingent, pellets were presented. There is good evidence that a reinforcer can acquire discriminative control over responding during free-operant training (Rescorla and Skucy, 1969). Thus, it is possible that the effect of devaluing the contingent pellets was mediated by their role as a discriminative stimulus rather than their reinforcing function brought about by the instrumental contingency.

A prerequisite for interpreting a reinforcer devaluation effect in terms of the associative structure underlying instrumental responding is a demonstration that the effect is, at least in part, mediated by the response-reinforcer contingency. In the second study we attempted to provide such a demonstration by equating the potential Pavlovian relationships between contextual cues and the reinforcer and non-contingent food. It is, of course, impossible to ensure the same distribution of response-dependent and truly response-independent events within the contextual cues, for the pattern of responding itself must determine both distributions if they are to be similar. As a result, we chose to present the reinforcer and non-contingent food in strict alternation throughout each baseline instrumental training session, while degrading the reinforcing function of the non-contingent food by imposing a fixed delay between a lever press and its presentation. This schedule brings about approximately similar distribution of reinforcer and non-contingent food presentations throughout the session. Furthermore, it has the advantage of ensuring that the best discriminative stimulus for reinforced lever presses is the presentation of the non-contingent food, rather than the reinforcer. Consequently, if animals with an aversion to the reinforcer showed less responding in an extinction test than those with a comparable aversion to the non-contingent food, it would be reasonable to attribute this devaluation effect to the instrumental contingency rather than to the Pavlovian relationship between the contextual cues and the reinforcer or the discriminative function of the reinforcer.

Method

Subjects and apparatus

The subjects were 48 experimentally naive male hooded Lister rats with a mean free-feeding weight of 350 g (range: 254–480 g). They were reduced to and maintained at 80% of their free-feeding weights as for Experiment I.

Subjects were tested in two operant chambers as described for Experiment I. Each chamber was modified by adding a second pellet dispenser, so that both 45-mg Noyes sucrose pellets and Camden Instruments mixed-composition food pellets could be delivered to each food magazine.

Procedure

Baseline training. The experiment was carried out in two replications ($N=24$). In the first replication the reinforcer was sucrose and the non-contingent pellets were the mixed-composition food, whereas in the second replication this relationship was reversed.

All subjects were given two 30-min sessions of magazine training, with the levers retracted, throughout which non-contingent and reinforcer pellets were delivered in strict alternation, programmed on a VT 60-s schedule. In the next session 50 lever-press responses were reinforced. The session began with insertion of the lever and delivery of a non-contingent

pellet. Reinforcer and non-contingent pellets were thereafter available in strict alternation. Each non-contingent pellet was delivered 5 s after collection of the preceding reinforcer as indexed by the operation of the magazine flap; furthermore, any responses occurring in this interval were not reinforced and delayed the delivery of the non-contingent pellet for a further 5 s. Only when the subject had received and collected the non-contingent pellet would the next response be reinforced. This patterning of reinforcer and non-contingent pellets was maintained in the final session of baseline training, but responses were now reinforced on a VR-9 schedule. Half way through each ratio, the VR schedule was suspended and a non-contingent pellet was delivered when the animal had refrained from responding for 10 s. As soon as the non-contingent pellet was collected, the VR schedule was reinstated and the animal then had to complete the ratio to earn the next reinforcer. The session ended when a subject had earned 50 reinforcers.

Food-aversion training. This was identical to the procedure employed in Experiment 1. In the paired condition an aversion was established to the pellets previously serving as the instrumental reinforcer, and in the unpaired condition to the non-contingent pellets.

Extinction and reacquisition. 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 two reacquisition sessions in which responding was reinforced, first with the original reinforcer, and then with the non-contingent pellets, both programmed on a simple VR-9 schedule.

Results and discussion

In the first replication six subjects were eliminated because they failed to eat all of the pellets during the magazine training sessions, so reducing the number of subjects in the paired and unpaired conditions to nine. Similarly, in the second replication, two subjects were excluded for failing to magazine train. Furthermore, to equate the number of subjects in each group of the two replications, two subjects were eliminated from both the paired and unpaired groups of the second replication. The eliminated subjects were those in each group with the least difference between their response rates in the two reacquisition tests. The size of this difference reflects the extent to which the food-aversion procedure selectively attenuated the reinforcing capacity of the appropriate pellet. Consequently, the analyses presented below are based on the performance of the nine subjects remaining in each of the four groups comprising two replications.

The mean response rates on the last day of baseline training in the paired condition were 13.0 and 14.8 responses per minute for animals for which the reinforcer was sucrose (Group P-S) and food (Group P-F) respectively. The response rates for the corresponding unpaired groups (Groups U-S and U-F) were 12.5 and 15.0 responses per minute respectively. There were no significant effects of either aversion treatment ($F < 1$) or whether the reinforcer was sucrose or food [$F(1,32) = 2.5$, $P > 0.05$]. As in the previous experiment, all animals rapidly learned a discriminated food-aversion to the food paired with LiCl.

Animals with an aversion to the reinforcer responded less in extinction than those with an aversion to the non-contingent food. This difference is illustrated in Figure 2, in which response rates for the paired and unpaired aversion treatments are presented separately for each reinforcer type. The data were not collapsed across reinforcer type because an analysis of variance revealed that animals receiving the mixed-composition food as the reinforcer responded significantly faster than those for which the sucrose was the reinforcer, [$F(1,32) = 5.6$, $P < 0.05$]. How-

ever, the main effect of the aversion treatment was significant [$F(1,32)=7.3$, $P<0.02$] and this factor did not interact significantly with reinforcer type ($F<1$). There was also a significant decrease in responding across successive blocks [$F(3,96)=57.9$, $P<0.01$], but none of the interactions involving this factor were significant [$F(3,96)<2.5$, $P>0.05$].

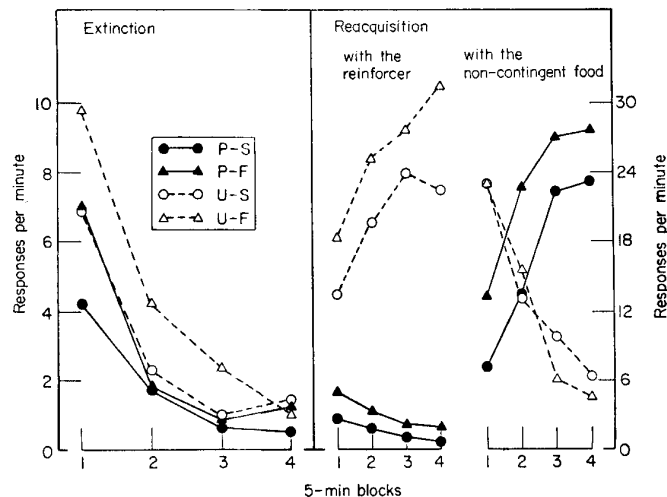


FIGURE 2. Experiment II: mean response rates in 5-min blocks of all groups during extinction and reacquisition sessions. P-S: paired-sucrose reinforcer; P-F: paired-mixed composition food reinforcer; U-S: unpaired-sucrose reinforcer; U-F: paired mixed composition food reinforcer.

The pattern of reacquisition performance confirmed that the aversion treatment was effective in selectively attenuating the reinforcing capacity of the appropriate pellets in the paired and unpaired conditions. The mean response rates for each group during the two reacquisition sessions are shown in Figure 2, and clearly follow a very similar pattern to those of Experiment I. In the first session, with the reinforcer, the two unpaired groups showed a rapid recovery across successive blocks, whereas the two paired groups failed to show sustained responding. An analysis revealed significant effects of aversion treatment [$F(1,32)=115.1$, $P<0.01$] and blocks [$F(3,96)=6.6$, $P<0.01$] and a significant Aversion treatment \times Block interaction [$F(3,96)=16.6$, $P<0.01$]. As in the extinction test, animals for which the reinforcer was the mixed-composition food tended to respond at somewhat faster rates, although this difference was not significant [$F(1,32)=3.8$, $P>0.05$]. The performance of the two unpaired groups in the second reacquisition test confirmed that the reinforcing capacity of the non-contingent food was markedly reduced for these subjects. By contrast, the two paired groups showed a rapid and complete recovery of responding by the fourth block. There was a significant effect of aversion treatment [$F(1,32)=11.9$, $P<0.01$] and a significant Aversion treatment \times Block interaction [$F(3,96)=72.5$, $P<0.01$], but no significant effects of reinforcer type [$F(1,32)=1.8$, $P>0.05$] nor of blocks ($F<1$). During the re-

acquisition with the reinforcer, no subject in Groups P-S and P-F ate any of the reinforcer pellets earned, whereas every subject in Groups U-S and U-F ate all pellets earned. By contrast, in the reacquisition test with the non-contingent food, paired group subjects consumed all pellets, whereas no subject in the unpaired groups consumed any pellets.

The results of this study replicate those of the first experiment in that animals with an aversion to the reinforcer responded at a lower rate in extinction than those with a comparable aversion to the non-contingent food. Furthermore, in the present study this devaluation effect could not have been mediated by a change in a Pavlovian response established by the actual correlation between the reinforcer and the contextual cues, for the reinforcer and non-contingent food bore the same correlation to these contextual stimuli. It is also unlikely that the discriminative role of the reinforcer was important. If anything, the schedule of non-contingent food presentation placed it in a more favourable relationship for the development of discriminative control than the reinforcer. In the absence of any more plausible accounts, we can conclude that the reinforcer devaluation effect was mediated by the instrumental contingency established during initial baseline training.

General discussion

Even if we accept that the devaluation effect depends upon the response-reinforcer relationship, there are a variety of mechanisms by which this contingency could exert its effect. The most straightforward account is to assume that instrumental performance is based on some form of knowledge about the response-reinforcer contingency (Asratyan, 1974; Bolles, 1972; Irwin, 1970; Mackintosh and Dickinson, 1979; Mowrer, 1960) and reflects the deployment of such knowledge in a way that is appropriate given the current value of the reinforcer. Thus, when the reinforcer is devalued, the animals should be less ready to respond. It must be acknowledged, however, that our experiments do not force us to this conclusion.

Although the procedure employed in Experiment II controlled for the role of Pavlovian conditioning brought about by the actual correlation between the contextual stimuli and the reinforcer, it is possible to offer a purely Pavlovian account in terms of the perceived correlation. At the time the reinforcer is delivered the instrumental contingency ensures that the animal is in the vicinity of the lever and thus likely to be selectively registering local features of the chamber, such as the lever itself. If such perceived correlations can support selective Pavlovian conditioning to these local stimuli, we might expect subsequent devaluation of the reinforcer to cause the animal to avoid these stimuli, and thereby interfere with the instrumental response. A similar account could be developed in terms of two-process learning theory by appealing to the role of the local features as Pavlovian conditioned stimuli. This theory assumes that a Pavlovian conditioned expectancy of the reinforcer, brought about by the correlation between the environmental stimuli and the reinforcer, either forms part of the stimulus complex controlling the response by a S-R mechanism (Trapold and Overmier, 1972) or provides a motivational influence on instrumental responding (Rescorla and Solomon, 1967).

Once again, if the Pavlovian expectancy is selectively conditioned to features of the chamber in the vicinity of the lever, reinforcer devaluation could operate by modulating this Pavlovian process. As long as one employs as an instrumental response an activity which, when performed, produces a change in external stimulation, it remains possible that behavioural adjustments to change in reinforcer value reflects the operation of a purely Pavlovian process rather than knowledge about the consequences of an action.

The present results stand in marked contrast to previous studies on the effect of devaluing a free-operant reinforcer by food-aversion training (Adams, 1980; Holman, 1975; Morrison and Collyer, 1974), which have uniformly failed to find any effect on extinction performance. At present, we do not know which factors determine whether or not an instrumental activity will be autonomous of the current value of the reinforcer. Recently, Wilson, Sherman and Holman (1980) observed that extinction performance, following aversion training to the reinforcer, was depressed only when responding continued to produce a stimulus which had been associated with the reinforcer during initial training. In the present studies, however, a devaluation effect was observed in the absence of such stimuli. Our experiments differed from those revealing behavioural autonomy both in terms of the reinforcement schedule employed during initial training and the extent and distribution of this training. The potential importance of the reinforcement schedule is highlighted by Chen and Amsel's (1980) observation that their devaluation effect could be abolished by employing a partial reinforcement schedule. In addition, we have found that extending the amount of initial instrumental training and distributing such training in a spaced, rather than massed, pattern may be important in enhancing resistance to reinforcer devaluation (Adams and Dickinson, in press). Finally, starting from the observation that second-order Pavlovian conditioning can be insensitive to reinforcer devaluation (e.g. Holland and Rescorla, 1975), Rescorla (1973) has suggested that instrumental behaviour may show a corresponding autonomy to the extent that analogous processes are involved in supporting the behaviour.

It has long been known that operant behaviour is sensitive to post-conditioning changes in the value of the reinforcer brought about by alterations in the motivational state of the animal (Holman, 1975; Kriekhaus and Wolf, 1968). On the most general level, the present results provide a further demonstration of the flexibility of such behaviour by demonstrating that operant activity is also sensitive to changes in the conditioned significance of the reinforcer.

This work was supported by project grants from the SRC and MRC and by an SRC postgraduate studentship to C. D. Adams. We should like to thank Peter Lovibond for his comments on the manuscript.

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. and DICKINSON, A. (in press). Actions and habits: Variations in associative representations during instrumental learning. In Miller, R. R. and Spear, N. E. (Eds), *Memory Mechanisms in Animal Behavior*. Hillsdale, N. J.: Erlbaum.

- ASRATYAN, E. A. (1974). Conditioned reflex theory and motivational behavior. *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**, 831-3.
- CLARKE, J., WESTBROOK, R. F. and IRWIN, J. (1979). Potentiation instead of overshadowing in the pigeon. *Behavioral and Neural Biology*, **25**, 18-29.
- GALEF, B. G., Jr. and OSBORNE, B. (1978). Novel taste facilitation of the association of visual cues with toxicosis in rats. *Journal of Comparative and Physiological Psychology*, **92**, 907-16.
- GARCIA, J., KIMELFORF, D. G. and KOELLING, P. A. (1955). Conditioned aversion to saccharine resulting from exposure to gamma radiation. *Science*, **122**, 157-8.
- HOLLAND, P. C. and RESCORLA, R. A. (1975). The effect of two ways of devaluing the unconditioned stimulus after first- and second-order appetitive 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**, 65-78.
- HOLMAN, E. W. (1975). Some conditions for the 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.
- KRIEKHAUS, E. E. and WOLF, G. (1968). Acquisition of sodium by rats: Interaction of innate mechanisms and latent learning. *Journal of Comparative and Physiological Psychology*, **65**, 197-201.
- LETT, B. T. (1980). Taste potentiates color-sickness associations in pigeons and quail. *Animal Learning and Behavior*, **8**, 193-8.
- 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.: Lawrence Erlbaum Associates.
- 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 conditioned aversion to an exteroceptive stimulus following LiCl poisoning. *Journal of Comparative and Physiological Psychology*, **80**, 51-5.
- MOWRER, O. H. (1960). *Learning Theory and Behavior*. New York: Wiley.
- RESCORLA, R. A. (1973). Second-order conditioning: Implications for theories of learning. In McGUIGAN, F. J. and LUMSDEN, D. B. (Eds), *Contemporary Approaches to Conditioning and Learning*, pp. 127-150. Washington, D.C.: Winston.
- RESCORLA, R. A. and SKUCY, J. C. (1969). Effect of response-independent reinforcers during extinction. *Journal of Comparative and Physiological Psychology*, **67**, 381-9.
- 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.
- RUSINIAK, K., HANKINS, W., GARCIA, J. and BRETT, L. (1979). Flavor-illness aversions: Potentiation of odor by taste in rats. *Behavioral and Neural Biology*, **25**, 1-17.
- 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. (1980). An aversion to the reinforcer differentially affects conditioned reinforcement and instrumental responding. Unpublished manuscript.

Manuscript received 11 July 1980