The influence of context-reinforcer associations on instrumental performance

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In each of two experiments, rats were trained to press the lever in a Skinner box, food reinforcement being available on a variable-interval 60-sec schedule (VI 60). There followed an "exposure phase" for which the levers were removed from the boxes, and then a final test with the levers replaced to assess the effects of the intervening treatment on instrumental responding. Experiment 1 showed that simple exposure to the box reduced the vigor of instrumental performance in comparison with a condition in which food was made available during the exposure phase. Animals which received no exposure treatment also showed a relatively high rate of response. Experiment 2 demonstrated that an exposure treatment in which the occurrence of food is signaled by a light stimulus also leads to a decline in instrumental responding. These results are held to support the notion that associations between the context and the reinforcer serve to energize appetitive instrumental behavior.

It is now widely accepted that procedures designed to produce instrumental learning may also permit the formation of Pavlovian or classically conditioned associations. Thus, when a rat is trained to press a lever for food in a Skinner box, there is probably formed, in addition to some association involving the response, some stimulus-stimulus association. It is likely, for instance, that the Skinner box itself becomes associated with the presentation of food pellets. The experiments reported here are concerned with assessing the role played by such a context-food association in determining instrumental performance.

There are a number of reasons for anticipating that the strength of instrumental responding should be directly related to the strength of a context-food association. For example, although neither Hull (1952) nor Spence (1956) conceived of Pavlovian conditioning as the formation of stimulus-stimulus associations, they both assumed that context-elicited conditioned responses (CRs) could influence the vigor of instrumental responding by generating incentive motivation. Much of the theorizing of Hull (1952) and Spence (1956) is now no longer widely accepted, but the notion of incentive motivation remains a common feature of more recent two-process theories of learning (Konorski, 1967; Logan, 1960; Rescorla & Solomon, 1967). According to these theories, the strength of a context-food association will determine

the level of activity in an incentive motivational system which will, in turn, determine the vigor of behavior. A similar prediction can also be found in those theories which assume that context-elicited CRs influence the performance of instrumental responses purely by associative processes (cf. Trapold & Overmier, 1972). According to this approach, a context-food association will lead to the elicitation of an anticipatory goal response r_g . The feedback from this response s_g , is then assumed to play a prominent role in behavior since it will form a component of the stimulus complex that elicits the instrumental response. Thus, procedures designed to modify the strength of s_g (by manipulating the strength of the context-food association) will have a corresponding influence on the probability of the occurrence of the instrumental response. The purpose of the present paper is not to choose between these different accounts, but to determine whether their common prediction concerning the relationship between the strength of the context-food association and instrumental responding is correct.

At present, the evidence in support of this prediction is not convincing. Several studies have reported that it is possible to reduce the rate of instrumental responding by changing the context after the completion of instrumental training (e.g., Welker & McAuley, 1978; Welker, Tomie, Davitt, & Thomas, 1974). But in these studies it is not clear whether the decrement in responding is due specifically to the removal of context-food associations or to generalization decrement. In addition, a number of somewhat different experiments (e.g., Tomie, 1976) have shown that the presence of context-food associations can retard the development of keypecking in pigeons. This finding need not, however, contradict the pre-

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diction that such associations should facilitate responding. It is likely that Tomie's (1976) results were due to the context-food association blocking the development of a Pavlovian association necessary for autoshaping, rather than to any interaction between Pavlovian and instrumental learning. The reported experiments were designed to provide a more direct test of the role of context-food associations.

Rats were initially given a number of sessions of instrumental leverpress training to establish the instrumental response and any context-food association that might be formed. In the second stage, instrumental training was discontinued (the levers were removed from the Skinner boxes) and the rats were exposed to training designed to modify the strength of the context-food association. Finally, the levers were replaced and the rate of response was used to assess the effectiveness of the Stage 2 training. To be more specific, we examined the effects of two types of Stage 2 training, both of which might be expected to reduce the strength of the context-food association and thus, according to the theories discussed above, produce a reduction in response rate in the final test stage.

EXPERIMENT 1

In this experiment, three groups of rats were trained to press the lever in a Skinner box for food reinforcement. During the second phase of training with the levers removed, one group (the exposure-food group) received occasional pellets of "free" food. For a second group (exposure only), no food was delivered. This treatment should be sufficient to maintain a context-food association in the first group, but such an association will suffer extinction in the second group. The effects of the treatment were examined in a single test session during which the levers were replaced. A third group (no exposure) received identical Stage 1 training, but during the exposure phase (Stage 2) the subjects remained in their home cages. This group allowed us to determine what effects, if any, were produced by simply interpolating a time interval between instrumental training and the test phase. During the test phase, no food was available, since it was felt that the presentation of reinforcers might lead to a rapid increase in response rate in all groups which might mask any differences produced by the exposure phase.

Method

Subjects. The subjects were 24 male hooded Lister rats approximately 3 months old at the start of the experiment. Before training, they were reduced to 80% of their free-feeding weights by food deprivation and were maintained at this level by being fed a limited amount of food after each experimental session. At the beginning of the experiment, they were distributed at random among the three experimental groups (eight/group).

Apparatus. Two identical Skinner boxes, $20.3 \times 23.8 \times 22.9$ cm, were used. Each was equipped with a single Campden Instruments response lever adjacent to a recessed food tray to which 45-mg food pellets could be delivered. Each box was housed in a sound- and light-resistant chamber which contained an exhaust fan providing background masking noise of 53 dB re $20 \mu\text{N/m}^2$. The Skinner boxes were not illuminated.

Procedure. For the first two sessions, the levers were removed from the boxes and subjects were magazine-trained, food pellets being delivered on a variable time (VT) 60-sec schedule. The levers were replaced for the third session, and the first 64 responses were reinforced by the delivery of a single food pellet. Shaping was used where necessary. On the fourth session, responding was reinforced on a variable-interval (VI) 30-sec schedule. There followed seven sessions of Stage 1 instrumental training, during which responding was reinforced according to a VI 60-sec schedule. On the last of these sessions, the pellet dispenser failed for one subject in the no-exposure group, and this subject was excluded from the remainder of the experiment.

The levers were removed from the Skinner boxes for the next two sessions, during which subjects in the exposure-food group were placed in the apparatus and received "free" food pellets delivered on a VT 60-sec schedule. The exposure-only group subjects were also placed in the apparatus for these sessions, but they received no food. The no-exposure group remained in their home cages during this stage of the experiment.

On the following day, all subjects received the test session, during which the levers were replaced but no food was delivered. With the exception of Session 3 and the two exposure sessions, each of which lasted 45 min, the session duration throughout the experiment was 30 min.

Results

The mean rate of responding shown by each group on the final acquisition session and on the test session is shown in Figure 1. The response rates of the three groups appear to be closely similar on the acquisition session but to differ on the test session, and this impression is confirmed by statistical analysis. There was no significant difference among the groups

Figure 1. Group mean response rates in Experiment 1 for the last session of instrumental acquisition and for the test session.

Figure 2. Group mean extinction ratios for Experiments 1 and 2. The ratio is between response rate on the test session and response rate on the last session of instrumental acquisition.

on the acquisition session (Kruskal-Wallis $H = .40$), but there was a significant difference on the test session (Kruskal-Wallis $H = 10.70$, $p < .01$). Further analysis revealed that the rate of response was significantly lower in the exposure-only group than in either the exposure-food group (Mann-Whitney $U = 10$, $p < .02$) or the no-exposure group ($U = 3$, $p < .001$).

To obtain what is perhaps a more accurate reflection of the effects of the exposure phase on the extinction of the leverpress response, we devised a measure which, for each subject, compared the rate of response on the test session with that shown on the final session of instrumental acquisition. This measure, which we will call an "extinction ratio," was computed by dividing the response rate for the extinction session by the response rate for the last acquisition session. A ratio of 1 indicates no decline in the rate of response, whereas a ratio of 0 indicates profound extinction. The mean extinction ratios for the three groups are depicted in the left portion of Figure 2.

Analysis of individual extinction ratios revealed a significant difference among the groups ($H = 12.03$, $p < .01$). Subsequent analysis showed that the extinction ratios were significantly lower; that is, extinction was more profound, in the exposure-only group than in either the exposure-food group ($U = 10$, $p < .02$) or the no-exposure group ($U = 0$, $p < .001$). The difference between these latter two groups was not significant ($U = 22$, $p > .15$).

Discussion

Since the response rates of the three groups were similar on the final session of acquisition, the difference in response rate on the test session must be a result of the different treatments given during

the exposure phase. The similarity in the performance of the no-exposure group and the exposure-food group during the test phase indicates that exposure to the apparatus was not in itself responsible for the significantly lower rate of response shown by the exposure-only group. Instead, it appears that this result was specifically a consequence of nonreinforced exposure to the context. Although other interpretations of this finding will be discussed below, it is sufficient for the time being to point out that it supports the claim that the rate of instrumental responding is directly related to the strength of a context-food association. The initial instrumental conditioning can be assumed to provide the subjects with the opportunity to form an association between the context and food. This association would be maintained during the exposure phase in the no-exposure and exposure-food groups, but would be weakened by a process of extinction in the exposure-only group. The vigor of instrumental responding during the test would be correspondingly weaker in this last group.

Two-process theory has previously sought support for its contention that an appetitive CS energizes appetitive instrumental behavior from experiments in which a discrete stimulus, such as a light or tone, is paired with "free" food and is then superimposed on a baseline of instrumental responding. Such studies have proved difficult to interpret because of the possibility that the CS might have its effects not by way of some central motivational state but because of particular responses it elicits (see, e.g., Karpicke, 1978). A further problem arises in the case of at least two of the studies (Bolles & Grossen, 1970; Estes, 1943), which have demonstrated an enhancement of responding during the presence of an appetitive CS. In these experiments, the CS was presented during instrumental extinction, and Baum and Gleitman (1967) have argued that the enhancement observed might be a result of the stimulus disinhibiting the extinguished instrumental response (see Brimer, 1970). It should be stressed that the results obtained in the previous experiment, although they were derived from an extinction test, cannot be accounted for in terms of disinhibition effects. In our experiment, no stimuli which can be regarded as potential disinhibitors were presented during the final test session.

EXPERIMENT 2

In this experiment, we employed a different procedure to weaken the context-food association in the hope of extending the generality of our previous results. In outline, two groups of rats were given instrumental leverpress training as before and then

both groups received "free" food during an exposure phase. For a signaled-food group, the delivery of each food pellet was preceded by a 30-sec light CS. No stimulus was presented to an unsignaled-food group.

The rationale for this procedure is derived from the work of Wagner and his colleagues (Wagner, 1969; Wagner, Logan, Haberlandt, & Price, 1968), which has shown that the associative strength of a CS is determined, in part, by its relative validity as a predictor of reinforcement. Thus, a stimulus which, like the context in the present experiment, is present both in the presence of reinforcement and its absence will gain associative strength if no better predictor of reinforcement is available. The presence of a better predictor, however, will prevent the less good predictor from gaining associative strength. Further, if preliminary training is given with just the stimulus that is imperfectly correlated with reinforcement, the introduction of a better predictor will cause the first stimulus to lose much of the associative strength gained during the first stage of training (Hall, Mackintosh, Goodall, & dal Martello, 1977).

In the present experiment, therefore, the context-food association should remain strong or even be strengthened further during the exposure phase for the unsignaled-food group. For these animals, the context will be the most reliable predictor of reinforcement. In contrast, the light will be a better predictor of food than the context for the signaled-food group, and we might thus expect a weakening of the context-food association for these subjects. If the rate of response in the final test is determined, in part, by the strength of the context-food association, we should find that the unsignaled-food group responds more readily than the signaled-food group. A third group of animals, given exposure to the apparatus only and no presentations of the light or of food, was included in this study. These animals can be expected to respond at a lower rate than the unsignaled-food group in the final test phase, thus replicating the difference found in Experiment 1 between the exposure-only and exposure-food groups.

Method

The subjects were 24 naive male Lister rats about 3 months old at the beginning of the experiment. The deprivation conditions and apparatus were the same as for Experiment 1. A 3-W bulb, operated at 24 V and situated 10 cm above the food tray, provided the light CS.

The rats were trained to press the lever and were then given seven sessions of VI training, as in Experiment 1. They were then divided into three equal groups for the exposure phases, which consisted of four 45-min sessions. The exposure-only group received no stimuli during this phase. For the remaining two groups, food was delivered on a modified VT 60-sec schedule. The timer controlling this schedule was halted for 30-sec after scheduling each reinforcer, and during this interval the light was presented to subjects in the signaled food group. At the end of the 30-sec interval, the light was turned off, food delivered, and the timer restarted. The final session was the extinction test ses-

sion. Procedural details not given here were the same as those described for Experiment 1.

Results and Discussion

The response rate on the final session of instrumental acquisition was 12.1 responses/min for the signaled-food group, 11.3 for the unsignaled-food group, and 11.5 for the exposure-only group. There was no significant difference among these scores ($H = 1.8, p > .3$).

Figure 2 presents the mean extinction ratios for the three groups. It is evident that more vigorous responding was shown (as reflected in the higher ratio) by the unsignaled-food group than was shown by either of the other groups. Analysis of the extinction ratios showed a significant difference among the groups ($H = 7.04, p < .05$). Further analysis indicated that the extinction ratios in the unsignaled-food group were higher than in either the signaled-food group ($U = 12, p < .05$) or the exposure-only group ($U = 9, p < .05$). The two latter groups did not themselves differ significantly ($U = 30, p = .4$).

This experiment replicates, therefore, one of the findings of Experiment 1 by showing that a period of exposure to the experimental apparatus produces a lower rate of responding in the final test than does a similar period of exposure in which free food is made available. Our new finding is that by signaling the food presentations during the exposure phase it is possible to reduce their effectiveness to the extent that animals which have received this treatment respond no more readily than those subjects that received no food at all during exposure. If it is accepted that signaling the occurrence of food weakens the context-food association, then this pattern of results can be seen as providing further evidence for the idea that the strength of such an association determines the rate of instrumental responding.

GENERAL DISCUSSION

The results of the two experiments reported here are quite consistent with the view that context-food associations are formed during instrumental conditioning and that these associations play a part in energizing instrumental performance. It is appropriate, however, to consider an alternative explanation for these results.

We should mention the possibility that the results of the test phase reflect the effects not of classical but of some form of instrumental conditioning occurring during the exposure phase. Certainly the fact that the levers were removed does not preclude the possibility that some patterns of behavior relevant to leverpressing were modified by the treatment

administered during the exposure phase. In particular, it is necessary to assume that some pattern of behavior which tends to promote leverpressing was maintained in animals given exposure-food training but was extinguished in animals given exposure only (Experiments 1 and 2) or signaled food (Experiment 2). It is difficult to assess this idea without a further specification of what this pattern of behavior might be, and consequently we do not wish to discuss it further here.

It should be added, finally, that not all theorists subscribe to the view that a CS for food will invigorate instrumental performance. Mackintosh (1974) has argued that "on intuitive grounds it is hard to see why an animal should be expected to engage in more vigorous instrumental activity in the presence of stimuli which, it has learned, signal the imminent delivery of food. It is precisely in the absence of food that a hungry animal needs to be active" (pp. 231-232). Mackintosh (1974) does not go on to specify a formal theory, but the implication of this view seems to be that by reducing the effectiveness of the context as a signal for the delivery of food it may be possible to produce an increase rather than a reduction in instrumental responding. Although our intuitions accord with those of Mackintosh (1974), it is clear that our experimental results supply no support for the conclusion they lead to.

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