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AUTOSHAPING IN THE RAT: EFFECTS OF OMISSION ON THE FORM OF THE RESPONSE

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Two experiments were conducted to investigate the effect of an omission contingency on behavior related to and characterizing autoshaped lever contacts in the rat. In Experiment I an omission contingency imposed on autoshaped lever contacts forceful enough to produce a press (.078N) resulted in a significant decrease in lever presses, but had no effect on frequency of lever touches (contacts of insufficient force to produce a press) or rate of food tray entry during lever presentation. In contrast, rats which received a similar number of lever-food pairings, but whose behavior had no programmed consequences (yoked control subjects), showed an increase in lever press rate, a significant decrease in rate of food tray entry, and no change in rate of lever-touches. In Experiment II, the effect of a similar omission contingency on the topography of lever contact responses was investigated. Prior to omission training subjects contacted the lever primarily by pawing it. Following omission training this behavior was suppressed, with a subsequent increase in lever contacts characterized as nosing. Yoked control subjects showed no significant changes in lever contact topography. The results indicate that (1) an omission contingency does not simply eliminate wholesale those topographies which incur the contingency but produces subtle adaptive changes in lever contact topography; and (2) the nature of the autoshaped response in the rat does not appear to be rigid enough to depend solely upon the nature of the unconditioned stimulus or the conditioned stimulus, but can also be determined by the relationships existing between the animal's behavior and these stimuli.

Key words: autoshaping, sign tracking, goal tracking, omission contingency, response topography, yoked control, rats

In one of the first demonstrations of the phenomenon known as autoshaping, Brown and Jenkins (1968) showed that pigeons will rapidly learn to peck an illuminated key if that key is reliably followed by food. This demonstration was important primarily because it showed that an integrated skeletal response could be developed by means of what was ostensibly a classical conditioning procedure. In the simple autoshaping paradigm a localizable stimulus (the conditioned stimulus, CS) is presented to the subject at varying intervals, with each presentation of the CS being immediately followed by food delivery (the unconditioned stimulus, UCS). Even though food delivery is independent of the subject's behavior, this procedure normally results in the subject approaching and contacting the CS during its presentation. Using this procedure, autoshaped responding has been demonstrated in a wide variety of species, using different reinforcers, and many physically different CSs (see Hearst & Jenkins, 1974; Schwartz & Gamzu, 1977, for reviews).

A popular method for attempting to assess the relative contributions of stimulus-reinforcer and response-reinforcer correlations to the generation and maintenance of autoshaped behavior has been to utilize an omission-training procedure in which responses to the CS result in food being withheld at the end of that trial. When compared with appropriate controls, such procedures have shown that signal-directed responses still persist even in the face of this negative contingency (Atnip, 1977; Schwartz & Williams, 1972a; Stiers & Silberberg, 1974). These are results which suggest that stimulus-reinforcer contingencies do play an important role during autoshaping, and, especially in the pigeon, may even override adventitious or programmed response-reinforcer

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contingencies (Peden, Browne, & Hearst, 1977; Williams & Williams, 1969).

However, from these studies two potentially important questions regarding the effect of the omission contingency are unanswered. First, what is the effect of the omission contingency on behavior which is in conflict with the autoshaped response? Boakes (1977) has suggested that autoshaped responses (sign-tracking) and food tray approach (goal-tracking) are response tendencies which are in competition during an autoshaping procedure. If this were so then it could be argued that any manipulation which weakened the sign-tracking response (e.g., an omission contingency) should enhance the goal-tracking response, even though the two responses might initially be under the control of different kinds of contingencies (CS-reinforcer vs. response-reinforcer correlations). Secondly, what is the effect of an omission contingency on the topography of the autoshaped response? On a gross level, Schwartz and Williams (1972b) have shown that an omission contingency on autoshaped key pecking in the pigeon will effectively eliminate long duration key pecks (>45 msecs), but leave short duration key pecks (<20 msecs) relatively unaffected. Similarly, Atnip (1977) has reported that after an omission contingency on pressing a response lever predictive of food delivery in rats, the behavior of "nosing" the lever was the most dominant response (see also Stiers & Silberberg, 1974). However, it is not clear whether this behavior was prevalent before the omission contingency was introduced or whether it appeared after its imposition as a novel adaptive reaction which allowed the animal to contact the lever without effecting a press.

Understanding the nature of behavioral changes brought about by an omission contingency during autoshaping is theoretically important for at least two reasons. First, if one takes the view that the nature of the autoshaped response is determined primarily by the nature of the UCS (e.g., Jenkins & Moore, 1973, Moore, 1973) then being able to produce either subtle or gross changes in response topography to accommodate the effects of an omission contingency should be relatively difficult, since the only manipulations which would effect these changes should be manipulation of the nature of the UCS. Secondly, it is unclear whether an omission contingency has its effect by selectively eliminating or "stamping out" those response topographies which lead to the omission of food, or whether it acts to redirect a specific response or set of responses to a different part of the animal's environment. For instance, Barrera (1974) found that after an omission contingency the frequency of a pigeon's pecking was at a level comparable with that prior to omission, but that the contingency had the effect of directing this pecking to the area around the key. This latter finding could suggest that the omission contingency has its effect by establishing some other part of the environment (e.g., the area around the pecking key) as a more reliable predictor of food than the programmed CS—and hence a target for pecking—and not by weakening the strength of the autoshaped response per se.

In the experiments to be described in the present study, we attempted to characterize some of the behavioral changes that occur during an omission contingency following the acquisition of autoshaped lever contacts in the rat. The first experiment reports the interaction between lever presses, lever touches (of insufficient force to record a press), and food tray approach following omission on lever presses. The second experiment describes more fully the topography of lever contacts during autoshaping acquisition and the effect on these topographies of a subsequent omission contingency imposed on those types of behavior which resulted in a lever press.

EXPERIMENT I

The first experiment was designed to investigate the effect on overall CS contact rate and food-tray approach of an omission contingency on only one aspect of the CS contact response—namely contacts forceful enough to produce a press. In a retractable two-lever autoshaping situation, the presentation of one lever (the CS+) signaled food delivery, and the presentation of a second lever (the CS^0) predicted food only on a chance basis. When it was established that subjects were reliably tracking the CS+ (by reversing the predictive significance of the levers), half of the rats were subjected to an omission contingency on CS+ lever contacts which were of sufficient force to cause a press (> .078N), whereas lever contacts of insufficient force to cause a press had no scheduled consequences. The remainder of the rats were used as control subjects which were yoked to those receiving the omission training.

METHOD

Subjects

The subjects were 6 male Hooded Lister rats approximately 90 days old at the outset of the experiment. All were experimentally naive and maintained at approximately 80% of their free-feeding body weights throughout the experiment. The animals were housed in individual home cages.

Apparatus

The internal dimensions of the experimental chambers, marketed by Campden Instruments Limited, were 20.5 cm high, 23.5 cm wide, and 23.0 cm long. Each chamber contained two retractable levers which were situated on one wall of the chamber, 3.0 cm to the left and right of an aperture into which food pellets could be delivered. When extended, the levers projected 2.2 cm into the chamber, were 3.8 cm wide, and were located 13.5 cm from the ceiling and 4.0 cm from the grid floor. A weight of approximately 8 g (.078N) was required to operate the levers and when retracted they were flush with the wall of the chamber. When the levers were extended into the chamber, touches of insufficient force to cause a press could also be recorded by means of drinkometer circuits connected to the levers.

The food aperture was 5.0 cm high and 4.0 cm wide, and the entrance to this food tray was covered by a perspex door hinged at the top of the aperture. Pushing the perspex door activated a microswitch which recorded tray entries. Reinforcement consisted of the delivery of a single 45-mg food pellet and was accompanied by the characteristic "click" of the food hopper and a brief flash of the food-tray light. General illumination throughout each experimental session was provided by a small houselight situated on the ceiling of the chamber. The experimental chambers were housed in sound-attenuating boxes; the experiment was controlled, and data (lever presses, lever touches, and tray entries) were recorded by solid-state logic programming equipment.

Procedure

The experiment consisted of seven phases which were preceded by adaptation to the experimental chamber. During adaptation each subject was placed in the chamber for 30 mins with 10 food pellets present in the food tray.

1. *Magazine training.* After adaptation each subject was given 8 sessions of magazine training in which food pellets were delivered into the food tray on a variable-time (VT) 100-sec schedule. This schedule had a minimum interval of 15 sec and a maximum interval of 120 sec. Each session lasted for 40 food deliveries.

2. *Acquisition.* For the following five sessions, food delivery was paired with each of 40 insertions into the chamber of a response lever. In this phase the left lever (LL) was inserted into the chamber 10 sec prior to pellet delivery and was retracted on delivery of the pellet.

3. *Differentiation.* During this phase of the experiment (five sessions), pairings of LL and food remained as they had been during acquisition, but the right lever (RL) was now inserted into the chamber for 10-sec periods independently of food. RL insertions were programmed on a VT 100-sec schedule identical to, but independent of, the schedule controlling food delivery.

4. *Reversal 1.* A further 10 sessions consisted of reversing the lever-food relationships such that the RL now preceded food delivery and the LL was inserted into the chamber on an independent VT 100-sec schedule.

5. *Reversal 2.* For a further 10 sessions, the relationships between food and levers reverted to those during differentiation: LL preceded food and RL predicted food only on a chance basis.

6. *Omission.* At this stage the subjects were divided into three pairs, equated as near as possible on rates of lever pressing and touching. One member of each pair was subjected to omission training in which any press on the food-correlated lever (LL) resulted in food being withheld at the end of the 10-sec lever insertion period. Only lever presses activated this negative contingency, lever touches were recorded but had no programmed consequences. The second member of each pair acted as a yoked control by receiving food only on the trials in which his omission master

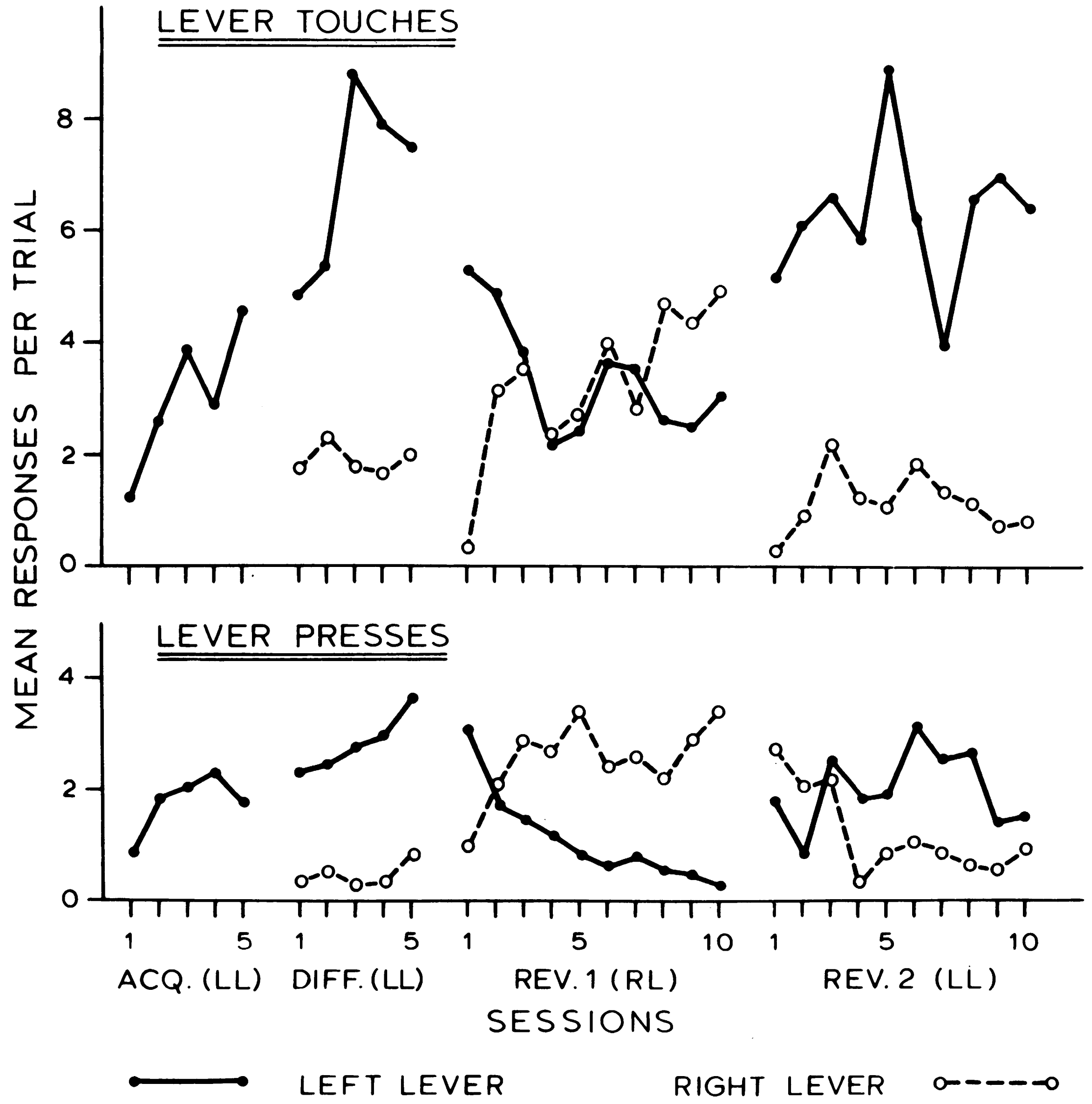

Fig. 1. Mean number of responses per trial (touches and presses) averaged over all subjects. Filled circles indicate responses on the left lever (LL) and unfilled circles represent responses on the right lever (RL). Acq = acquisition; diff = diffferentiation; Rev 1 = Reversal 1; Rev 2 = Reversal 2. Abbreviations in brackets denote the lever which was paired with food (CS+) during each phase.

received food. No aspect of the yoked control animals' behavior had any programmed effects on the delivery of food. The omission phase lasted for 10 sessions and each session lasted for 40 LL presentations.

7. *Reversal 3.* The final phase was a direct replication of Reversal 1 in which the omission contingency was removed entirely, and now the RL was paired with food delivery and the LL inserted into the chamber on an independent VT 100-sec schedule. This phase lasted for 12 sessions.

RESULTS

Differentiation and Reversal

Figure 1 illustrates the rate of lever touching and lever pressing during the first four phases of the experiment (acquisition-differentiation-Reversal 1-Reversal 2). During acquisition, when only the left lever (LL) was presented

(CS+), both lever touches and lever presses were observed. However, only rate of lever touching showed a significant increasing trend over the five days of acquisition (Page's L test for trend, $L = 300$, $K = 5$, $n = 7$, $p < .01$). During the following five days of differentiation, rate of LL touching continued to increase ($L = 341$, $K = 5$, $n = 7$, $p < .05$), and rate of LL pressing also exhibited a significant increasing trend ($L = 354.5$, $K = 5$, $n = 7$, $p < .01$). Touches and presses on the right lever (RL, CS^0) during this phase remained at a relatively low level showing no significant increase or decrease. However, when the predictive roles of the two levers were reversed over the next ten days (Reversal 1), the approach and contact tendencies of the subjects to the two levers also reversed. Thus, during the last three days of Reversal 1, rate of RL touches (now CS+) was significantly greater than rate of LL touching (now CS^0) ($t = 2.708$, $p < .05$). Similarly, during Reversal 2 the behavior of the subjects again reversed as they continued to track the lever scheduled as the CS+. Both the rate of touching ($t = 2.828$, $p < .05$) and pressing ($t = 2.516$, $p < .05$) were significantly higher to the CS+ lever than to CS^0 during the last three sessions of Reversal 2.

Lever Contacts During Omission

For Phase 5 of the experiment, the subjects were paired off into two groups. One group was subjected to an omission contingency which was imposed on lever presses to CS+ (LL in this phase). The remaining subjects acted as yoked controls, receiving food only on the same trials as their master partners, with their behavior having no effect on the delivery of food. Figure 2 shows rate of CS+ pressing and touching for the omission and yoked groups expressed as a ratio of their pre-omission baseline response rate. For the omission subjects rate of CS+ pressing for the final 3 days of omission was significantly suppressed in comparison with the final 3 days of Reversal 2 ($t = 4.682$, $p < .05$). In contrast, however, rate of CS+ pressing for the yoked controls during the last 3 days of omission showed a significant increase over the rate for the corresponding period during Reversal 2 ($t = 4.205$, $p < .05$). No significant differences in rate of CS^0 pressing was observed between Reversal 2 (presses per trial: omission subjects mean = .70±.1; yoked subjects mean = .57±.4), and omission (presses per trial: omission subjects mean = 1.14±.08; yoked subjects mean = .36±-.06) for either group of subjects. Perhaps more importantly, however, no statistically significant difference was found between within-session rate of CS+ pressing and CS^0 pressing for the omission subjects during the last 3 days of omission (mean CS+ presses per trial = .66±.06; mean CS^0 presses per trial = 1.14±.08).

The top panel of Figure 2 shows the rate of CS+ touching during omission for the two groups of subjects. Although the negative response contingency imposed on lever presses did reduce rate of lever pressing in the omission group, it did not significantly alter their rate of lever touching during CS+. A similar result was obtained with the yoked control group whose rate of CS+ touching during the last 3 days of the omission phase did not differ significantly from the last 3 days of Reversal 2. Moreover, although omission subjects did not show a difference in rate of CS+ and CS^0 pressing during the last 3 days of omission, they did show a significantly higher rate of CS+ touching than CS^0 touching during the same period ($t = 7.487$, $p < .05$).

Following the 10 days of omission training, all subjects were given 12 days of a further reversal (Reversal 3), during which RL became CS+ and the omission contingency was no longer in operation. All subjects now switched levers to track the RL, and during the last 3 days of Reversal 3, rate of RL pressing ($t = 2.488$, $p < .05$) and RL touching ($t = 2.531$, $p < .05$) was significantly greater than these responses on the LL.

Tray Entry

Figure 3 shows that rate of tray entry during CS+ was affected differentially by omission and yoked treatments. Whereas rate of tray entry during CS+ did not differ significantly for the omission group between the last 3 days of Reversal 2 and the last 3 days of omission, it was significantly reduced in the yoked group ($t = 4.489$, $p < .05$). Similarly, this reduction in rate of tray entry for yoked subjects appeared to be part of an overall decrease in rate of tray entry which was also observed during ITIs ($t = 5.812$, $p < .05$). The omission group showed no significant change in rate of ITI tray entry between Reversal 2 and omission. Finally, Figure 3 shows that rate of tray en-

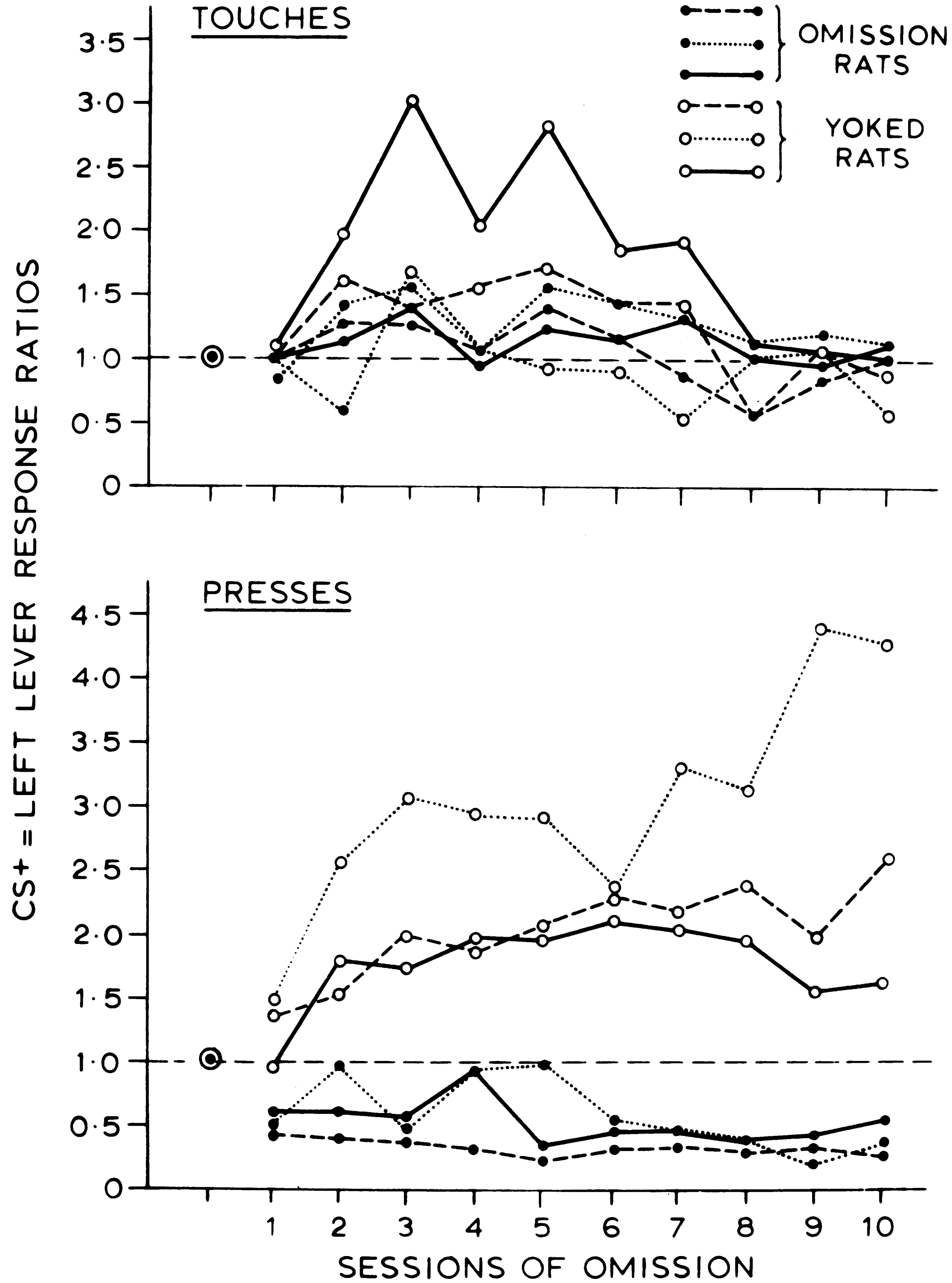

Fig. 2. CS$^+$ presses and touches of insufficient force to cause a press during omission expressed as a ratio of the pre-omission baseline rate of responding. The baseline rate of touching and pressing was calculated by averaging the rate of these responses respectively over the 3 sessions prior to the introduction of omission. This was calculated separately for each subject and expressed on the left of the graph as 1 in each case. CS$^+$ response ratios were then calculated by dividing the rate of responding on each omission session by the pre-omission baseline figure for that animal. Ratios greater than 1 indicate that responding during a session was higher than the pre-omission baseline and ratios smaller than 1 indicate a decrease.

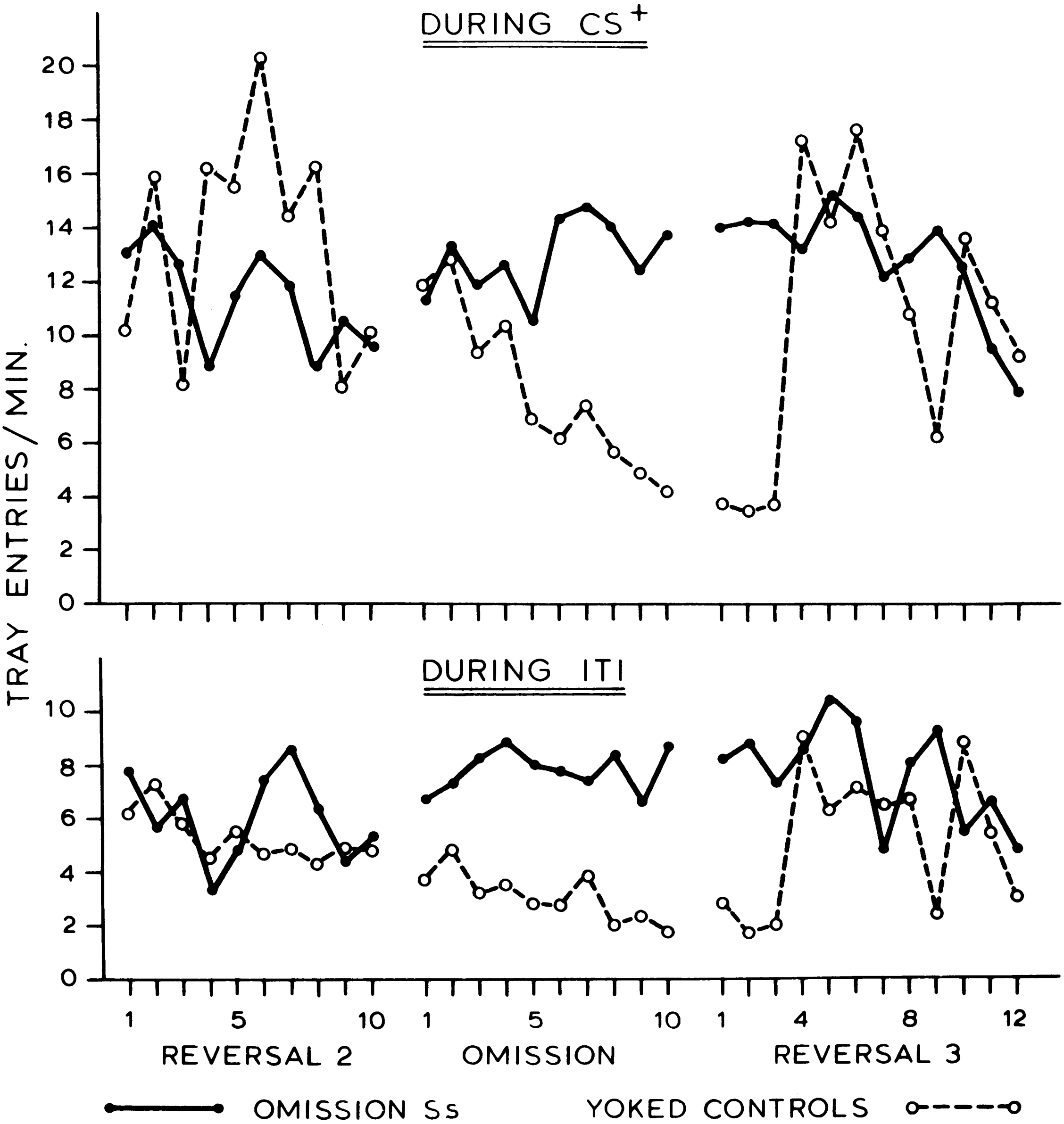

Fig. 3. Rate of tray entry during CS+ and intertrial interval (ITI) for omission *Ss* (filled circles) and yoked *Ss* (unfilled circles) during Reversal 2 (Rev. 2), omission, and Reversal 3 (Rev. 3).

try for the yoked subjects recovered during Reversal 3 to a level comparable with that prior to the omission phase.

Discussion

Figure 1 shows that, as expected, rats did learn to track the lever which was positively correlated with food (CS+) and to differentiate it from one which was not (CS^0). Similarly, the persistence of the subjects in differentially tracking the CS+ during Reversals 1 and 2 suggests that the lever contacts engendered by this procedure were a result of the lever-food contingency rather than any nonassociative factors which may have elevated the operant level of lever pressing. In this respect these results parallel those of similar studies that have used within-subject random control procedures (Peterson, Ackil, Frommer, & Hearst, 1972; Stiers & Silberberg, 1974).

The introduction of a negative response contingency on lever presses to the CS+ successfully reduced the frequency of lever presses in those subjects experiencing the contingency. This finding is also in accord with other studies that have subjected autoshaped rats to omission training (Atnip, 1977; Locurto, Terrace, & Gibbon, 1976; Stiers & Silberberg, 1974). However, the rate of lever touching in the omission group was unaffected by the omission contingency on presses, and it remained at a rate similar to that maintained before the omission training phase was begun. This does suggest that subtle aspects of the autoshaped response can be modified by an instrumental contingency while CS contacts are still maintained. Furthermore the behavior of the yoked partners, who actually showed an *increase* in lever-pressing rate, indicates that the selectivity with which the omission contingency affected the behavior of the omission subjects could not in a simple way be attributed to the fluctuations in the stimulus-reinforcer correlation engendered by the omission contingency. However, these data do not necessarily imply that the omission contingency is selectively affecting a dimension of the response such as force. For example, it is quite reasonable to assume that responses that result in a lever press are topographically different to responses which result in a lever touch. The omission contingency may well be operating at a grosser level to eliminate those topographically distinct sets of behavior which lead to lever presses.

Finally, the results of Experiment I also show that rate of tray entry was differentially affected in omission and yoked groups. Although tray entry (goal tracking) was unaffected in the omission group, the yoked subjects showed a significant decrease in tray entry, both during the CS+ presentation and during intertrial intervals. This might be explained by suggesting that during autoshaping procedures for the rat, sign-tracking and goal-tracking tendencies may be in conflict (cf. Boakes, 1977). A variable such as reinforcement probability could consequently have effects on the frequency of both types of behavior by directly affecting only the frequency of one of them. More specifically, the reduction in reinforcement frequency experienced by the yoked group may have generally reduced the rate of goal tracking (as evidenced by decreases in tray-entry rate during both CS+ presentation and intertrial intervals). During CS+ presentation this would have allowed more time for sign tracking; hence the increase in lever-pressing rate for this group.

EXPERIMENT II

The results of Experiment I demonstrate that a response-reinforcer contingency can selectively suppress a subtle aspect of the autoshaped response without eliminating CS contact. There are a number of possible ways in which this could have been brought about. First, the omission contingency may selectively eliminate certain response topographies—in particular those topographies which lead to full presses—whereas other nonpress contacts remain at their pre-omission level. Secondly, the subject may have adapted to the omission contingency by developing a new contact topography which permitted contact but did not result in a press. Thirdly, the typical contact topography generated during acquisition may have been shifted to a different area of the lever where presses were not recorded (e.g., licking the topside of the lever could easily result in presses being recorded, whereas licking the underside of the lever—and hence pushing it upwards—would not produce presses). These possibilities have somewhat different theoretical implications. The first would suggest that at least some responses generated by stimulus-reinforcer correlations are directly sensitive to response-reinforcer contingencies. The second implies that the interaction between CS contact and omission contingencies is a more complex process than merely the establishment of contact repertoires by stimulus-reinforcer contingencies and their selective elimination by omission contingencies. The third would require no more than the establishment of a new stimulus-reinforcer association which would redirect existing responses to a new part of the environment. This second experiment is an attempt to differentiate between some of these possibilities by describing in detail the lever contact topographies generated by an autoshaping procedure, and reporting the subsequent changes brought about in these topographies by an omission contingency.

METHOD

Subjects

The subjects were 12 male Hooded Lister rats approximately 90 days old at the outset of the experiment. All were experimentally naive and maintained at approximately 80% of their free-feeding body weights throughout the experiment.

Apparatus

The experimental chambers and programming and recording apparatus were identical to those used in Experiment I. In addition a black and white video tape recording was made of selected acquisition and omission sessions. In order to indicate the occurrence of lever presses and lever touches on the video film, two small 2.8-W bulbs were mounted behind the front wall of the experimental chambers in view of the video camera but out of view of the experimental subject. Each bulb was illuminated on the occurrence of either a lever contact or a lever press respectively. For the purpose of filming, the front of the sound-proof boxes remained open throughout acquisition and omission procedures. A hardboard screen was erected around the chambers at a distance of .6 m from the open fronts, above which the video camera projected. To obtain separate data on each trial of a session, a 4-channel kymograph pen recorder was used to record frequency and duration of lever presses, lever touches, and tray entries on a trial by trial basis.

Procedure

All 12 subjects were initially given eight sessions of magazine training according to the procedure outlined for Experiment I. Following this, eight subjects were given between 30 and 40 sessions of autoshaping acquisition training, and four subjects were given 20 sessions on a random control procedure.

Autoshaping acquisition. Food delivery was paired with insertion into the chamber of a response lever. Four subjects received a 10-sec insertion of the right lever (RL) prior to food delivery, and the remainder received pairings of the left lever (LL) and food. Only one lever was used with each subject, and the lever was retracted on delivery of the pellet. A single session consisted of 30 pairings of lever and food with a mean intertrial interval of 100 sec.

Random control. Four subjects received the same frequency of food and lever presentations as the autoshaping acquisition animals, but the lever presentations occurred randomly with relation to food. Sessions were terminated after 30 food deliveries.

Omission training. After between 30 and 40 acquisition sessions, the autoshaping acquisition subjects were divided into two groups. The omission group, as in Experiment I, was subjected to omission training in which any press on the inserted lever resulted in food being withheld at the end of that 10-sec insertion period. Only lever presses activated this negative contingency, with lever touches being recorded but having no programmed consequencies. The remaining subjects were yoked individually to one of the four omission subjects and received food only on the trial on which their omission masters received food. As in Experiment I, no aspect of the yoked controls' behavior had any programmed effects on the delivery of food. This omission plus yoked control phase lasted for 16 sessions, and each session lasted for 30 lever presentations.

Observational procedures. Recordings of rates of lever pressing, lever touching, and tray entry were taken throughout the different phases of Experiment II, but, in addition, selected sessions during acquisition, omission training, and random control procedures were video recorded and the lever contact behavior of the subjects during lever insertions was analyzed according to a number of preselected topographic categories, which with one or two isolated exceptions, covered the total range of lever contact behavior in all subjects. The categories were as follows: *Left paw:* contacting the lever with the left paw alone; *right paw:* contacting the lever with the right paw alone; *both paws:* both paws contacting the lever simultaneously, usually with one paw above and one below the lever in a fashion which resembled holding an object; *chin:* resting the chin on the upper surface of the lever; *nose:* contacting the lever with the end of the nose or with the vibrissae; *lick:* contacting the lever with the tongue, usually along the vertical front edge of the lever; *bite:* grasping the lever between the teeth. These categories are not necessarily mutually exclusive and in the case of licking or biting, a pawing response could occur concurrently. These occurrences—which in practice were few—were scored as *both* the oral response *and* the manual response.

The last two sessions of acquisition and the last session of omission were video recorded and analyzed in this way. Observational data from the random control subjects came from the last two sessions of their training.

Two independent observers (one naive as to the purpose of the experiment) scored the responses for the first recorded session with 85% agreement between the two, suggesting that the selected categories were reliable and objectively definable. Following analysis of these sessions a profile was built up of response topographies characterizing lever touches and response topographies characterizing lever presses for each rat. The duration of lever touches, presses, and tray entries during lever presentation were also noted during video sessions by means of a kymograph pen recorder.

RESULTS

Response Rates

Table I summarizes the rate of pressing, touching, and tray entry for omission, yoked, and random control subjects respectively at the end of the different stages of Experiment II. The results of a battery of small sample Wilcoxon tests comparing responding on the different measures between the last six sessions of acquisition and the last six sessions of omission, indicated that all four omission subjects exhibited a significant decrease in press rate between acquisition and omission (in all cases $p < .025$). In contrast there was no significant change in the rate of lever touching for these subjects over the same period, confirming results obtained in Experiment I. Three yoked control subjects showed no significant change in either press or touch rate between acquisition and omission, whereas R59 did show a significant *increase* in both touch and press rate over this period ($p < .025$). Table I also shows that the press and touch rates of the random control animals are extremely low, and at the end of omission, omission subjects are pressing at a significantly higher rate than the random control animals ($t = 4.942$, $p < .001$).

Response Topographies

Figures 4 and 5 show the touch and press topography profiles prior to and following omission in the omission and yoked subjects. In Figure 4 the dominant touch response in all 8 subjects prior to omission was pawing of some kind with nosing and licking of the

Table I

Mean (and standard error of the mean) of the number of lever presses, lever touches, and tray entries per trial for all three groups of subjects at the end of acquisition and omission phases. Data are calculated from the final two sessions for each phase of the experiment.

		Acquisition			*Omission*		
Group	*Subject*	*Presses*	*Touches*	*Tray entries*	*Presses*	*Touches*	*Tray entries*
Omission	R58	3.7 ± 0.3	7.3 ± 0.8	2.4 ± 0.2	1.1 ± 0.2	4.8 ± 0.6	2.9 ± 0.4
	R60	3.5 ± 0.4	5.5 ± 0.4	1.6 ± 0.2	0.6 ± 0.1	4.9 ± 0.4	1.2 ± 0.3
	R61	5.0 ± 0.3	10.3 ± 0.9	1.5 ± 0.1	0.7 ± 0.1	9.7 ± 1.1	1.3 ± 0.2
	R62	4.2 ± 0.3	13.0 ± 1.5	2.1 ± 0.3	0.4 ± 0.1	13.6 ± 1.5	3.0 ± 0.2
	Mean	4.1 ± 0.3	9.0 ± 0.7	1.9 ± 0.2	0.7 ± 0.1	8.3 ± 0.7	2.1 ± 0.3
Yoked	R57	4.3 ± 0.5	7.1 ± 0.9	1.2 ± 0.1	4.0 ± 0.3	6.9 ± 0.8	0.2 ± 0.1
	R59	0.9 ± 0.1	2.8 ± 0.4	1.0 ± 0.3	4.0 ± 0.5	6.4 ± 0.6	0.5 ± 0.1
	R56	2.3 ± 0.1	8.4 ± 0.6	2.1 ± 0.2	1.9 ± 0.2	8.4 ± 0.9	0.4 ± 0.1
	R63	2.1 ± 0.3	6.0 ± 0.3	2.5 ± 0.1	1.7 ± 0.3	3.9 ± 0.4	0.5 ± 0.1
	Mean	2.4 ± 0.2	6.1 ± 0.6	1.7 ± 0.2	2.9 ± 0.3	6.4 ± 0.5	0.4 ± 0.1
Random	R36	0.1 ± 0.0	2.1 ± 0.2	2.8 ± 0.3			
	R37	0.0 ± 0.0	0.7 ± 0.1	1.9 ± 0.1			
	R38	0.0 ± 0.0	1.0 ± 0.1	3.2 ± 0.2			
	R39	0.1 ± 0.0	1.2 ± 0.3	2.7 ± 0.3			
	Mean	0.0 ± 0.0	1.3 ± 0.2	2.7 ± 0.2			

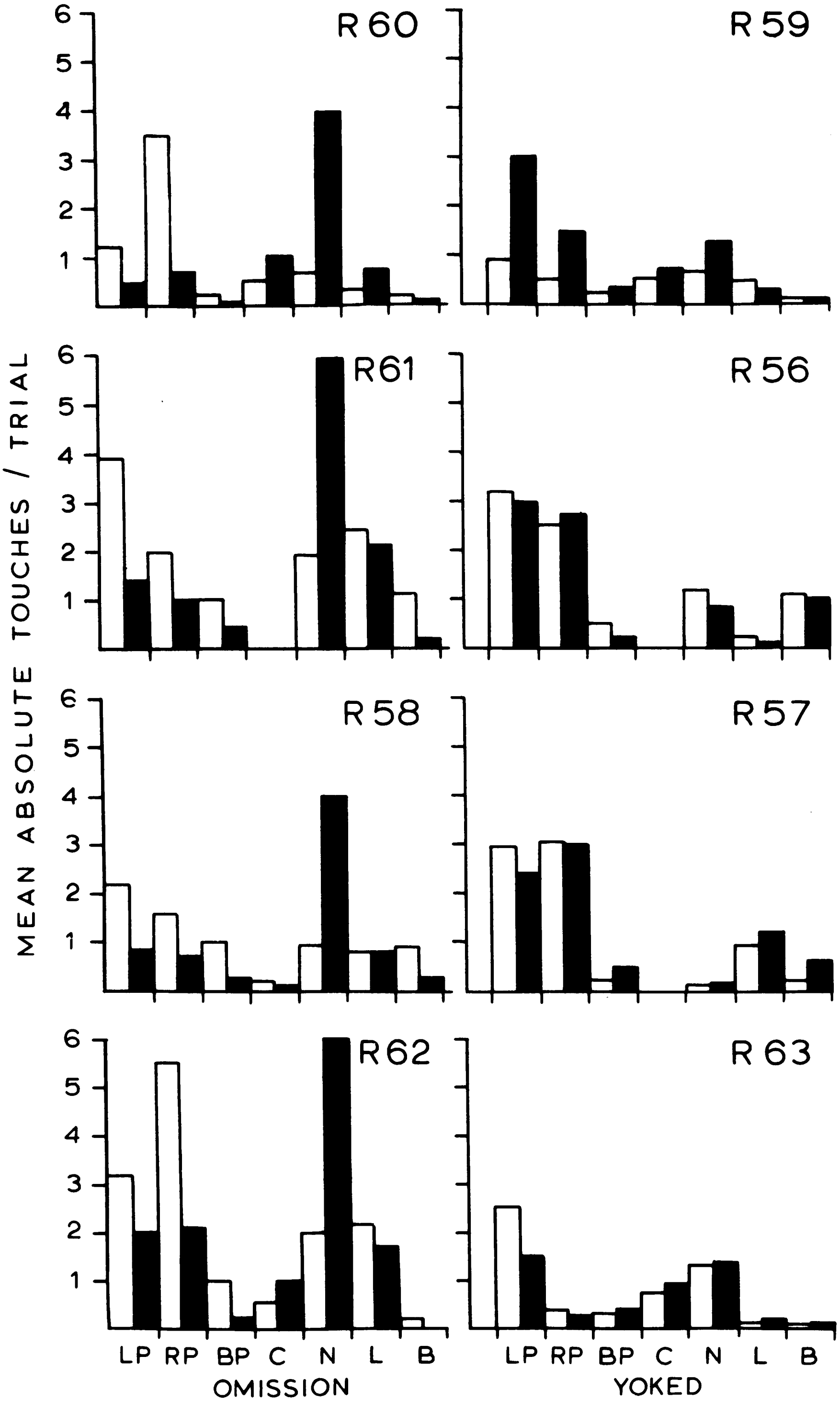

Fig. 4. Lever touch topography frequencies for omission and yoked subjects at the end of acquisition (unfilled bars) and at the end of omission (filled bars). Data are means taken from the final two sessions of acquisition and the final session of omission respectively. LP = left paw; RP = right paw; BP = both paws; C = chin; N = nosing; L = licking; B = biting.

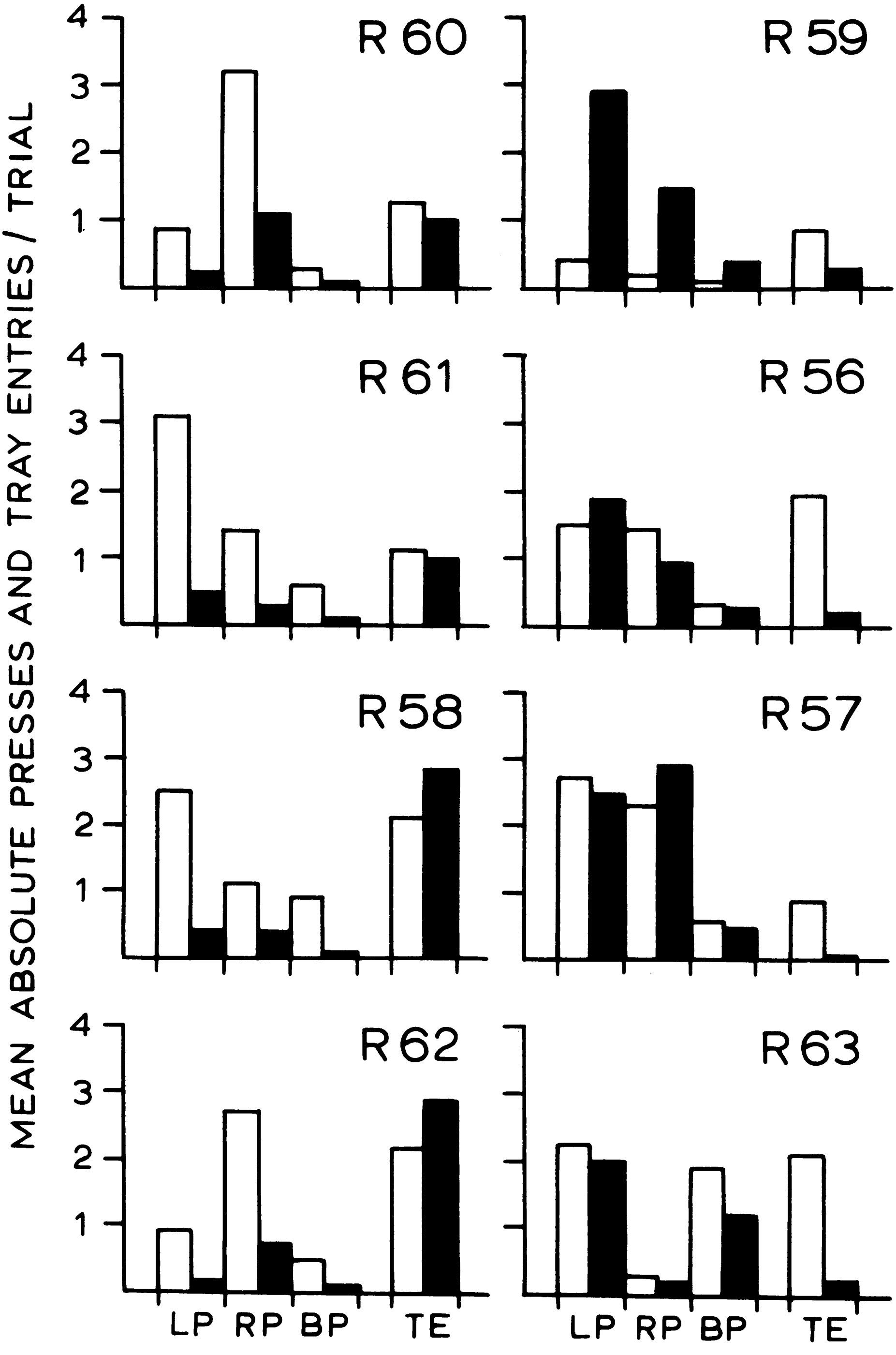

Fig. 5. Lever press topography frequencies and tray entry frequencies for omission and yoked subjects at the end of acquisition (unfilled bars) and at the end of omission training (filled bars). Data are means taken from the final two sessions of acquisition and the final session of omission respectively. LP = left paw; RP = right paw; BP = both paws; TE = tray entries.

lever occurring frequently in some cases (e.g., R61 and R62) and to a much lesser degree in others. Pawing was also the dominant, and only, topography producing lever presses (Figure 5) suggesting that the press and touch responses were not produced by differing topographies as might have been suspected from the results of Experiment I, but seemingly by the differing intensity of one major response group, i.e. pawing. However, at the end of omission both Figures 4 and 5 indicate the suppression of the pawing response in both press and touch profiles for the omission subjects, with little change occurring in the profiles for the yoked control subjects (with the exception of R59 who shows an increase in pawing responses). However, the touch profiles for the omission subjects at the end of omission are consistent in showing a dramatic increase in lever nosing compared with the level of this response at the end of acquisition.

Lever contact occurrences in the random group were so few that they have not been graphed. The instances that did occur during the video-taped sessions were all categorized as lever nosing, and only five instances occurred across all four subjects.

Response Durations

In order to give some picture of the distribution of lever presses, lever touches, and tray entries throughout a trial, and the effect of the omission contingency on this distribution, the kymograph recordings were analyzed to give the amount of time spent indulging in each type of behavior during the first and second halves of the 10-sec trial. Figure 6 illustrates the findings for sessions at the end of acquisition and at the end of omission. All subjects show a greater tendency to lever touch in the first half of the trial than the second ($t = 2574$, $p < .05$) and conversely a greater tendency to lever press ($t = 2.411$, $p < .05$), in the second half rather than the first. Time spent lever pressing in the omission group was significantly decreased following omission training, both for presses occurring in the first half of the trial ($t = 6.9219$, $p < .01$) and in the second half of the trial ($t = 9.5161$, $p < .01$). There was no significant change in time spent lever touching for these subjects. Figure 6 also shows that following omission, yoked control subjects show an increase in time spent lever pressing. Although this result did not quite reach statistical significance, it does perhaps indicate an increase in response vigor in yoked animals comparable with the increase found in press rate in yoked controls in Experiment I (see Figure 2). Finally, Figure 6 also indicates a significant fall in the time spent tray entering in yoked controls between acquisition and omission sessions ($t = 2.960$, $p < .05$), but no change in the level of this response in omission animals. Both of these findings replicate similar effects on tray entry rate found in Experiment I (compare with Figure 3).

DISCUSSION

These results strongly indicate that the ability of an omission contingency to suppress autoshaped lever pressing without substantially affecting rate of lever touching is not simply the effect of eliminating one discrete response topography. Although omission subjects do show a suppression in the occurrence of those topographies which generally result in lever presses, all subjects consequently developed an alternative lever-contact response —namely nosing the lever. Furthermore, the yoked-control subjects did not exhibit any significant changes in response topography. This suggests that the response modifications observed in the omission subjects were not simply due to the reduction in reinforcement frequency experienced during omission, nor to the weakened correlation between lever and food presentations.

Consistent with the results of Experiment I were the findings that the omission phase reduced the amount of time spent tray entering in yoked subjects but produced no significant change in the level of this response in omission subjects. Also, amount of time spent lever pressing in omission subjects was substantially reduced, but in all yoked subjects the tendency to indulge in this response was increased—albeit not to a level which reached statistical significance. This increase in time spent lever pressing in yoked subjects parallels the increase in rate of lever pressing found in yoked subjects in Experiment I. Both measures seem to indicate an increase in strength of the sign-tracking response with the introduction of partial reinforcement (see also Boakes, 1977).

Finally, lever touches, lever presses, and tray entries are not uniformly distributed across the duration of the trial. Both tray entries

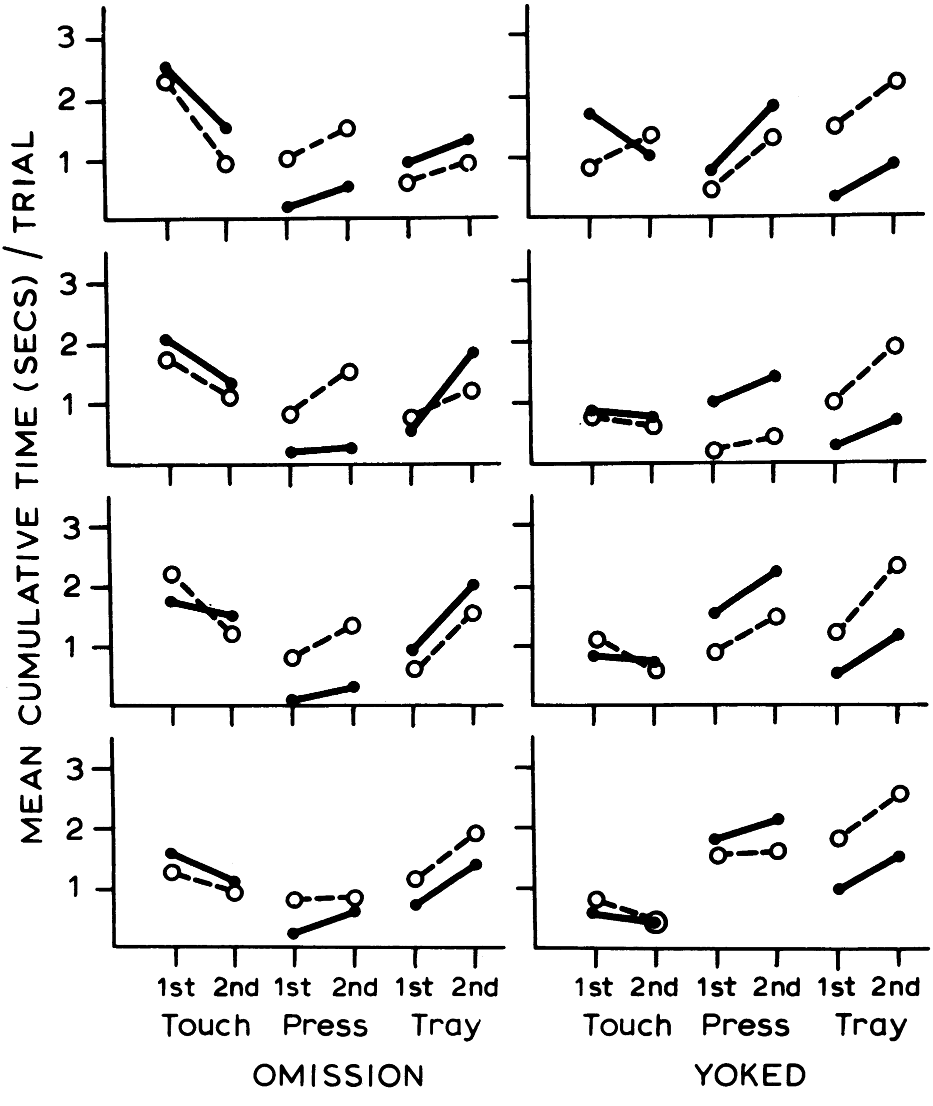

Fig. 6. Mean cumulative time spent lever touching, lever pressing, and tray entering in the first 5-sec and the second 5-sec of a 10-sec trial. Unfilled circles represent the mean time calculated from the last two sessions of acquisition. Filled circles represent the mean time calculated from the last session of omission training. (From top to bottom omission subjects are R60, R61, R58, and R62: yoked subjects are R59, R56, R51, and R63).

and lever presses occur more frequently in the later half of the trial as food delivery becomes imminent, whereas lever touches are more predominant in the first half of the trial. Since both press and touch responses showed essentially the same topography profile during acquisition, this seems to suggest that there is an increase in the vigor of responding as the trial progresses. This effect is reminiscent of the differential peck durations observed in pigeons by Schwartz (1977) during fixed-interval schedules. He found that early in the interval short-duration key pecks were predominant whereas late in the interval long-duration key pecks occurred more frequently. Ziriax and Silberberg (1978) have reinterpreted these data to suggest that response strength varies with the temporal proximity of reinforcement and that response duration will vary as a function of response strength. The results from the acquisition phase of the present experiment are consistent with this reinterpretation by indicating that touches and presses by and large comprise a single response form (primarily pawing) which appears to increase in vigor as the time for food delivery approaches. There is no evidence to suggest that touches and presses result from different response topographies or, indeed, are generated by different processes as the two-process classification of Schwartz (1977) would imply.

GENERAL DISCUSSION

The principal effect of the omission contingency on the form of autoshaping responding was to replace one response topography (pawing) with an alternative CS-contact response (nosing). Such a finding does not substantiate the claim that omission contingencies merely relocate a single response to a part of the environment where it cannot incur the omission contingency (e.g., Barrera, 1974). In fact the form of the major CS-contact response was changed quite dramatically from a manual response to a fairly discrete orienting and nose-contact response. Furthermore, this transition was brought about not simply by the wholesale "stamping out" of responses which incurred the omission contingency, but also by a concurrent *increase* in frequency of a response which was acceptable to the imposed response contingency relations.

A number of putative processes might be considered responsible for this substitution of CS-contact behavior. First, the omission contingency could have acted to eliminate the final sequences of a response chain that resulted in lever pawing. For instance, lever nosing may have been the initial component of the behavior sequence that terminated in pawing the lever. Indeed, most subjects were observed to nose the lever with a paw raised on many occasions, but without subsequently touching the lever with the paw. Thus, lever nosing might not in a strict sense be a *new* response but a weakened version of the approach-nose-and-paw sequence. This interpretation would probably be consistent with the views of Ziriax and Silberberg (1978) on the effects of omission on autoshaped key-peck duration in pigeons. By their account, the decrease in rate of lever pressing during omission would indicate a reduction in response strength probably brought about in this case by a weakening of the final components of the response sequence leading up to CS-contact (see also Lucas, 1975). If this is the case, the present study indicates that this reduction in response strength results not from a weakening of Pavlovian correlations, but only from direct experience of the omission contingency. The yoked subjects who did not experience the omission contingency showed no change in their response topography profiles even though they received a reduction in the number of lever-food pairings.

A second explanation of the present results alludes to the possible competitive interactions between different activities. Because the observed lever responses may be mutually inhibitory, suppressing the frequency of one of them could disinhibit one or more of the competing responses and allow them to increase in frequency. An example is provided in an experiment by Morrison (Note 1). Using pigeons autoshaped to a pecking key preceding a water reinforcer he found that his subjects not only pecked the key but also exhibited "bowing" and "rooting" responses when the key was on. Systematically imposing an omission contingency on each of these responses not only suppressed the target behavior but also produced an increase in the frequency of those types of behavior not subjected to the contingency. In the present case, lever pawing, licking, biting, and sniffing might be independent food-related activities elicited by the CS, each in a competitive relationship with the others. Hence, imposing a negative contingency on one would allow one or more of the competing responses to increase in frequency. However, which responses would replace the suppressed activity would not be immediately obvious. This would depend on discovering the inhibitory or excitatory relationships between the different activities, and perhaps, the hierarchical nature of these responses. Furthermore, the validity of this account in the present case would depend to some extent on demonstrating that pawing and nosing were functionally similar *food-related* CS activities. For instance, although it is possible to conceive of sniffing the lever as a food-related activity, (cf. Barnett, 1956; Reberg, Mann, & Innis, 1977), it could equally plausibly be a simple orienting response directed at the CS (cf. Holland, 1977, 1980), or as we have already discussed, a natural behavioral precursor to lever pawing. One way of testing between some of these possibilities would be to impose an omission contingency solely upon lever nosing. If this response functions as a necessary component in the behavior chain leading to pawing, biting, etc. then these responses too would be suppressed. If it functions as a food-related CS activity which is independent of other contact topographies then it should be suppressed without suppressing these other topographies. Finally, if it is an CS-orienting reaction similar to the kind described by Holland (1977, 1980) then, in comparison with other CS activities, it should be relatively insensitive to omission contingencies (Holland, 1979).

In summary, although the exact functional status of the different contact topographies and their interactions with the omission contingencies still need to be clearly defined, the present results do indicate that CS contact behavior in the rat can be selectively and directly influenced by an omission contingency. This does not appear as the simple or wholesale "stamping out" of response topographies which incur the omission contingency, but as a more subtle adjustment of topographies which allows continued CS contact. At the very least, such an effect suggests that the terminal components of the autoshaped response in the rat are not solely influenced by the effect of fluctuations in Pavlovian correlations on elicited responses.

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