

Omission Learning after Instrumental Pretraining

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Hungry rats were pretrained to press two levers on a concurrent schedule for food pellets. Following either limited or extended pretraining, presentations of a sucrose solution were programmed on a random time schedule while the animals continued pressing on a concurrent schedule for food pellets. Presses on one of the levers—the omission lever—postponed deliveries of the sucrose solution scheduled to occur within a fixed period of time following the press, whereas presses on the other, control lever had no effect on the random time contingency. The animals pressed less frequently on the omission lever than on the control lever following limited pretraining but failed to discriminate between the two levers following extended pretraining. The insensitivity to the omission contingency produced by extended pretraining was due to either the number of presses performed during the initial training or the number of reinforced presses, rather than the number of reinforcers received. Finally, the insensitivity of performance on the omission lever to sucrose devaluation suggests that adaptation to this negative contingency was mediated by an inhibitory stimulus–response association.

The idea that the processes controlling instrumental performance change with training can be traced back at least as far as Tolman's (1932) claim that animals can become "fixated" upon instrumental activities. More recently, Dickinson and his colleagues (Dickinson, 1985, 1989; Dickinson, Balleine, Watt, Gonzalez, & Boakes, 1995) have suggested that performance during the initial stages of training is predominantly controlled by knowledge of the relationship between the response (R) and the reinforcer or outcome (O), but that with extended training control shifts to a stimulus (S)–response (R) mechanism.

The main evidence in favour of this dual-process theory comes from studies of variations in the resistance to outcome devaluation with the extent of training. Dickinson et al. (1995), for example, trained food-deprived rats to press a lever for a food reward on an interval schedule across a series of sessions in which they were allowed to earn 30 food pellets per session. Animals in the limited, 120-reward condition (120 condition) were

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trained for only four sessions, whereas those in the extended, 360-reward condition (360 condition) received a further eight sessions of training. Following this training, the food reward was devalued by shifting the motivational state of the animals in combination with an incentive learning treatment. During this treatment the rats had unrestricted access to their maintenance diet and were allowed to consume the food reward in this undeprived state. When instrumental performance was subsequently tested in extinction, a devaluation effect was observed in the limited-training condition, in that animals for whom the food reward had been devalued by the incentive learning treatment pressed less during the extinction test than those who had not received the incentive learning treatment. By contrast, no devaluation effect was observed following extended training, and performance was autonomous of the current value of the outcome. A number of years ago, Adams (1982) also reported behavioural autonomy—in this case after outcome devaluation by aversion conditioning, following extended training (but see Colwill & Rescorla, 1985a, 1988).

On the assumption that outcome devaluation is mediated by the R–O but not the S–R process, Dickinson et al. (1995) argued that the variation in resistance to devaluation reflected a shift in the dominant process. Although there are a variety of reasons why such a shift may occur, Dickinson et al. offered an account in terms of the experienced reinforcement schedules. They pointed out that during the initial stages of their study lever pressing was trained on a relatively rich schedule, which should establish strong R–O learning, whereas overtraining occurred on a leaner schedule, which should sustain weaker R–O learning. This decrement in the contribution of the R–O process to performance was counteracted, they argued, by a progressive strengthening of the S–R association with training. Thus, the R–O process makes a relatively greater contribution to performance during the initial stage of training than during the later stages, with the reverse being true of the S–R process.

Given this dual-process analysis, a surprising feature of the test performance in the Dickinson et al. (1995) study is that the amount of training did not have a major impact on resistance to extinction in the test. This finding suggests that the instrumental performance sustained by R–O and S–R processes are equally resistant to response-decrementing operations, such as extinction. Although we know of no experimental evidence directly addressing this issue, this conclusion is at variance with the common “folk” belief that S–R habits are particularly resistant to extinction and other response-decrementing operations.

The purpose of the present experiments was to re-examine the effect of the amount of training on response persistence. Although the extensive literature on the effects of training on resistance to extinction has yielded highly variable results (see Mackintosh, 1974, for a review), there are reasons to believe that extinction may not be the most sensitive assay of response persistence. Uhl (1973) compared the effect of extending free-operant lever-pressing training on an interval schedule on response persistence under extinction with that under an omission schedule in which lever pressing postponed the delivery of the reward. Although extending the instrumental training produced a general enhancement of response persistence, performance under the omission contingency appeared to be more sensitive to the amount of training than that under extinction. However, the same food reinforcer was employed for the interval and omission training,

and therefore the effect of extended training on response persistence could be attributed to a change in the effectiveness of the reinforcer rather than the nature of the process controlling the response. The greater exposure to the food reward during extended training may have decreased its effectiveness as a reinforcer when presented under the omission contingency. Consequently, we re-examined whether the training parameters employed by Dickinson et al. (1995), which establish differential sensitivity to outcome devaluation, also affect response persistence under an omission contingency. In contrast to Uhl's (1973) procedure, we employed different reinforcers for the training and omission contingencies.

EXPERIMENT 1

The pretraining followed that employed by Dickinson et al. (1995) in their study of outcome devaluation, except that animals were trained to press two levers on a concurrent schedule rather than just a single lever. In the limited training condition (120 condition) the animals received four sessions of instrumental pretraining on a positive contingency; in each session they were allowed to earn 30 food pellets on each lever. By contrast, animals in the extended condition (360 condition) received eight further sessions of initial training.

Following this pretraining, an omission schedule was introduced for presses on one of the levers. A sucrose solution was scheduled to be delivered at various intervals, but each press on the omission lever postponed the delivery of any programmed sucrose presentation for a set omission period. The duration of this omission period was progressively increased across sessions because there is evidence that learning under such a negative contingency is enhanced by gradually lengthening the omission period (Topping, Larmi, & Johnson, 1972; Uhl, 1974). Throughout this omission training, pressing on both the omission lever and the other, control lever continued to be reinforced on a positive schedule with the food pellets to sustain responding.

As rats discriminate between the food pellets and the sucrose solution employed in this experiment (e.g. Dickinson & Dawson, 1989; Dickinson & Nicholas, 1983), there is no reason why the positive contingency between lever pressing and the food pellets, either during pretraining or during omission training, should interfere with learning under the negative relationship with the sucrose solution. To the extent that the negative contingency between lever pressing and the sucrose reward reduces responding, the animals should press at a lower rate on the omission lever than on the control lever. Moreover, this discrimination should be attenuated in the 360 condition relative to the 120 condition if extended training under a positive contingency enhances response persistence.

Method

Subjects and Apparatus

Sixteen naive adult male hood Lister rats of at least 90 days of age and 250 g in weight were housed in groups of four with unlimited access to water in their home cages. Training took place in four operant chambers (Paul Fray Ltd), each equipped with two retractable levers and a dispenser

that delivered 45-mg Noyes pellets (improved Formula A) into a recessed magazine. The rats could gain access to the magazine through a flap door positioned in the centre of the front wall equidistant between the two levers. A peristaltic pump delivered 0.1-ml quantities of a 20% sucrose solution into the same magazine. Each chamber was illuminated by a 3-W 24-V house light mounted in the centre of the roof. A BBC microcomputer, equipped with the Spider extension for on-line control (Paul Fray Ltd), controlled the equipment and recorded lever presses.

Procedure

Pretraining. Food was removed from the home cages on the day prior to the start of the experiment, and thereafter all rats were given free access to their maintenance diet in their home cages for 1.5 h on each day following the completion of training. Half of the animals were assigned to the 120 condition and the remainder to the 360 condition. The animals in the 360 condition received two 30-min sessions of magazine training with the levers retracted on Days 1 and 2. During each of these sessions, pellets were delivered on a random time (RT) 60-sec schedule. On Day 3 each animal received two sessions of instrumental training on a random interval (RI) 2-sec schedule, the first with the left lever and the second with the right one. Each session started with the insertion of the appropriate lever and the onset of the house light and ended with its retraction and the offset of the house light after 30 reinforcers had been delivered.

Thereafter the animals in the 360 condition received a single session per day during which both levers were inserted. Reinforcement was controlled by a single RI schedule that assigned any programmed reinforcer to the left and right levers with equal probability. During each session a total of 60 pellets were delivered—30 contingent upon pressing one lever and 30 contingent on pressing the other. Once the animals had received the 30 scheduled reinforcers on one lever, pressing this lever no longer delivered pellets, but the session continued until the 30 pellets for pressing on the other had been delivered, at which time both levers were retracted to end the session. This schedule ensured that the reinforcers were evenly distributed to the two levers across the session whatever the relative frequencies of left and right presses. On Day 4 the RI parameter was 7 sec, which was then increased to 15 sec for the next 10 days (Days 5–14 inclusive). As the average inter-reinforcement interval for pressing on each lever was double the schedule parameter, this training ensured that the contingencies for each lever approximated those experienced by the animals in the Dickinson et al. (1995) study for pressing on a single lever. Thus, the average inter-reinforcement interval for pressing on each lever was 14 sec on the first day of concurrent training and 30 sec thereafter. A total of 360 reinforcers were presented for pressing on each lever across the 12 sessions of pretraining.

In order to match the handling and transport conditions to those experienced in the 360 condition, on Days 1–8 inclusive the animals in the 120 condition were removed from their home cages and placed in individual cages in an adjacent colony room for approximately the same time as it took the 360 animals to complete a training session. Starting on Day 9, the 120 animals received exactly the same magazine and instrumental training as did those in the 360 condition, except for the fact that they had only two sessions of training on the concurrent RI 15-sec schedule. As a consequence, their pretraining also terminated on Day 14 after 120 pellet reinforcers had been delivered for pressing on each lever.

Omission Training. The omission contingency was assigned to the left lever for half of the animals in each training condition and to the right lever for the remaining animals. The sucrose reward was scheduled on a RT 30-sec schedule. However, if this delivery was programmed to occur within a certain time period—the omission period—following a press on the omission lever, the sucrose delivery was postponed until the termination of the omission period. This period was 10 sec

on the first session of omission training (Day 15) and was then increased through 15 sec (Day 16) to 20 sec. The 20-sec omission contingency remained in force for four sessions (Days 17–20) before the omission period was finally increased to 30 sec for the final four sessions (Days 21–24). Throughout the ten 30-min sessions of omission training, pressing on the two levers was also reinforced by food pellets on concurrent but independent RI 120-sec schedules.

Results and Discussion

The rates of lever pressing during omission training are illustrated in Figure 1. The animals in the 120 condition were sensitive to the introduction of the omission contingency in that the rate of pressing on the omission lever was considerably lower than that on the control lever. Extended pretraining in the 360 condition attenuated this discrimination due to a higher rate of pressing on the omission lever than that in the 120 condition.

These differences are assessed by a mixed analysis of variance in which the between-subject factor distinguishes between the limited and extended pretraining and the within-subject factors of contingency and session contrast performance of the omission and control levers across the sessions of omission training. The reliability of the effects is evaluated against a Type I error rate of 0.05. This analysis yields a significant effect of contingency, $F(1, 14) = 14.16$, and of session, $F(9, 126) = 3.74$, but not of pretraining, $F(1, 14) = 1.26$. Although the interaction between the extent of pretraining and the contingency on the two levers fails to reach the criterion of significance, $F(1, 14) = 3.91$, $p = .07$, planned simple main effects reveal that the rates of pressing on the omission and control levers differ significantly in the 120 condition, $F(1, 14) = 16.48$, but not in

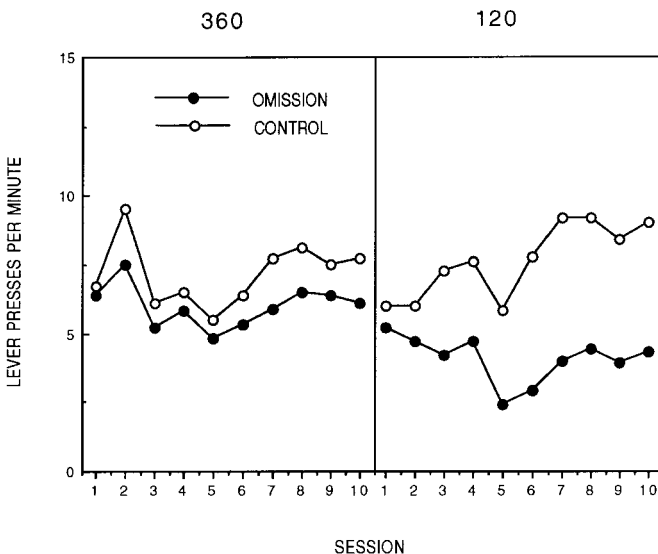


FIG. 1. Experiment 1: Mean number of presses per minute on the omission and control levers following training in the 120 (right panel) and 360 (left panel) conditions.

the 360 condition, $F(1, 14) = 1.59$. Moreover, the animals in the 120 condition pressed at a lower rate on the omission lever than those in the 360 condition, $F(1, 14) = 7.83$, although there is no reliable difference in performance on the control lever, $F < 1$. None of the other interactions from the overall analysis is reliable, $F_s(9, 126) < 1.82$.

The interpretation of the effects observed under the omission contingency is not comprised by performance differences at the end of pretraining. The mean number of presses per minute in the last session of pretraining on the omission and control levers, respectively, are: 8.3 and 7.6 in the 360 condition; and 7.3 and 6.3 in the 120 condition. The animals pressed slightly but reliably faster after 360 than after 120 pretraining reinforcers, $F(1, 14) = 5.31$, and the rates on the omission lever were marginally higher than those on the control lever, $F(1, 14) = 4.41$, $p < .06$. Critically, however, the F ratio for the interaction is less than one. We were somewhat concerned that the higher rates of lever pressing established during pretraining in the 360 condition may have affected the animals' initial contact with the omission contingency. There is, however, no effect of pretraining on the rates of sucrose presentation during the first session of training on the omission contingency, $F < 1$. Animals in the 360 condition received, on average, 1.4 sucrose presentations per minute, whereas those in the 120 condition experienced 1.5 per minute.

The results of this study replicate Uhl's (1973) observation that extended pretraining under a positive contingency enhances response persistence under a negative schedule. Moreover, by employing different rewards for the two contingencies, the present study demonstrates that this persistence is due to the amount of response training rather than prior exposure to the omission reinforcer during the pretraining. Although the animals in the 360 condition pressed at a slightly but reliably higher rate than those in the 120 condition at the end of pretraining, we think it unlikely that the effect of the omission contingency was masked by a "ceiling" effect on the rate of responding in the extended training condition. The rates of pressing on the control lever during the critical omission sessions were similar for the two pretraining conditions. It should be noted, however, that the critical interaction between pretraining and contingency fails to reach the conventional level of reliability and so we sought to replicate this effect in a second study.

EXPERIMENT 2

Dickinson et al. (1995) tested the dual-process theory of behavioural autonomy by attempting to attenuate R-O learning during the limited training condition. Their procedure capitalized on the well-established observation that non-contingent preexposure to a reinforcer retards subsequent learning of a S-O relationship in Pavlovian conditioning (Randich & LoLordo, 1979) by assuming that such preexposure would also retard learning about the R-O association in an instrumental procedure. In fact, there is evidence for retarded acquisition of an instrumental response following non-contingent reinforcement (e.g. Dickinson, Watt, & Varga, 1996). As there is no reason to expect non-contingent preexposure to attenuate the reinforcement of S-R learning, Dickinson et al. (1995) anticipated that, following extensive preexposure to the reinforcer, instrumental performance established by the 120 training condition should be controlled primarily by the residual S-R association established by this limited training. Consequently, performance

after such training, even though restricted in length, should be relatively impervious to reinforcer devaluation.

To assess this prediction, Dickinson et al. (1995) considered the case in which animals received the same total number of reinforcers during initial training as those received in the 360 condition, and in which reinforced lever presses were limited to the number performed by animals in the 120 condition. This was achieved by extending the magazine training so that the animals initially received 240 reinforcers non-contingently without an opportunity to press the lever, before this action was trained under the regime used in the 120 condition. According to the dual-process theory, performance in this 240/ 120 condition should be primarily controlled by a S–R association, albeit a weak one, and therefore should be relatively impervious to outcome devaluation. In accord with this prediction, the 240/ 120 training condition, like the extended 360 condition, yielded behavioural autonomy in that subsequent devaluation of the reinforcer by an incentive learning treatment had little impact on performance relative to the 120 condition. Adams (1982) had previously shown that non-contingent reinforcer pre-exposure also attenuates outcome devaluation by aversion conditioning.

The present study compared the rate of learning under an omission contingency following pretraining in the 240/ 120 condition with that observed following the 360 and 120 pretraining conditions. On the basis of the first study, we expected the animals in the 120 condition to learn the omission contingency more rapidly than those in the 360 condition. More important, however, is the rate of omission learning after 240/ 120 pretraining. The theory assumes that the strength of the S–R process following 240/ 120 pretraining is comparable to that in the 120 condition and weaker than that in the 360 condition. Therefore, on the assumption that the S–R process engenders more persistent responding than the R–O process, the dual-process theory of behavioural autonomy predicts that animals in the 240/ 120 condition should learn the omission contingency at least as fast, if not faster, than do those in the 120 condition and certainly faster than do the rats in the extended 360 condition.

Method

Subjects and Apparatus

Twenty-four naive male hooded Lister rats of an age and weight comparable to those used in the previous studies were housed under the same conditions and trained in the same apparatus.

Procedure

The animals were allocated equally to three different pretraining conditions. Those in the 120 and 360 conditions were pretrained with the same procedure as that employed for the corresponding groups in the previous study. That is, after two sessions of magazine training and two of instrumental acquisition with the left and right levers, the animals received concurrent training with both levers present and pellet reinforcement controlled by the RI schedule. This schedule was such that the average inter-reinforcement interval for each lever was 14 sec on the first session of concurrent training and 30 sec thereafter. This training was scheduled so that it terminated on the same day (Day 14) for the 120 and 360 conditions.

Pretraining in the third condition started at the same time as that in the 360 condition with two sessions of magazine training. Thereafter, however, these animals received eight sessions in each of which 60 pellets were delivered on a RT 15-sec schedule with the levers retracted. These animals then received the same schedule of instrumental pretraining as that employed in the 120 condition and at the same time. Thus, this training regime scheduled the same number of pellet reinforcers with a similar temporal distribution to that used in the 360 condition but an instrumental pretraining procedure that matched that used in the 120 condition. It should be noted that during the RT training these animals received a total of 480 pellets but because conceptually these reinforcers are matched to those earned by pressing on two levers in the 360 conditioning, only 240 are treated as being equivalent to the contingent reinforcers for a particular lever. As the condition designations specify the reinforcer number with respect to a single action, this condition is referred to by the label 240/ 120, in which the first term designates the number of non-contingent reinforcers conceptually allocated to a given action and the second to the number of contingent reinforcers.

Following this pretraining, all animals received 12 sessions of training on the omission contingency using a procedure identical to that employed in Experiment 1. Pressing on both levers continued to be reinforced with the food pellets on concurrent but independent RI 120-sec schedules upon which were superimposed deliveries of the sucrose solution on the 30-sec RT schedule. In addition, presses on the omission but not the control lever postponed the delivery of any scheduled sucrose presentation for a fixed period, which was progressively increased up to a value of 30 sec.

Results and Discussion

Figure 2 illustrates the rates of lever pressing under the omission contingency separately for each training condition. The results from the 360 and 120 conditions replicate those observed in Experiment 1. The animals learned to discriminate between the two levers in

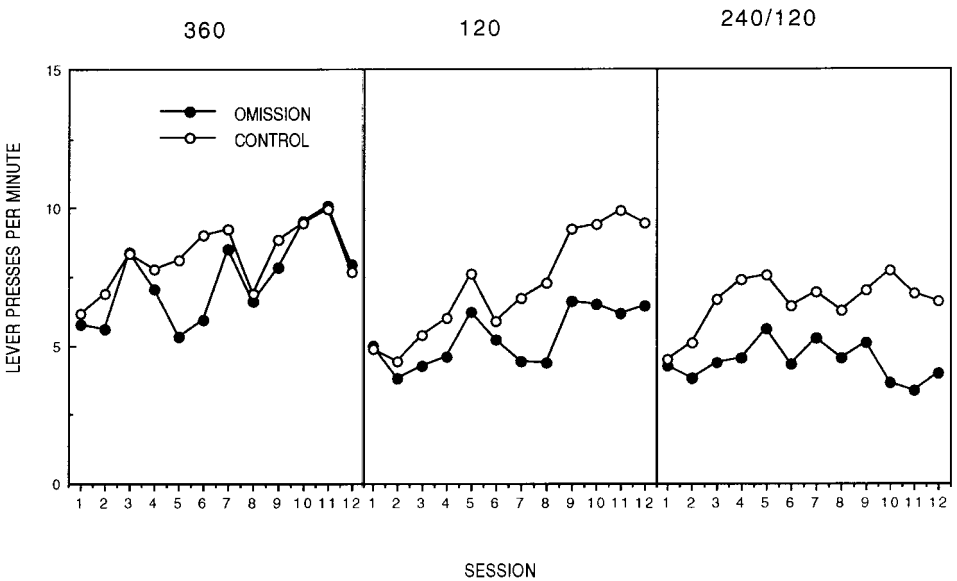


FIG. 2. Experiment 2: Mean number of presses per minute on the omission and control levers following training in the 240/ 120 (right panel), 120 (middle panel), and 360 (left panel) conditions.

the 120 condition so that by the end of this training the rate of pressing on the omission lever was consistently lower than that on the control lever. No such difference was observed in the 360 condition, however. The novel finding is that the 240/ 120 condition produced reliable discrimination which was very similar to that observed for the limited training, 120 condition.

The overall analysis yields significant main effects of contingency, $F(1, 21) = 13.61$, and session, $F(11, 231) = 6.43$, but not of pretraining, $F(2, 21) = 2.59$. More important, however, are the significant Pretraining \times Session interaction, $F(22, 231) = 2.01$, and Pretraining \times Contingency \times Sessions interactions, $F(22, 231) = 1.77$, which prompted separate analyses in each training condition. There are significant effects of contingency in both the 120 condition, $F(1, 21) = 6.13$, and 240/ 120 condition, $F(1, 21) = 8.11$, but not in the 360 condition, $F(1, 21) = 1.14$. Moreover, separate analyses of the rates on each lever produce a significant effect of pretraining for the omission lever, $F(2, 21) = 4.80$, and pairwise comparisons by the Newman-Keuls procedure show that the animals in the 360 condition pressed faster than those in the 120 and 240/ 120 conditions, which did not differ from each other. There is, however, no effect of pretraining on the rate of pressing on the lever control, $F < 1$.

Although the animals in the 360 condition on average pressed at a higher rate on the last session of pretraining than those in the 120 and 240/ 120 conditions, this difference just fails to reach the conventional level of significance, $F(3, 21) = 3.14$, $p = .06$. Importantly, however, there is no difference in performance on the two levers, $F(1, 21) = 2.53$, nor does this difference interact with the pretraining condition, $F < 1$. The mean number of presses per minute on the omission and control levers, respectively, on the final session of pretraining are: in the 360 condition, 10.8 and 10.0; in the 120 condition, 8.5 and 7.8; and in the 240/ 120 condition; 8.7 and 7.5.

This study replicates the effect of extended pretraining on sensitivity to an omission contingency observed in Experiment 1. Although the animals pressed less on the omission lever than on the control manipulandum after limited pretraining, more extended initial training prevented a reliable discrimination emerging. Moreover, the present results confirmed the prediction of the dual-process theory that persistence under the omission contingency is determined by the amount of response pretraining. When the total number and distribution of pretraining reinforcers are matched to those in the extended, 360 condition, but the amount of response pretraining is matched to that in the limited, 120 condition, the degree of response reduction under the omission contingency in the 240/ 120 condition is similar to that exhibited in the limited training conditioning. If it is accepted that the 240/ 120 regime minimizes the contribution of the R-O process (Dickinson et al., 1995), this finding suggests that response persistence is primarily determined by the S-R process.

EXPERIMENT 3

The variation in sensitivity to an omission contingency brought about by the different instrumental pretraining regimes has implications for the nature of the learning process mediating the effect of an omission contingency. An instrumental omission contingency is often referred to as a *differential reinforcement of other behaviour* (DRO) schedule, with

the implication that the response reduction under this contingency is brought about by reinforcing other, competing behaviour. We think that an account of the present results in terms of a DRO process is unlikely for a number of reasons. There are two classes of activities that may compete with pressing the omission lever under the present procedure: pressing the alternative, control lever and engaging in some other activities, such as approaching the food magazine. There is no reason, however, why an enhancement of activities other than lever pressing should interfere selectively with pressing the omission lever rather than the control lever. An enhancement of any third class of behaviour should compete equally with pressing both levers and therefore can not provide an account of variations in the discrimination between performance on the two levers.

Moreover, the overall pattern of performance is not readily explained in terms of competition between the responding on the two levers. Specifically, the comparable performance on the control lever in the extended (360) and limited (120 and 240/120) pretraining conditions is problematic for this account. If the reduction in responding on the omission lever is produced by competition from an enhancement of pressing on the control lever, an elevation in pressing on the control lever should be evident when the omission contingency produces a discrimination between the two levers but not when animals fail to adapt to the contingency. In both experiments, however, we failed to detect reliable differences between the rates of pressing the control lever as a function of pretraining in the presence of differential performance on the omission lever.

An alternative account is that animals learn about the negative relationship between the instrumental response and the reinforcer under an omission contingency. As we have already noted, the standard procedure for detecting control by such a R-O process is that of outcome devaluation (e.g. Adams & Dickinson, 1981; Colwill & Rescorla, 1985b). Having trained an action under an instrumental contingency, the outcome is devalued—for example by conditioning aversion from it—before the performance of the action is tested in the absence of the reinforcer. To the extent that the action is mediated by a R-O process, the performance pattern established during training should be attenuated by the devaluation.

Outcome devaluation was employed in the final study to determine whether a R-O process contributes to performance under the omission contingency. Having trained the animals to press both levers for food pellets under the 120 condition of the previous studies, performance on one lever was suppressed by arranging the omission contingency between pressing and the sucrose solution. Following this training, an aversion was conditioned to the sucrose by pairing its consumption with toxicosis induced by injections of lithium chloride (LiCl). The subsequent test performance of this devaluation group was compared with that of animals in a control group, which received unpaired presentations of the sucrose and LiCl. During the test, pressing both levers was reinforced with the food pellets but no sucrose was presented. To the extent that performance under the omission contingency is mediated by a R-O process, the differential pressing on the omission and control levers should be reduced in the devaluation group relative to the control animals.

Method

Subjects and Apparatus

Sixteen naive male hooded Lister rats of an age and weight comparable to those used in the previous studies were housed under the same conditions and trained in the same apparatus.

Procedure

The animals were trained with the same procedure as that employed for the 120 conditions of the previous studies. After two sessions of magazine training, and two of instrumental acquisition with the left and right levers, the animals received concurrent training with both levers present and the food pellets scheduled by the RI schedule. This schedule was such that the average inter-reinforcement interval for each lever was 14 sec on the first session of concurrent training and 30 sec for a further two sessions. Following this pretraining, all animals received training on the omission contingency using a procedure identical to that employed in the previous studies except for the fact that this training terminated after six sessions. Pressing on both levers was reinforced with food pellets on concurrent but independent RI 120-sec schedules upon which were superimposed deliveries of the sucrose solution on the RT 30-sec schedule. In addition, presses on the omission but not the control lever postponed the delivery of any scheduled sucrose presentation for a fixed period, which was progressively increased across sessions to a terminal duration of 20 sec. Following this training the animals were divided into two equal groups for aversion training: the devaluation (DEV) group and the non-devaluation (NON) group.

During aversion conditioning the animals received sessions in the operant chambers on alternate days. The levers were removed from the chambers during these sessions, and the sucrose solution was delivered on the RT 30-sec schedule. To prevent the sucrose solution accumulating in the magazine as the aversion developed, the schedule was suspended whenever the solution was presented and restarted by a subsequent entry into the magazine as detected by the flap door. Each session terminated after 30 sucrose presentations or 30 min, whichever occurred first. Each animal in Group DEV received a 20-mg/kg i.p. injection of a 0.15-M LiCl solution immediately following these sessions, whereas those in Group NON received the same injections but on the days on which they remained in the home cages. At least two hours elapsed between the injections and the daily maintenance feeding. This procedure continued until all animals had received four injections.

On the next day all animals received a 10-min test session with the levers reinserted, during which pressing was reinforced on the concurrent 120-sec RI schedule with food pellets, but no sucrose solution was presented. This was followed by a 20-min session to assess whether the aversion treatment had successfully devalued the sucrose as a positive reinforcer in Group DEV. Only the control lever was inserted during this session, and pressing on this lever presented the sucrose solution on a RI 30-sec schedule. No pellets were presented during this test.

Results and Discussion

Figure 3 shows that the omission contingency was effective in reducing pressing on the omission lever relative to the control lever, $F(1, 14) = 19.87$, and that the size of this difference increased with training, $F(5, 70) = 6.30$. There is no evidence, however, that the effect of the omission contingency differed in the two groups. The F ratios for the main effect of group and all interactions with the contingency factor are less than one.

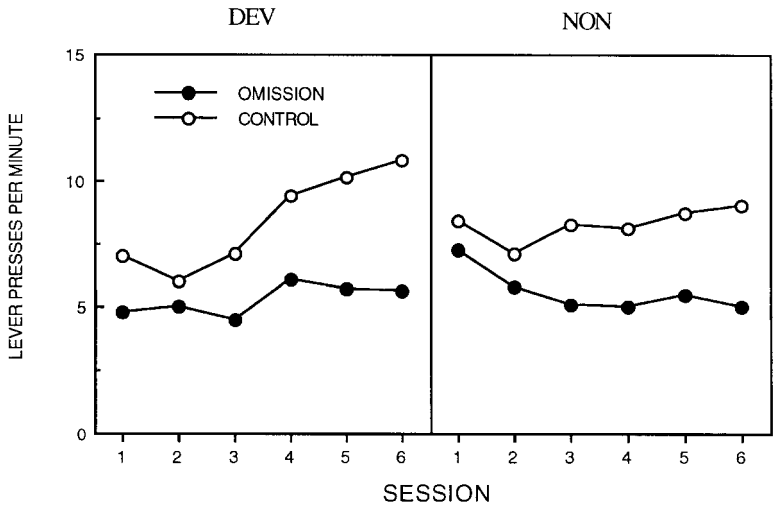


FIG. 3. Experiment 3: Mean number of presses per minute on the omission and control levers during omission training by group DEV (left panel) and group NON (right panel).

Figure 4 displays the critical results from the test session following aversion training, in which performance was assessed on both levers in the absence of any sucrose presentations. There was no evidence that conditioning an aversion to the sucrose solution had any impact on the difference in the relative rates of pressing on the omission and control levers. If anything, Group DEV showed a larger difference than the control animals in Group NON, although not significantly so. Analysis of the rates of pressing during this test, including a within-subject factor distinguishing the successive periods of

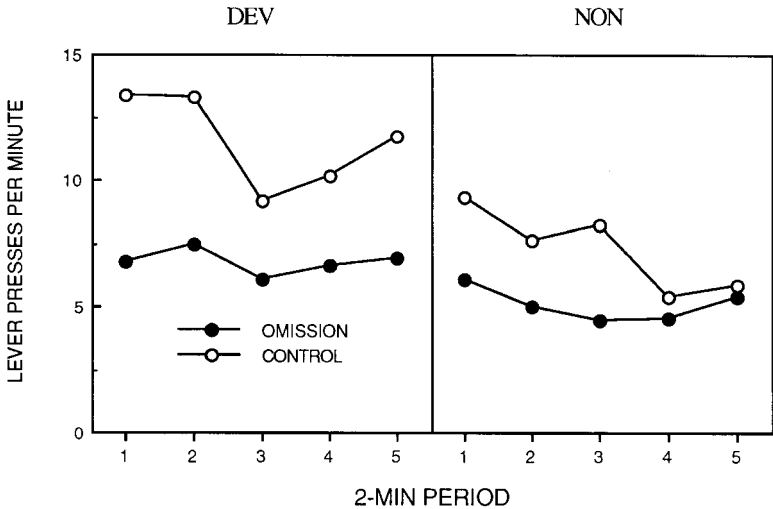


FIG. 4. Experiment 3: Mean number of presses per minute on the omission and control levers during the test session by group DEV (left panel) and group NON (right panel).

the test, yields a significant effect of contingency, $F(1, 14) = 7.65$, but no reliable effect of group, $F(1, 14) = 3.57$, nor any significant interactions involving this factor, $F(1, 14) = 1.05$; $F_s(4, 56) < 1.41$.

The absence of a devaluation effect was not due to the failure of the aversion conditioning to attenuate the reinforcing properties of the sucrose solution. Figure 5 shows the rates of pressing on the control lever that delivered the sucrose solution alone in the final session. Although the rates of pressing were comparable in the two groups at the outset of the session, they rapidly diverged with an almost total loss of pressing in Group DEV. There is a significant effect of group, $F(1, 14) = 42.83$, and a significant Group \times Period interaction, $F(4, 56) = 21.95$.

In conclusion, this study provides no evidence that the reduction in performance observed under the omission schedule was mediated by a R-O process. Although the aversion conditioning abolished the reinforcing capacity of the sucrose solution, the devaluation group showed as large an omission effect after aversion conditioning as did the control animals. If the arguments advanced against the DRO mechanism are accepted, there remain two other processes by which the omission contingency may operate. One possibility is an alternative version of the R-O process, in which the sucrose outcome is encoded not in terms of its sensory features but rather in terms of its affective properties alone. Such a process is the instrumental analogue of that advanced by Konorski (1967) to explain Pavlovian inhibitory preparatory conditioning. If sensory properties of the sucrose are not encoded in the representation of the omission contingency, the aversion conditioning with the sucrose can not impact on the value of the omission outcome. Alternatively, Konorski (1967) also suggested that in certain circumstances behavioural decrements can be mediated by inhibitory S-R associations, and in this respect both Colwill (1991) and Rescorla (1993, 1997) have more recently argued that simple instrumental extinction is mediated by such associations. Again, a response decrement brought about by an inhibitory S-R association should be impervious to outcome devaluation.

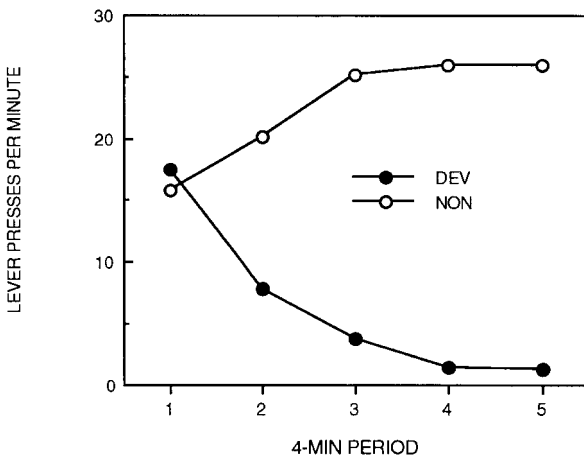


FIG. 5. Experiment 3: Mean number of presses per minute on the control lever when reinforced by the sucrose solution by groups DEV and NON.

SUMMARY AND CONCLUSIONS

The present studies were motivated by the question of whether an extended instrumental training regime, known to produce resistance to outcome devaluation (Dickinson et al., 1995), also enhances response persistence. When response persistence was assessed by an omission schedule, the animals that had received extended pretraining showed greater persistence than those that had received only limited pretraining. Indeed, so profound was this persistence that rats in the 360 condition failed to show any reliable discrimination between the control and omission levers across multiple training sessions.

The theoretical significance of this finding lies with the dual-process theory of instrumental performance espoused by Dickinson and colleagues (Dickinson, 1985, 1989; Dickinson et al., 1995). This theory assumes that instrumental responding is controlled concurrently by two processes—the R-O and S-R—processes, with the R-O process exerting primarily control after limited training and the S-R process after more extended training. Within the context of this theory, the present results suggest that performance controlled by the S-R contingency is far more persistent under a negative contingency than is responding controlled by the R-O process. Indeed, the results of Experiment 2 suggest that response persistence primarily reflects the strength of the S-R association. The 240/120 condition in this study trained animals on a regime thought to minimize the contribution of the R-O process while establishing a S-R association of comparable strength to that in the limited, 120 condition. These two conditions yielded comparable response reductions under the omission contingency, relative to the extended 360 condition, and similar discrimination between the omission and control levers, suggesting that response persistence is determined by the strength of the S-R association.

The final issue concerns the nature of the process mediating omission conditioning itself. The similar levels of performance on the control lever across variation in performance on the omission lever suggest that the negative contingency does not operate by a DRO process. Moreover, performance established by the omission contingency is impervious to outcome devaluation, suggesting that the animals do not learn about the negative relationship between the response and the specific, omitted reinforcer. By default, inhibitory associations either between the response and the affective process activated by the reinforcer or between the stimulus context and the response itself remain possible mechanisms. But whatever process mediates omission conditioning, the present results establish that training conditions favouring the development of S-R habits enhance response persistence. Old habits do in fact die hard.

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Entraînement par omission après pré-entraînement instrumental

Des rats affamés ont été pré-entraînés à presser deux leviers pour de la nourriture sur un programme concomittant. Suivant un pré-entraînement limité ou allongé, les rats furent exposés à une solution de sucrose présentée par un programme de temps aléatoire alors que la nourriture était présentée suivant un programme concomittant. Une pression sur un des deux leviers, le levier d'omission, retardait la présentation du sucrose qui devait être présenté dans une période de temps fixe après la pression, alors qu'une pression sur l'autre levier, le levier contrôle, n'avait pas d'effet sur la contingence aléatoire. Les animaux appuyaient de façon moins fréquente sur le levier d'omission que sur le levier contrôle avec un pré-entraînement limité, mais n'ont pu discriminer entre les deux leviers suivant une période de pré-entraînement allongée. Cet insensibilité à la contingence d'omission produite par le pré-entraînement allongé est le résultat ou bien du nombre de pressions durant la période d'entraînement initiale ou du nombre de pressions renforcées plutôt qu'au nombre de renforcements reçus. Finalement, l'absence de sensibilité dans la performance sur le levier d'omission lors de la dévaluation du sucrose suggère que l'adaptation à cette contingence négative fut le résultat d'une association stimulus-réponse inhibiteuse.

Aprendizaje de omisión después de un preentrenamiento instrumental

Se preentrenó a ratas hambrientas a presionar dos palancas en un programa concurrente para obtener bolitas de comida. Después de un preentrenado reducido o prolongado, se planearon presentaciones de una solución de sacarosa en un programa de tiempo aleatorio mientras los animales continuaban presionando en un programa concurrente para obtener bolitas de comida. Las presiones en una de las palancas, la palanca de omisión, aplazaban las administraciones de la solución de sacarosa programadas para que ocurrieran en un período de tiempo fijo después de la presión, mientras que las presiones en la otra, la palanca de control, no tenían ningún efecto en la contingencia de tiempo aleatoria. Los animales presionaron con menor frecuencia la palanca de omisión que la palanca de control después del preentrenamiento reducido, pero no consiguieron discriminar entre las dos palancas después del preentrenamiento prolongado. La insensibilidad a la contingencia de omisión que produjo el preentrenamiento prolongado se debió o bien al número de presiones que se realizaron durante el entrenamiento inicial o al número de presiones reforzadas más bien que al número de reforzadores recibidos. Finalmente, la insensibilidad de la actuación en la palanca de omisión a la devaluación de la sacarosa sugiere que la adaptación a esta contingencia negativa la medió una asociación inhibitoria estímulo-respuesta.