

Stimulus and Response Contingencies in the Misbehavior of Rats

William Timberlake, Glenda Wahl, and Deborah King
Indiana University

Misbehavior by rats, in the form of unnecessary and species-typical pawing, nosing, carrying, chewing, and retrieving a rolling ball bearing, was produced by pairing the ball bearing with food (Pavlovian procedure, Experiments 1 and 2) or by requiring contact with the ball bearing for food (operant procedure, Experiments 4 and 5). Misbehavior occurred both before and after eating the food pellet. The frequency, complexity, and duration of pre-pellet misbehavior was increased by delay of food until after the ball bearing exited (or was programmed to exit) and by requiring contact with the bearing to obtain food. Alternative goal-directed behavior, in the form of nosing, gnawing, and licking the food tray, occurred in Pavlovian contingencies in which food was delivered before the bearing was programmed to exit. Post-pellet misbehavior tended to occur when food was delivered before the bearing was programmed to exit and, in the case of required contact, before the animal released the bearing. Omission of food delivery on contact reduced the duration, complexity, and frequency of misbehavior, though experienced animals continued to contact (Experiment 3). In general, misbehavior was affected by both stimulus- and response-reward contingencies but showed characteristic organization and topography under both types of contingency.

While training a variety of animal species, Breland and Breland (1961, 1966) found that unnecessary, species-characteristic activities often interrupted a chain of learned behavior and delayed or prevented the receipt of food. A pig trained to deposit a token for food, for example, delayed its reward by repeatedly rooting and tossing the token, activities that are part of natural food-getting behavior in pigs. The Brelands referred to these activities as misbehavior. Despite its acknowledged importance, such misbehavior has seldom been studied explicitly in the laboratory. In a rare recent study, Boakes, Poli,

Lockwood, and Goddall (1978) trained rats to press a flap to obtain a ball bearing that had to be deposited in a chute to obtain food or water. After several training sessions the majority of the rats became reluctant to part with the ball bearing; they repeatedly mouthed, pawed, and retrieved it before finally releasing it down the chute. Similar behavior was noted incidentally by Skinner (1938, 1977) in Pliny (a rat), and by Cowles (1937) and Wolfe (1936) in chimpanzees.

In contrast to the paucity of experimental work, there is a surplus of theoretical explanation. Breland and Breland (1961, 1966) suggested the operant-instinctive-drift hypothesis—that misbehavior resulted from the drift of behavior originally under control of operant contingencies into more primitive phylogenetic pathways related to the “natural food gathering behaviors of a particular species” (Breland & Breland, 1961, p. 683). This “instinctive drift” is presumed to occur because appetitive behavior, evolved on the basis of phylogenetic contingencies (regular associations of responses and food in the species’ evolutionary history), comes to dominate behavior based on ontogenetic contin-

This research was supported by Biomedical Sciences Grant 46-314-10 and in part by National Science Foundation Grant BS79 15117. Experiment 1 was part of an undergraduate honor’s thesis by D. King and was presented as a paper by W. D. Timberlake and D. King at the meeting of the Animal Behavior Society, College Park, Pennsylvania, June 1977, “Misbehavior of rats in an auto-shaping paradigm.” We thank Richard Ellis, Eliot Hearst, and Peter Kaplan for their comments, and Boyd Dywer, Doug Koyanagi, and Helen Shaw for their assistance.

Requests for reprints should be sent to William Timberlake, Department of Psychology, Indiana University, Bloomington, Indiana 47405.

gencies (Skinner, 1971, 1977). Support for this view comes from the distinct resemblance of misbehavior to naturally occurring appetitive behaviors and from the fact that misbehavior has been demonstrated primarily under operant contingencies (Breland & Breland, 1961, 1966; though see Boakes & Jeffery, 1979; Jenkins & Moore, 1973).

Other theorists (e.g., Boakes et al., 1978; Jenkins & Moore, 1973) suggested that misbehavior is produced by Pavlovian conditioning (Pavlov, 1927) that results from the token-reward pairings that occur as a by-product of performing the operant chain. Support for this view is provided by the obvious temporal pairings between stimuli and responses within a chain, the fact that misbehavior competes with rather than facilitates efficient operant behavior, and the loose resemblance of misbehavior to unconditioned behavior elicited by the reward (though see Boakes et al., 1978).

A final view of misbehavior combines aspects of both the operant-instinctive-drift and Pavlovian conditioning hypotheses, while contradicting predictions of each. In the appetitive structure view (Timberlake, in press; Timberlake & Grant, 1975), misbehavior is assumed to reflect species-typical foraging and food-handling behaviors elicited by pairing food with stimuli that resemble the natural cues controlling food-gathering activities, (for related views, see Jenkins, Barrera, Ireland, & Woodside, 1978; Woodruff & Starr, 1978; Woodruff & Williams, 1976). The resemblance of experimental stimuli to natural cues is based on both their physical similarity and their temporal relation to food. Thus, appropriate pairing of food with a stimulus that only partially resembles a natural cue should still elicit elements of appetitive behavior. In this view, the Brelands' pig rooted tokens both because of their physical resemblance to cues eliciting and controlling rooting in natural episodes and because of their temporal relation to food within the operant chain.

The appetitive structure view of misbehavior resembles the Pavlovian conditioning view in that misbehavior may be elicited by pairing. It resembles the operant-instinctive-drift hypothesis in that misbehavior is not restricted to food-related behaviors identical

to those elicited by the reward. Instead misbehavior should vary as a function of the resemblance of the experimental stimuli to natural cues and circumstances (Timberlake, in press; Timberlake & Grant, 1975). If an experimental stimulus resembles the reward object, behavior may take the form of ingestive and food-handling behaviors that occur when the animal receives the reward. If an experimental stimulus resembles cues controlling other appetitive patterns related to feeding (such as predatory or social behavior), misbehavior will resemble appetitive behavior not typically directed toward the reward object. Finally, because misbehavior is determined largely by the resemblance of experimental stimuli to natural cues related to the reward, the basic topography of misbehavior directed to a particular stimulus should be similar whether produced by Pavlovian or operant procedures.

The purpose of the present experiments was to compare these different views of misbehavior by examining its topography and relation to stimulus and response contingencies imposed by the experimenter. Encouraged by the success of Boakes et al. (1978) with rats and ball bearings, we chose to study rats' behavior in the presence of a rolling ball bearing that predicted the delivery of food. First, we determined whether misbehavior toward the ball bearing could be obtained by pairing it with food in the absence of any requirement of contact (Experiments 1 and 2). Second, we examined characteristics of the pairing that were critical in producing and controlling misbehavior (Experiments 1 and 2). Third, we tested the effects of specific response contingencies on misbehavior toward the ball bearing. Animals received either omission of food contingent on contact (Experiment 3) or delivery of food contingent on contact (Experiments 4 and 5).

Experiment 1

This experiment determined whether rats would direct misbehavior toward a rolling ball bearing that predicted the response-independent delivery of food (Pavlovian procedure). If an operant contingency requiring

contact with the bearing is critical for the development of misbehavior, then none should occur in this experiment. On the other hand, if misbehavior is controlled in a Pavlovian fashion, then misbehavior should occur but resemble those behaviors directed toward the food. From the appetitive structure view, the natural appetitive behavior of the rat contains stereotyped predatory reactions of seizing and carrying that are directed at a variety of small moving stimuli such as mice and insects (Karli, 1956; Timberlake, Note 1). Thus, we considered it likely that the movement of the ball bearing, when paired with food, would produce species-typical predatory behaviors.

The use of a Pavlovian procedure provided an important opportunity to separate the associative effects of pairing food with the moving ball bearing from the nonassociative effects of random presentation of the bearing and food and of increased familiarity with the bearing. To measure these effects, we used one group that received presentation of the ball bearing alone (Group CS-Only) and another that received random pairings of the bearing and food (Group Random).

The Pavlovian procedure also allowed assessment of the effect of competition between actual feeding activities and misbehavior. In most previous studies of misbehavior (Breland & Breland, 1961, 1966; Boakes et al., 1978), food was delayed until the animal stopped the misbehavior and released the object. Since the delivery of food never overlapped the presence of the object, feeding activities never competed directly with misbehavior. In the present experiment, we tested the effect of competition between feeding activities and misbehavior by using two types of pairing of the ball bearing and food. Food was delivered to Group Programmed-Exit at a fixed time, just slightly before an unimpeded ball bearing would roll out of the chamber. The timing of food delivery thus allowed competition between initial misbehavior and behavior directed at the food. In contrast, food was delivered to Group Actual-Exit only after the bearing actually rolled out of the chamber. Thus, activities elicited by the presence of food did not compete directly with misbehavior, because food was never delivered while the

bearing was still present. If competition between misbehavior and feeding activities is important, less misbehavior would be expected in Group Programmed-Exit than in Group Actual-Exit.

Method

Subjects. The subjects were 16 Wistar female albino rats, approximately 120 days of age at the beginning of the experiment. The rats were housed singly under a 12:12 hr light/dark cycle and were maintained at 85% of their free-feeding weight by restricting their diet of laboratory chow.

Apparatus. The apparatus was a rectangular sheet-metal box, 1 × 1 × 2 ft. (30 × 30 × 61 cm), with a Plexiglas roof and front. A modified BRS feeder dispensed 5/8-in. (1.6-cm) ball bearings through a floor-level entry hole at one end of the long axis of the apparatus. The floor was slanted away from the entry hole at 5° and was creased from side to side to provide a channel leading from the entry hole to the exit hole. The channel and holes were 9 cm from the front wall of the apparatus. The ball bearing entered the chamber 1.5 sec after the bearing dispenser operated, and it left the apparatus 5.2 sec after the ball bearing dispenser operated. If impeded (and released) the ball bearing eventually returned to the channel and rolled out of the chamber. Two 1.4-cm baffles just inside the chamber slowed the ball as it entered. A Waltke feeder (Waltke Scientific Enterprises) dispensed 45-mg Noyes pellets into a recessed food tray located 14 cm to the right of the exit hole and 6.4 cm from the floor of the chamber. The observer sat 1 m from the front wall of the apparatus. Data recording and control equipment were located in the same room.

Procedure. Four groups of four rats each (Groups CS-Only, Random, Programmed-Exit, and Actual-Exit) were run in three replications; at least one subject from each group was run in each replication. Each replication consisted of four phases: (a) pretraining—1 day of adaptation to the room, 1 day of 20-min exposure to the chamber with food pellets present in the food tray, and 1 or 2 days of training to approach and eat from the food tray to a criterion of nine approaches out of 12 food deliveries; (b) baseline—1 to 4 days on which only the ball bearing was presented; (c) conditioning—16 days; and (d) extinction—8 days on which only the ball bearing was presented.

Each session in the last three phases consisted of 20 presentations of the ball bearing on a variable-time (VT) 45-sec schedule. The groups were matched on the basis of their frequency of contact with the ball bearing during the initial baseline phase. During conditioning, the Programmed-Exit group received food at the end of a fixed 5.1-sec interval, just slightly before the time the bearing exited if it were not impeded. The Actual-Exit group received food only after the ball bearing had left the chamber. For this group any interference with the ball bearing delayed delivery of food. The Random group received presentations of the ball bearing and food on two independent variable-time 45-sec schedules. Group CS-Only received periodic presentation of the ball bear-

ing alone. The ball bearings and the apparatus were washed after each subject with a weak organic-acid detergent mixture to remove odors deposited by that subject.

On each trial, at least one observer coded the animal's behavior in terms of the categories shown in Table 1 and recorded any additional comments beside each trial. In addition, a film was made of the behavior of one rat from each group at asymptote in conditioning and ex-

ting. The first seven categories in Table 1 were developed by the first and second authors after watching a set of pilot animals under the conditions of the experiment. Each observer in subsequent experiments was trained by at least one previous observer using lists of codes and definitions, a film of the rats' behavior, and simultaneous coding of the rats' behavior for at least 2 days. Reliability checks of the different observers produced a correlation between observers of .94 or better. The correlation was calculated from a two by two table of agreements and disagreements.

Table 1
Behavior Categories

Category	Description
Orient ^a	Point nose at the ball bearing
Approach ^a	Move nose or paw within one cm of the ball bearing ^b
Contact ^a	Touch ball bearing with nose, paw, or mouth ^b
Nose ^a	Touch the ball bearing with nose
Paw ^a	Touch the ball bearing with forepaw
Carry ^a	Hold the ball bearing in the mouth and take at least one step
Chew ^a	Mouth and bite the ball bearing while holding it in the forepaws, often includes rotating the bearing in the forepaws
Incidental contact	The rat's tail or body impedes the ball bearing while its nose is pointed elsewhere
Retrieve	Release ball bearing and stop or grasp it again
Dig	Dig (rapidly alternate and reach with the forepaws) at the entry hole after the bearing dispenser operated and before the bearing entered the chamber

^a Only these categories were explicitly coded on each trial of Experiment 1. The remainder were added in subsequent experiments. Each observer was trained by a prior observer using films and concurrent coding. Reliability checks yielded a minimum correlation of .94, .97 if only the first seven categories were used.

^b There were times when orient and approach were minimal prior to contact (e.g., the ball bearing rolled close to the rat which raised its paw and stopped it, and thereby oriented, approached, and contacted in the same movement). For consistency, we coded orient and approach whenever we coded contact. This procedure proved easier than specifying how long the animal had to point its nose at the bearing to record an orient, and how far it had to move to designate an approach. The procedure was not important in determining the experimental outcome, because we used contact as the primary measure in all experiments.

Results and Discussion

Figure 1 shows the mean percentage of trials with orient, approach, and contact behaviors as a function of groups, conditions, and trials. There was a baseline tendency to orient, approach, and contact the ball bearing on 20%-25% of the trials, a tendency that was not changed significantly by repeated presentation of the ball bearing alone, random presentation of the bearing and food, or by pairing of the ball bearing with food in the Programmed-Exit group. However, for the Actual-Exit group, pairing of the bearing and food markedly increased interaction for all subjects, and subsequent presentation of the ball bearing alone in extinction decreased interaction to baseline levels.

An analysis of variance comparing the percentage of trials with a contact at asymptote (three-trial medians) during conditioning showed a significant difference among the four groups, $F(3, 12) = 9.01, p < .01$. Subsequent planned tests showed that contacts for Group Actual-Exit exceeded those for both control groups (Groups CS-Only and Random), $t_s(6) = 4.96$ and $4.94, p < .01$. In contrast, Group Programmed-Exit did not differ in percentage of contact trials from the control groups, both $t_s(6) < 1$, and contacted significantly less than Group Actual-Exit, $t(6) = 2.61, p < .05$.

The two paired groups also differed during conditioning in terms of other behaviors recorded in the codes, in the written observations, and on films of the animals' behavior at asymptote. In the latter part of conditioning, two animals in the Actual-Exit group typically seized the ball bearing with their paws as it entered the chamber, stuffed it in their mouth, and carried the bearing to the opposite end of the apparatus where they

sat and chewed the bearing while turning it in their paws. One of these animals decreased chewing toward the end of conditioning, but the other did not. These rats frequently "patted" the bearing under one paw, releasing and retrieving it repeatedly before finally "committing" themselves to the food tray. Commitment to the food tray was signaled by burying the head in the tray while nosing, licking, gnawing, and digging. The rat's back was usually convex during these behaviors so that it appeared the animal was lying in the food tray with its hind paws on the floor. Once an animal committed itself to the food tray, it did not return to the bearing. The other two animals in the Actual-Exit group carried the ball bearing much less frequently; instead, they typically stopped the ball bearing with their nose or paw when it entered the chamber, sniffed it, and occasionally bit it, and then ran ahead of the bearing to commit to the food tray.

Both behavior patterns directed toward the bearing disappeared under extinction.

In contrast, the animals in the Programmed-Exit group responded to the sound and sight of the ball bearing by approaching or remaining at the food tray, and committing to it. On film we have an example of an animal in this group encountering a ball bearing while exploring near the entrance hole. The animal startled, dashed to the food tray, and committed itself. The behaviors of this group seemed analogous to goal tracking (Boakes, 1977).

An unexpected result in the Programmed-Exit group was the occurrence of considerable post-pellet interaction with the ball bearing. Often several times in a session, while a rat was committed to the hopper, its body or tail impeded the ball bearing, so that the bearing was still present after the animal ate the pellet. Under these circumstances, three of the four animals sometimes re-

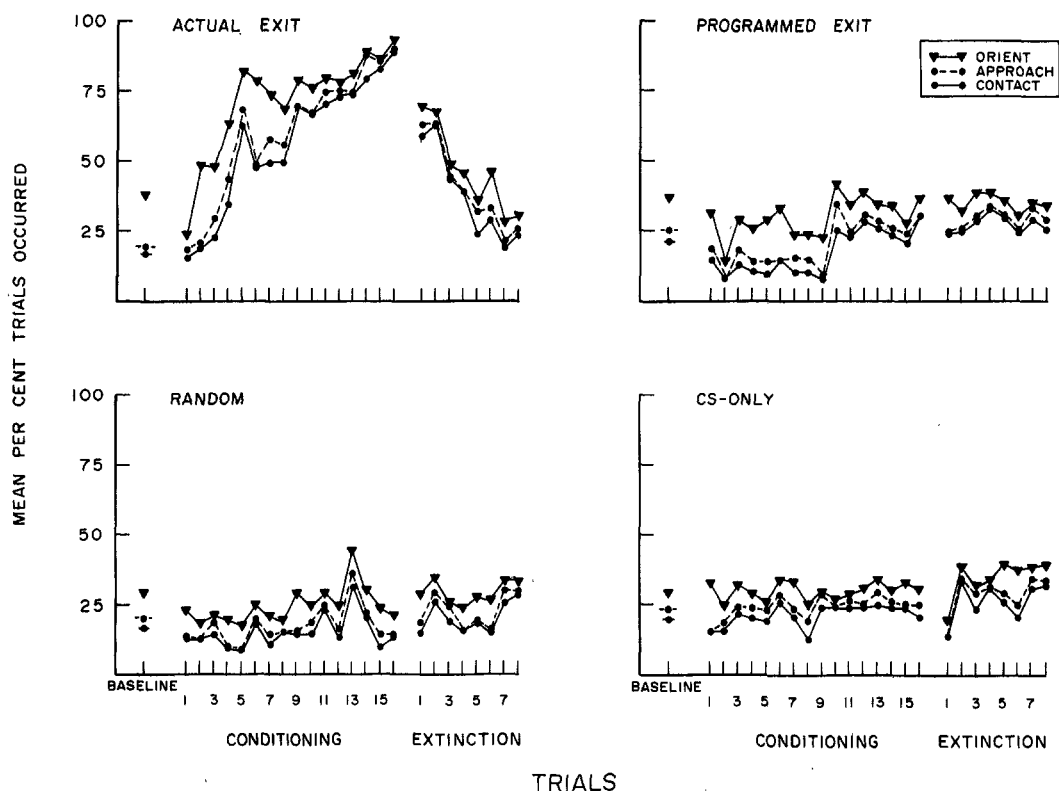


Figure 1. Mean percentage of trials with at least one orient, approach, or contact during baseline, conditioning, and extinction (Experiment 1).

tried the ball bearing before it rolled out, and they chewed and held the bearing before finally releasing it. When it occurred, this behavior sometimes continued for up to 2 min¹ and delayed the next pellet delivery because the intertrial interval did not begin until the ball bearing left the chamber. Since this behavior closely resembled the pre-pellet misbehavior of two of the animals in the Actual-Exit group, we called it post-pellet misbehavior.

It appeared that post-pellet misbehavior was instigated by pairing the bearing with food, but the delivery of food elicited behaviors directed toward the food tray that blocked the expression of behaviors directed toward the ball bearing. Eating the pellet allowed the blocked behaviors instigated by the ball bearing to appear. Support for this argument is found in the extinction results that showed an initial increase in chew and contact for the three animals that previously showed only post-pellet misbehavior. The delivery of food may also have partially blocked the acquisition of misbehavior as well as its expression. However, the post-pellet occurrence of misbehavior and its increase under extinction support only the blocking of expression.

Taken together, these results clearly dispute the hypothesis that an operant contingency requiring stimulus contact is necessary to produce misbehavior with respect to that stimulus. The results also contradict the Pavlovian hypothesis that misbehavior is limited to those behaviors directed to the food pellet. Pairing the ball bearing with food delivery produced complex appetitive behavior in the form of stopping, investigating, seizing, carrying, manipulating, and chewing the ball bearing. The rats directed none of these response topographies toward the food pellet. Instead, the rat picked up the pellet with its mouth and swallowed it with a few minimal jaw movements. The results also suggest that presenting food while the bearing is present blocks the expression of misbehavior in favor of behavior directed toward the food tray (goal tracking—Boakes, 1977). Given the opportunity, the blocked misbehavior was expressed after the pellet was obtained. This conclusion was tested further in Experiment 2.

Experiment 2

The results of Experiment 1 suggested that appetitive behavior (misbehavior) directed toward a stimulus with biologically relevant characteristics can be elicited simply by pairing that stimulus with food. However, it appeared that the expression of misbehavior could be blocked by goal-directed behavior elicited by the delivery of food while the ball bearing was present. The present study determined whether the timing of food delivery affected the blocking of misbehavior. Group Before-Programmed-Exit received food early in the trial at the point the bearing was programmed to have rolled halfway through the chamber. Group After-Programmed-Exit received food late in the trial, 2.5 sec after the bearing was programmed to exit. These times were chosen on the basis of the operant characteristics of misbehavior so that during initial trials on which an animal directed behavior toward the bearing, the subjects in Group Before-Programmed-Exit received food during approach or initial contact of the bearing. In contrast, under similar circumstances subjects in Group After-Programmed-Exit received food after several seconds of contact. It should be emphasized that these response-reward conjunctions occurred only during trials on which the animal directed behavior toward the bearing. A more frequent response-reward conjunction on initial trials was between food and approaching the food tray (or related behavior).

A replication of the Actual-Exit group of Experiment 1 was used to evaluate the effect of the timing of food delivery. If simple overlap of the bearing and food is sufficient to block misbehavior, then both Programmed-Exit groups should show less misbehavior than the Actual-Exit group. On the other hand, if the critical effect of food delivery is to interrupt the expression of misbehavior in its initial stages, then the After-Programmed-Exit group should show misbehavior comparable with that of the Actual-

¹ On some occasions post-pellet interaction with the bearing would have continued longer than 2 min, but the experimenter distracted the subject by raising the lid of the apparatus and, if necessary, gently poking the ball bearing out of the subject's paws with the eraser end of a pencil.

Exit group and greater than that of the Before-Programmed-Exit group.

This experiment also examined more carefully the nature and eliciting conditions of post-pellet misbehavior. The apparatus was changed to minimize the chance that post-pellet misbehavior could be elicited incidentally by contact of the bearing with the rat's body or tail while its attention was directed elsewhere. In the new apparatus it was possible for the bearing to pass under the rat without touching it. In addition, the topography and duration of post-pellet misbehavior were recorded for each trial.

Method

Subjects. The subjects were 15 Sprague-Dawley female albino rats, approximately 110 days of age at the beginning of the experiment. Housing and maintenance were identical to that in Experiment 1.

Apparatus. The apparatus was identical to Experiment 2 except that a brass channel replaced the sheet-metal crease leading from the entry to the exit hole. The channel was inserted below the level of the floor so that the ball bearing could roll beneath any part of the rat that was across the exit path. The small baffles to slow the ball bearing were removed. To replace their function, the bearing was forced to drop through a small hole just prior to entering the chamber. A running time meter and a stopwatch were added to record contact times for pre- and post-pellet misbehavior, respectively. Films were again made of behavior at asymptote.

Procedure. The rats were assigned randomly to three groups of five animals each. All groups received the same four phases as in Experiment 1: pretraining, baseline, conditioning, and extinction. The only change from the pretraining condition in Experiment 1 was that each rat received a maximum of 15 pellets during shaping to approach and eat from the food tray. Training was discontinued previous to this point if the rat approached the click of the feeder from across the chamber on four successive deliveries. Baseline, conditioning, and extinction lasted 4, 18, and 12 days, respectively. On each day each subject received 12 presentations of the ball bearing on the same schedule as in Experiment 1 (VT 45 sec). During conditioning, the Before-Programmed-Exit group received food 1.6 sec after the ball bearing entered the box. In this apparatus, the ball bearing entered the chamber 2 sec after operation of the bearing dispenser and, if undisturbed, left the chamber 3.1 sec later for a total of 5.1 sec from the operation of the dispenser to exit. The subjects in the Actual-Exit group received food immediately after the bearing left the box. The After-Programmed-Exit group received food 2.5 sec after the ball bearing would have left the box (5.6 sec after the ball bearing entered the chamber and 7.6 sec after the dispenser was operated). Note that as in Experiment 1, food was delivered independently of whether the animal contacted the bearing, so all animals received food on all trials.

Results and Discussion

Figure 2 shows the percentage of trials with a contact for the three groups (orient and approach showed effects similar to contact and are not reported). Separate analyses of variance comparing asymptotic (3-day) medians in baseline and conditioning, and in conditioning and extinction, confirmed an overall increase in contact under conditioning and a decrease in contact in extinction, $F_s(2, 12) = 10.33$ and 4.83 , $p_s < .01$ and $.05$. Sizable Groups \times Trials interactions were produced by the failure of the Before-Programmed-Exit group to increase contact with the ball bearing during conditioning or to decrease contact during extinction, $F_s(2, 12) = 4.33$ and 3.27 , $p < .05$ and $.10 > p > .05$. Both changes were insignificant for this group, $t_s(4) < 1$, $p > .10$. Instead, the films and comments showed that these animals committed to the food tray when the ball bearing entered the chamber.

Figure 3 shows that pairing the presentation of the ball bearing with the delivery of food markedly changed the pattern of interaction with the bearing. In all groups, the mean percentage of carry per contact trial at asymptote increased from baseline to conditioning, $F(1, 12) = 11.8$, $p < .01$. In both Actual-Exit and After-Programmed-Exit groups, four of the five animals carried on all trials at asymptote. Three of the five animals in the Before-Programmed-Exit group also carried, though only two of them on all of the contact trials. In contrast, the mean percentage of occurrence of pre-pellet chew per contact trial decreased under conditioning, $F(1, 12) = 12.1$, $p < .01$. This last finding is at variance with the results for the Actual-Exit group in Experiment 1 and the results for subsequent groups showing similar high levels of misbehavior.

Figure 4 shows average duration of misbehavior per contact trial at asymptote, both prior to and after pellet delivery. The average duration of pre-pellet contact decreased from baseline to conditioning and increased from conditioning to extinction for all groups, $F_s(1, 12) = 8.78$ and 9.67 , $p_s < .05$ and $.01$. For the Before-Programmed-Exit group, the delivery of the pellet immediately interrupted any contact with the ball bearing.

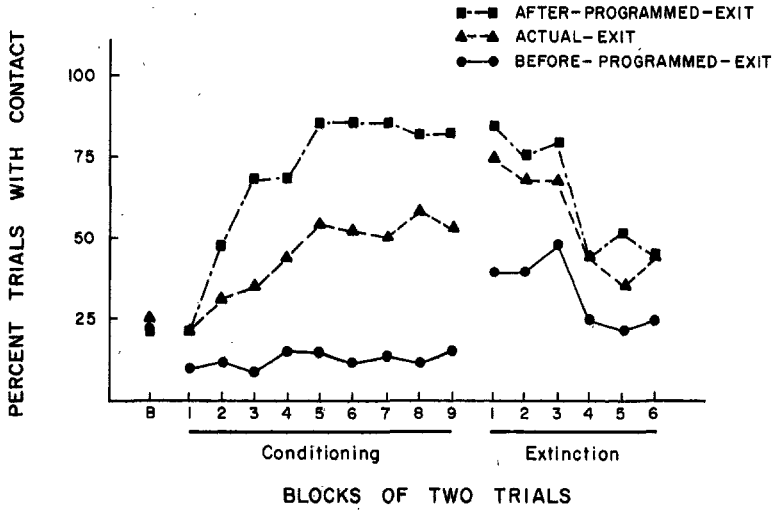


Figure 2. Mean percentage of trials with at least one contact during baseline, conditioning, and extinction (Experiment 2).

The average duration of a contact was less than .1 sec. For the After-Programmed-Exit group, the delivery of the pellet exerted less effect. Once initiated, contact with the bearing continued for an average of 2 sec after the pellet was delivered. There was a suggestion that food delivery shortened inter-

action with the ball bearing in comparison with that of the Actual-Exit group, 6.1 versus 2.7 sec on the average, but this difference was not significant, $t(8) = 1.38, p > .10$.

Finally, despite the virtual elimination of occasions on which the bearing struck the tail or body of a rat, post-pellet misbehavior

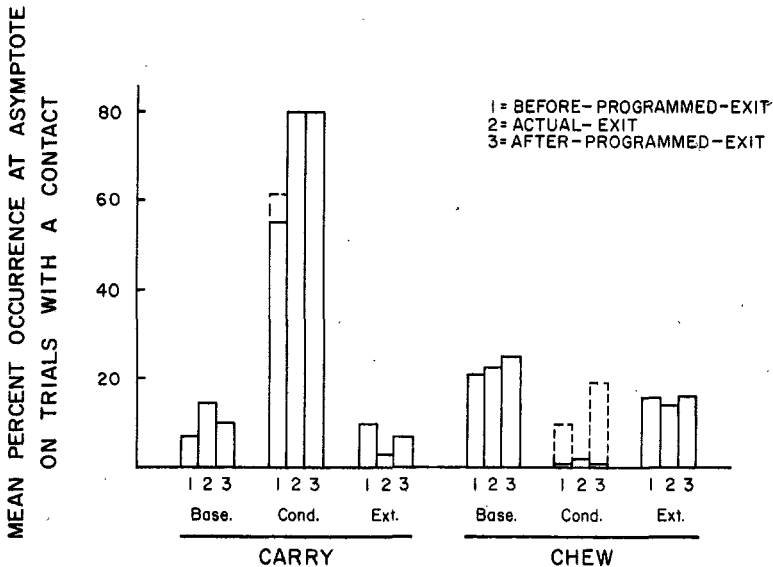


Figure 3. Mean percentage of contact trials at asymptote (three-trial medians) with at least one carry or chew during baseline, conditioning, and extinction (Experiment 2). The dotted lines refer to post-pellet interaction with the ball bearing.

still occurred in all but one of the animals in the programmed-exit groups. These animals retrieved and interacted extensively with the bearing after obtaining the pellet. Two animals in each group showed post-pellet chewing on more than 35% of the trials. As can be seen from Figure 4, the average duration of a post-pellet interaction exceeded 20 sec. This duration should be contrasted with the much shorter duration of pre-pellet interaction in the After-Programmed-Exit and Actual-Exit groups.

In summary, the early response-independent delivery of food blocked any increase in pre-pellet behavior directed toward the ball bearing, though the topography of the contacts that occurred changed slightly (percentage of contact trials with a carry increased). However, later response-independent delivery of food did not interfere markedly with the expression of pre-pellet misbehavior. Apparently once misbehavior was well underway, it was less susceptible to interruption by the delivery of food.

Lastly, despite the near elimination of incidental blocking of the bearing with the body or tail, 9 out of 10 rats in the programmed-exit groups still showed post-pellet misbehavior.

Experiment 3

The data reported in Experiments 1 and 2 are consistent in showing that misbehavior is elicited by Pavlovian pairings of food with presentation of the ball bearing, though expression of misbehavior may be blocked by behaviors elicited by the delivery of food. The data also show that misbehavior can be affected by a negative contingency relating misbehavior to food. The average duration of pre-pellet misbehavior per contact was decreased relative to baseline by the opportunity to obtain food contingent on stopping misbehavior and allowing the bearing to roll out of the chamber. However, the average duration of post-pellet misbehavior relative to baseline was not affected by the oppor-

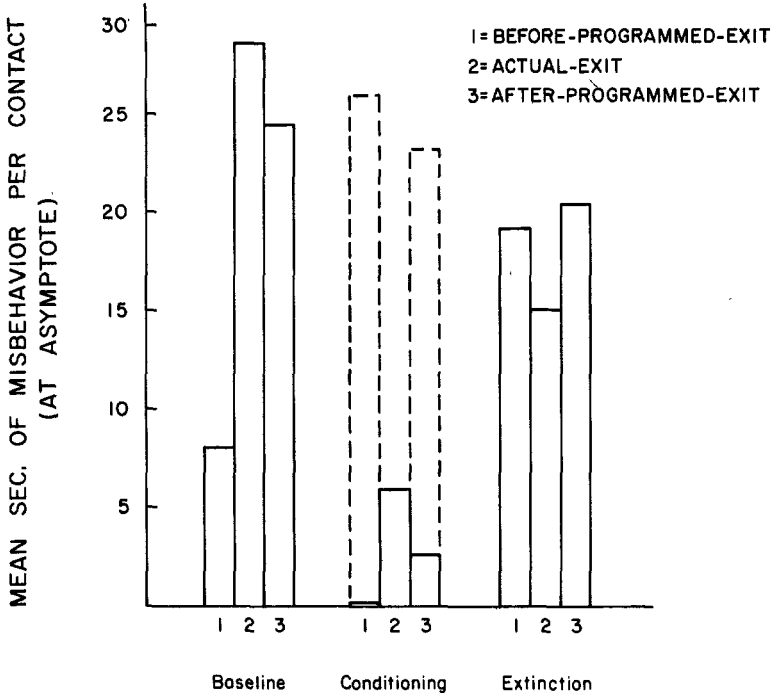


Figure 4. Mean seconds of misbehavior per contact trial at asymptote (three-trial medians) during baseline, conditioning, and extinction (Experiment 2). The dotted lines refer to post-pellet interaction with the ball bearing.

tunity to begin a new trial contingent on stopping the misbehavior.

The present experiment explored the effects of a more specific negative contingency by testing whether current pre-pellet misbehavior could be reduced in frequency or duration by a contingency between bearing contact and food that omitted food contingent on contact with the ball bearing. Based on the apparent importance of the Pavlovian pairing in producing misbehavior, we expected contact to be reduced but not eliminated by the omission contingency (e.g., Williams & Williams, 1969).

Method

Subjects and apparatus. See the preceding experiment.

Procedure. Following extinction in the previous experiment, the animals were placed for 20 sessions on a response contingency that omitted food on trials with a contact. On trials without a contact, food was delivered for each group under the conditions specified in the previous experiment. Following omission, the animals were returned to extinction for 12 sessions.

Results and Discussion

Figure 5 shows that the omission contingency reduced the contacts of all groups from their baseline levels, $F(1, 12) = 7.50$, $p < .05$. The subsequent extinction condition resulted in an increase in contacts, $F(1,$

$12) = 10.0$, $p < .01$. The omission contingency had an immediate negative effect on the Before-Programmed-Exit group, reducing contact close to zero by the fifth trial. Contact in the other groups initially increased before declining to slightly below baseline levels.

Table 2 shows that the omission contingency also changed the pattern of contact with the ball bearing. All groups reduced the conditional probability of carry and chew, though only the latter effect was significant, $F_s(1, 12) = 3.33$ and 8.50 , $.10 > p > .05$ and $p < .05$. All but one animal simply stopped the bearing with its paw and nosed it briefly. This decreased complexity of interaction is reflected in the decreased duration of each contact, also shown in Table 2, $F(1, 12) = 12.1$, $p > .01$.

In short, the omission contingency reduced the frequency of contacts and their complexity and duration in all groups. However, contact was reduced effectively to zero only in the Before-Programmed-Exit group. In the other two groups, 7 of the 10 animals continued to contact the bearing. It might be argued that the reduction in misbehavior was due only to the decreased frequency of reward rather than to the omission contingency, but this possibility seems unlikely. We know of no reports of a sustained (20 sessions) reduction in the level of a behavior

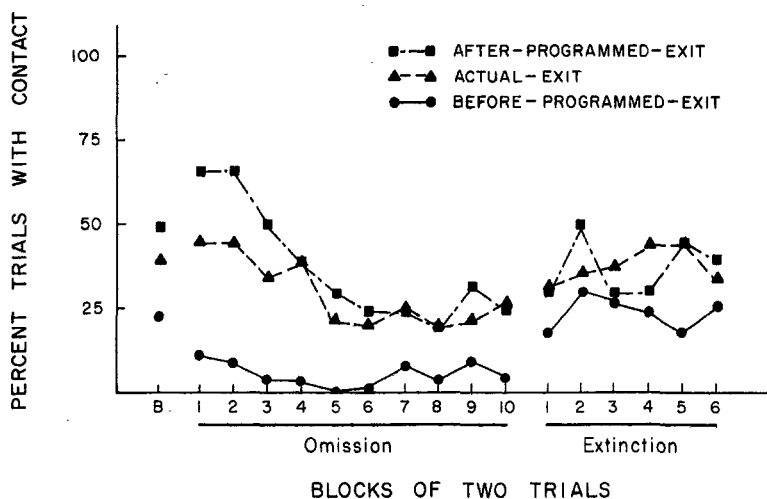


Figure 5. Mean percentage of trials with at least one contact during baseline (extinction from Experiment 2), omission, and extinction (Experiment 3).

below its *unrewarded baseline* resulting from reduction in the frequency of reward. That the animals increased misbehavior under a subsequent no-reward condition (extinction) also indicates an inhibitory effect of the omission contingency. Further, unpublished data (1979) from our laboratory showed no reduction in misbehavior under a 50% rate of partial reward, a reduction larger than that which occurred under the present omission contingency (though see Boakes & Jeffery, 1979).

Experiment 4

Experiments 4 and 5 investigated the effects of a positive response contingency on misbehavior. Subjects were required to contact the bearing in order to obtain food. Using this procedure, we were able to answer three questions: (a) whether the nature of past misbehavior affects subjects' behavior under a response contingency, (b) whether a positive response contingency modifies the form or duration of contact with the bearing, and (c) whether delivery of food while the ball bearing is present blocks the expression or development of misbehavior in an operant contingency.

In Experiment 4, animals from the preceding experiment were divided into two groups, both of which were required to contact the bearing within 8 in. (20.3 cm) of

the entrance to receive food. The Exit group received its earned food when the bearing left the chamber (Operant 1 phase) or 2 sec after the bearing left the chamber (Operant 2 phase). The Before-Exit group received its earned food 1.6 sec after the bearing entered the chamber (Operant 1 phase) or immediately on contact (Operant 2 phase). The second conditioning phase (Operant 2) was designed to exaggerate the trends shown in the first phase. If food delivery under an operant schedule elicits behaviors that potentially compete with and block pre-pellet misbehavior, then the Before-Exit group should show less extensive pre-pellet misbehavior than the Exit group, and considerable post-pellet misbehavior. Finally, if pre-pellet misbehavior in the Before-Programmed-Exit group of Experiment 2 was blocked by conditioned goal-directed behavior, then these animals should show the slowest acquisition of contact in the present experiment. They should have to extinguish goal-directed behavior before increasing contact with the bearing.

Method

Subjects and apparatus. See previous experiments.

Procedure. Seven subjects from Experiment 3 were assigned to each of two groups, the Before-Exit group and the Exit group; one animal was discarded. The groups were matched on their baseline percentage contact scores in Experiment 3, and two animals from the

Table 2
Conditional Probabilities of Carry and Chew and Average Duration of Misbehavior by Groups in Baseline, Omission, and Extinction (Experiment 3)

Measure and group	Condition		
	Baseline	Omission	Extinction
Conditional probability of carry			
Before-Programmed-Exit	.08	0	0
Actual-Exit	.02	.02	0
After-Programmed-Exit	.17	.02	.08
Conditional probability of chew			
Before-Programmed-Exit	.16	0	0
Actual-Exit	.14	.02	.06
After-Programmed-Exit	.16	0	.15
Average duration of misbehavior			
Before-Programmed-Exit	19.1	1.0	2.1
Actual-Exit	15.4	2.2	5.9
After-Programmed-Exit	20.3	1.6	10.4

Before-Programmed-Exit group of the last experiment were assigned to each group. Subjects in both groups received food only if they contacted the ball bearing with their nose or paw in the first 8 in. (20.3 cm) of the apparatus. In Operant 1 (24 days) the Before-Exit group received food 1.6 sec after the ball bearing entered the chamber, and the Exit group received food when the ball bearing left the chamber. In Operant 2 (14 days) the Before-Exit group received food immediately on contact, and the Exit group received food 2 sec after the bearing exited. An extinction phase was run after each conditioning phase, 20 days for the first extinction and 16 days for the second.

Results and Discussion

Figure 6 shows that the response contingency markedly increased the percentage of trials with a contact for both groups. The Before-Exit group appeared to acquire the contact more rapidly, but the two groups were indistinguishable at asymptote, $t(12) < 1$, $p > .10$. Figure 6b shows that the animals increased contact more rapidly in the second operant phase, combined $t(13) = 9.63$, $p < .01$, and achieved a slightly (though unreliably) higher asymptote, combined $t(13) = 1.68$, $p > .10$. The difference in speed of increase occurred partly because the majority of the animals from the Before-Programmed-Exit group in Experiments 2 and 3 were slow to increase contact in the initial operant phase. Of the five animals not contacting on 100% of the trials at asymptote in Operant 1, three were among the four animals from the Before-Programmed-Exit group of Experiment 2.

Figure 7 shows that the mean percentage of carry per contact for both groups increased over baseline, combined $ts(13) = 1.87$ and 2.83 , $p < .05$. However, the mean percentage of carry per contact did not differ significantly from that for the same subjects in Experiment 2, combined $t(13) < 1$, $p < .10$. Neither operant phase affected the percentage of chew per contact in the Before-Exit group, both $ts(6) < 1$, $p > .10$, but both phases increased the percentage of chew per contact in the Exit group, $ts(6) = 2.03$ and 3.13 , $p < .05$. The operant contingencies also increased the mean percentage of contact trials with a chew in the Exit group over its level in the same animals in Experiment 2, $ts(6) = 1.87$ and 2.83 , $.10 > p > .05$ and $p < .05$. Percentage of contact trials with a chew in the Exit group also exceeded that

in the Before-Exit group of the present experiment, $ts(12) = 2.19$ and 3.42 , $p < .05$.

Figure 8 also suggests a difference between the misbehavior of the Exit group and that of the Before-Exit group by showing greater average duration of a contact for the Exit group under both operant phases, $ts(12) = 1.77$ and 3.09 , $p > .10$ and $< .05$. In the Operant 2 phase, delivery of food immediately on contact significantly shortened the duration of misbehavior of the Before-Exit group, $t(6) = 2.66$, $p < .05$. Delay of food until 2 sec after the bearing exit produced an insignificant increase in average duration of contact for the Exit group, $t(6) < 1$, $p > .10$. Duration of each contact decreased from baseline in both operant phases for the Before-Exit group, $ts(6) = 3.18$ and 3.98 , $p < .05$, but not for the Exit group, both $ts(6) < 1$, $p > .10$. It should also be noted that there was a considerable duration of post-pellet chew for the Before-Exit group.

In summary, a positive response contingency slowly overcame any previously learned tendency to go to the food source upon presentation of the ball bearing, and it produced complex, highly reliable, stereotyped behaviors directed toward the ball bearing. In addition to previously described misbehavior, movies of each animal at asymptote showed that all but two animals usually attempted to dig the ball bearing out of the entry hole and thereby retarded its entry into the chamber. The response contingency also increased the frequency of pre-pellet misbehavior in both groups and the percentage of chew per contact in the Exit group relative to baseline and to what occurred under stimulus contingencies alone. However, the percentage of carry per contact trial did not exceed that obtained simply by pairing the ball bearing and food in Experiment 2. Lastly, just as under stimulus contingencies, the average duration of pre-pellet misbehavior was greater for the Exit group than for the Before-Exit group, while the latter group showed considerable post-pellet misbehavior.

Experiment 5

The main purpose of this experiment was to test further the importance of past ex-

perience in producing and determining the form of misbehavior in the response-contingent procedure. The data of Experiments 3 and 4 and those of Boakes et al. (1978) suggest that some aspects of misbehavior, once established, persist in form and amount despite changes in the stimulus and reward conditions. Thus, the pre- and post-pellet misbehavior obtained in Experiment 4 may have been partly determined by the prior experience of the animals. The present experiment tested whether naive animals, re-

warded at onset or offset of contact with the ball bearing, would show the same complexity and expression of misbehavior. The present experiment also directly tested the effects of experience by reversing the conditions of food delivery once an instrumental chain was acquired.

The second purpose of this experiment was to test the hypothesis that post-pellet misbehavior was due to blocking of pre-pellet expression by competition from feeding activities against the alternative hypothesis

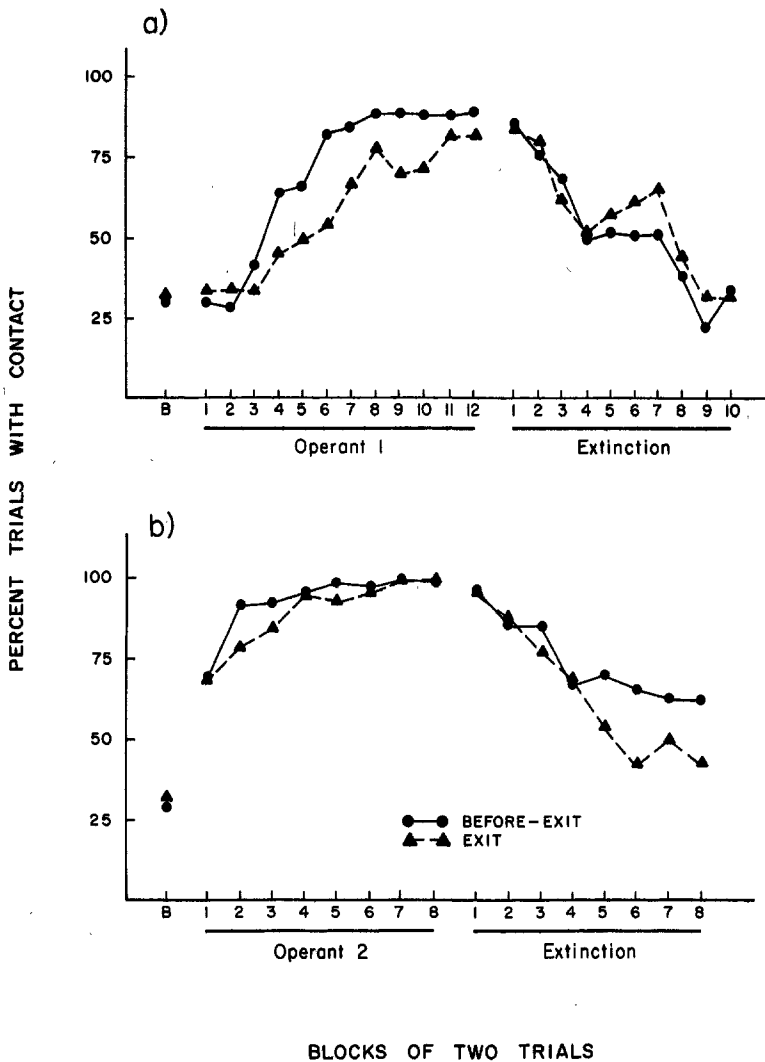


Figure 6. Mean percentage of trials with at least one contact during (a) baseline, Operant 1, and extinction and (b) baseline, Operant 2, and extinction (Experiment 4).

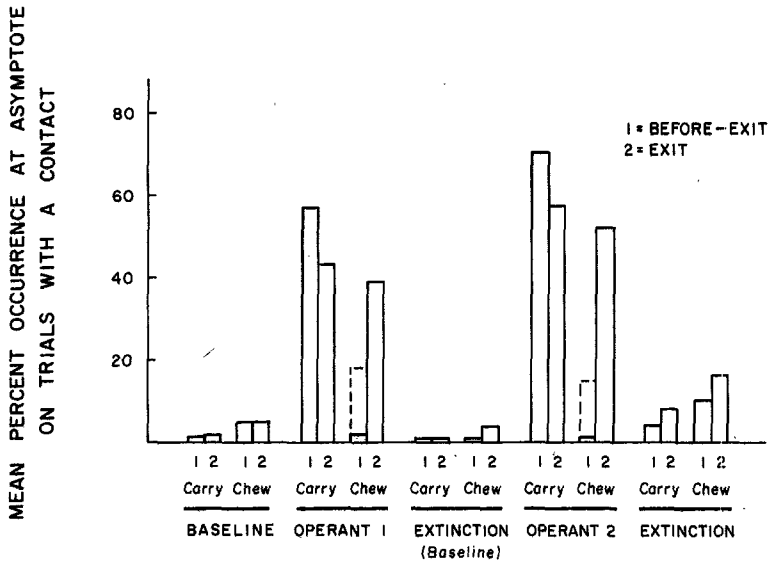


Figure 7. Mean percentage of contact trials with at least one carry or chew during baseline, Operant 1, extinction (baseline), Operant 2, and extinction (Experiment 4). The dotted lines refer to post-pellet interaction with the ball bearing.

that post-pellet misbehavior was due simply to the availability of the bearing after receipt of the pellet. In the previous experiments, animals for which food delivery did not interrupt misbehavior also never had access to the bearing following food delivery. The present experiment separated the conditions

of no potential interruption and lack of access to the ball bearing following food delivery by rewarding an Offset group immediately after they stopped interacting with the bearing; thus the bearing was available to contact for the 2-3 sec it took to roll out of the chamber after the rat released it and

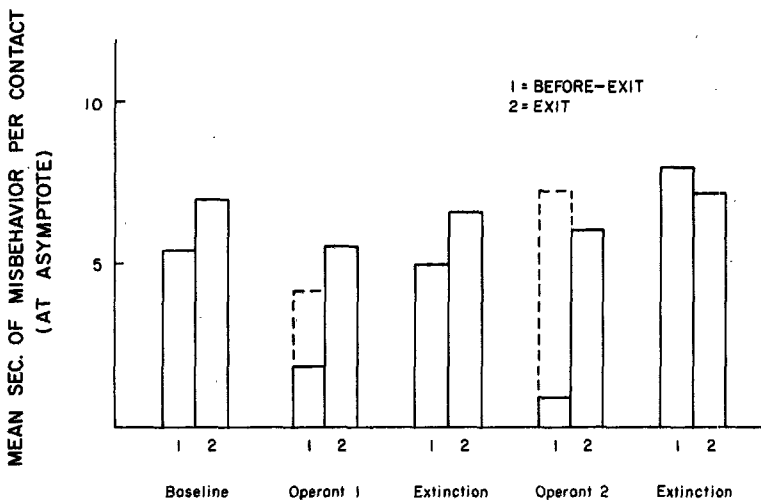


Figure 8. Mean seconds of misbehavior per contact trial at asymptote (three-trial medians) during baseline, Operant 1, extinction (baseline), Operant 2, and extinction (Experiment 4). The dotted lines refer to post-pellet interaction with the ball bearing.

food was delivered. It took considerably less time than this for the animal to eat the pellet. If post-pellet misbehavior results from the blocking or interrupting of expression of pre-pellet misbehavior, then the Offset group should not show post-pellet misbehavior because their pre-pellet misbehavior was self-terminated. If simple availability of the ball bearing is sufficient to produce post-pellet misbehavior, then it should occur in the Offset group as well as the Onset group.

Method

Subjects. The subjects were 12 Sprague-Dawley female albino rats, approximately 100 days of age at the beginning of the experiment. Housing and maintenance were similar to that in Experiment 1. One animal died after the first conditioning phase, and its data were discarded.

Apparatus. The apparatus was identical to that in Experiment 4 except the stopwatch for recording post-pellet interaction was replaced by a running time meter.

Procedure. The animals were randomly assigned to two groups of six rats each: an Onset group and an Offset group. Subjects in the Onset group received food immediately when they contacted the ball bearing; subjects in the Offset group received food when they stopped contacting the bearing and were at least 2 cm away from it.

The experiment was divided into six phases: (a) pre-

training—4 days; (b) baseline—4 days; (c) conditioning—40 days; (d) reversal—14 days; (e) delay of reward in offset—12 days; and (f) extinction—10 days. All common phases were the same as in Experiment 2. In reversal, the conditions for food delivery were switched between the Onset and Offset groups, and in delay of reward, food delivery was delayed 8 sec after the ball bearing left the chamber.

Results and Discussion

The percentage of trials with a contact, carry, or chew is shown separately in Figure 9. A response contingency on either the onset or offset of contact produced a rapid increase in the percentage of trials with a contact and a carry. Analyses of variance comparing 3-day asymptotic medians during baseline and conditioning for contact and carry showed a significant trials effect, $F_s(1, 9) = 85.1$ and 22.2 , $p < .001$, but no significant groups or interaction effects. Percentage of trials with a chew increased slowly but steadily for the animals in the original Offset group. For the original Onset group, percentage of trials with a pre-pellet chew increased initially for the original Onset group and then decreased to zero for all but one animal. An analysis of variance on pre-pellet chew at asymptote

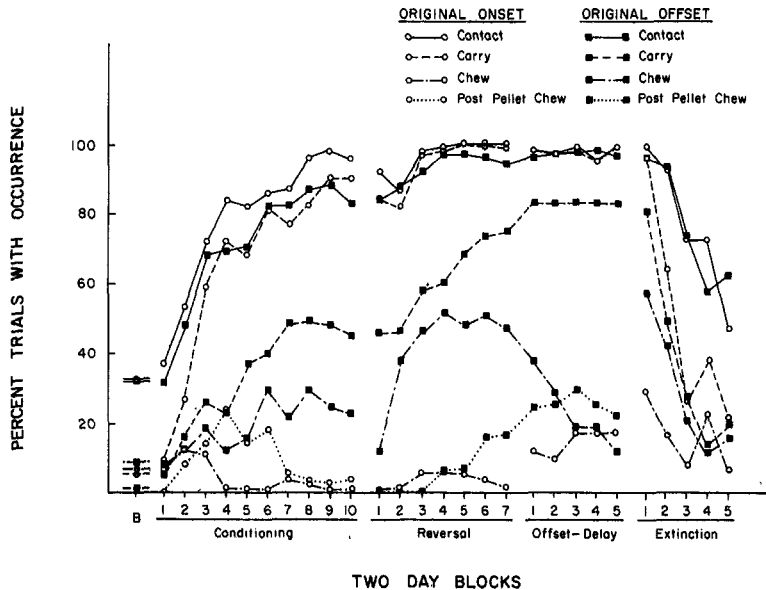


Figure 9. Mean percentage of trials with at least one contact, carry, or chew for the Original Onset group and the Original Offset group during baseline, conditioning, reversal, offset delay, and extinction (Experiment 5). The widely spaced dots show post-pellet interaction.

showed a significant interaction of conditions and groups, $F(1, 9) = 9.16, p < .01$. A test of simple main effects revealed that the Offset group chewed significantly more than the Onset group during conditioning, $F(1, 18) = 7.03, p < .025$. Only the Onset group showed post-pellet chew, which first increased for all animals and then decreased.

In reversal, the delivery of food on onset of contact increased the reliability of carry for the original Offset group, $t(5) = 3.39, p < .01$, to the point that the asymptotic scores (three-trial medians) did not differ from those of the original Onset group, $t(9) = 1.27, p > .10$. All animals carried on all trials. Pre-pellet chew increased initially and then slowly decreased to zero for all but one animal, a final level also indistinguishable from the scores of the original Onset group ($t < 1, p > .10$). Post-pellet chew began to occur in four of the six animals of the original Offset group. One of the remaining animals continued to show a high level of pre-pellet chew, and the other never chewed under any condition.

In contrast to these effects in the original Offset group, reversal had no significant ef-

fect on contact, carry, or chew in the original Onset group (new Offset group). On the chance that their well-practiced behavior of seizing the bearing and dashing toward the food tray prevented these animals from making contact with the new contingency, an 8-sec delay was imposed between the time the bearing left the chamber and the delivery of food. The conditions for the original Offset (new Onset) group remained the same. It was hoped that the delay would provide an opportunity for breakdown of the old pattern and for emergence of more complex misbehavior. However, only one animal (markedly) increased chew.

The above results are generally supported by the average duration of pre-pellet and post-pellet contact shown in Figure 10. At asymptote (three-trial medians) in the initial conditioning phase, the original Offset group showed considerably longer average pre-pellet contact than did the original Onset group, $t(9) = 3.19, p < .05$. Reversal of the contingency conditions produced an initial increase and then a decrease in the average duration of pre-pellet contact in the original Offset group, an effect parallel to the changes in

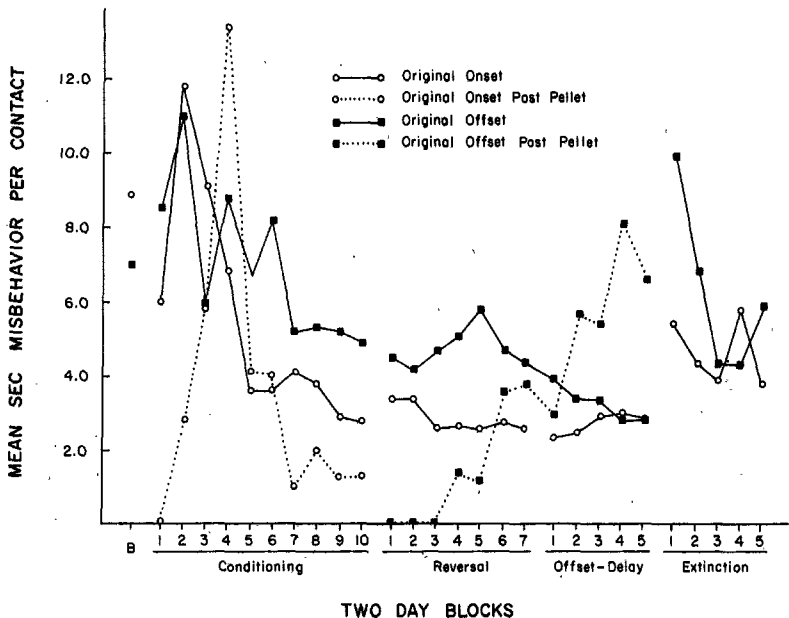


Figure 10. Mean seconds of misbehavior per contact trial for the Original Onset group and the Original Offset group during baseline, conditioning, reversal, offset delay, and extinction (Experiment 5). The widely spaced dots designate post-pellet interaction.

the percentage of trials with pre-pellet chew. At the end of the reversal phase, there was no difference between the groups in average duration of pre-pellet interaction, $t(9) < 1, p > .10$. As in previous experiments, the imposition of the onset contingency decreased the duration of misbehavior for both groups, $t_s(4 \text{ and } 5) = 1.78$ and 3.32 for the original Onset and Offset groups, $p > .10$ and $p < .05$. However, the imposition of the offset contingency did not significantly change the duration of misbehavior (both $t_s < 1, p > .10$).

One puzzling effect was the eventual decrease in frequency and average duration of post-pellet chew in the original Onset group. Post-pellet chew increased continuously in reversal for the original Offset group, and measures of post-pellet misbehavior in previous experiments had not shown such a large decrease. Sampling and experience may have played a role in the size of this decrease. The animal that died showed sustained post-pellet interaction on 30% of its trials. Further, with the exception of the animals in Experiment 2, extensive post-pellet misbehavior was produced in animals with considerable experience with pre-pellet misbehavior.

The most interesting explanation, though, involves the unique behavior of the Onset group. Instead of nosing and pawing the ball bearing and then dashing ahead of it to the food, these animals tended to dash to the food tray with the bearing in their mouth and to hold it in their paws while they checked the food tray for a pellet. When their search was successful, most of the animals dropped the bearing and ate the pellet. Since the bearing was usually dropped within 2 or 3 in. of the exit hole, it frequently rolled out before they could grab it again, even though they often lunged for it on its way out. The two animals that showed the highest levels of post-pellet chew frequently put the ball bearing in the food tray while they picked up the pellet; they then retrieved the ball bearing and chewed the pellet and the bearing simultaneously. The animals showing post-pellet misbehavior in the original Offset group also tended not to release the ball bearing when they picked up the food.

In short, the occurrence of complex misbehavior under an operant contingency did not depend on the requirement of sustained contact with the bearing, or on a considerable delay between contact with the bearing and delivery of food, or on prior experience with pairings of the bearing and food. Further, misbehavior apparently was not suppressed by overlap between the presence of the bearing and the presence of food unless food delivery interrupted the subject's initial interaction with the bearing. Complex misbehavior, including digging the ball bearing out of the exit hole, stuffing it in the mouth, and dashing to the end of the chamber, developed simply by requiring animals to contact the ball bearing. The average duration and complexity of pre-pellet misbehavior was decreased by food delivered on the onset, but not on the offset, of contact with the bearing. Post-pellet misbehavior was not due simply to the eliciting properties of the presence of the ball bearing following food delivery but depended on interruption of pre-pellet misbehavior by the delivery of food. Lastly, the development of post-pellet misbehavior appeared to be facilitated by prior experience with pre-pellet misbehavior and to be inhibited in inexperienced animals by the patterns of pre-pellet misbehavior produced by the onset contingency.

General Discussion

Effects of Stimulus and Response Contingencies

Misbehavior, defined as unnecessary, species-characteristic behavior that delays or prevents reward, was readily produced in the majority of rats in these experiments. Under most conditions rats showed either pre-pellet misbehavior (dig, nose, paw, carry, chew, retrieve) or post-pellet misbehavior (retrieve, carry, chew), though under some conditions subjects showed both forms. Both types of misbehavior were affected by stimulus and response contingencies.

Stimulus contingencies. Contact-independent pairings of the bearing and food generally increased the stereotypy and frequency of interaction with the ball bearing,

though the precise results depended on the temporal relations among food delivery, presentation of the bearing, and behavior (Experiments 1 and 2). Food delivery programmed to prevent any overlap with the bearing, or to overlap only if an animal had engaged the bearing for at least 2.5 sec, readily produced pre-pellet misbehavior (see also Boakes & Jeffery, 1979). Food delivery that occurred while the bearing was programmed to be present appeared to block misbehavior directed at the bearing by producing goal-directed behavior (Experiments 1 and 2). Post-pellet interaction with the bearing was likely in these latter circumstances. Apparently food delivery elicited behaviors more immediately related to feeding that competed with pre-pellet interaction with the bearing. The instigated but blocked interaction was often expressed in post-pellet interaction with the ball bearing and, later, in increased interaction in the extinction condition.

An issue that emerged in the course of these experiments was whether the delivery of food during the programmed presentation of the ball bearing affected the expression of misbehavior or its acquisition. There was clear evidence that food delivery blocked the expression of misbehavior. In addition to the post-pellet misbehavior and extinction results mentioned above, when food was delivered immediately on cessation of contact with the bearing (Experiment 5), there was no apparent blocking of misbehavior, and no post-pellet misbehavior, despite the opportunity to engage the ball bearing after obtaining the pellet. In contrast, delivery of food on onset of contact shortened the duration of pre-pellet misbehavior and usually resulted in extensive post-pellet interaction with the bearing (Experiments 4 and 5).

There is also some slight evidence that the timing of food delivery affected the acquisition of misbehavior. In Experiment 2, the Before-Programmed-Exit group showed less misbehavior in extinction than did the other two groups. In Experiment 5, animals showed an initial increase in post-pellet misbehavior in the group rewarded on onset of contact, but a decrease in misbehavior followed. Further, Experiment 4 showed that the acquisi-

tion of contact (and pre-pellet misbehavior) under an operant contingency was retarded by the previously learned goal-directed behavior.

In short, there is ample evidence of blocking of expression of misbehavior by food delivery occurring during the programmed period of ball bearing presentation. As might be expected, this blocking was more complete in the Pavlovian procedures than when contact with the bearing was required. In addition, there is some evidence that food delivery affected the acquisition of pre-pellet misbehavior, primarily by facilitating the learning of competing reactions to the presentation of the bearing.

Another complex issue is the relative importance of the conditioned stimulus/unconditioned stimulus (CS-US) interval versus the timing of food delivery in determining bearing-directed versus goal-directed behavior. Meltzer and Brahlek (1970) found that a short CS paired with delivery of sucrose inhibited bar pressing for food whereas a long CS facilitated bar pressing for food. Similarly Holland (1980a) found that immediate approach to the food hopper occurred more often under short CS-US intervals in rats expecting food. In the present studies, the short bearing-food intervals in the before-programmed-exit groups produced behavior directed at the food tray, whereas the long bearing-food intervals in the other groups produced appetitive behavior directed at the bearing.

However, the length of the CS-US interval does not account for all the present results. First, the Programmed-Exit group from Experiment 1 had a CS-US interval approximately that of the initial interval for the Actual-Exit group, and yet nearly all behavior was directed at the food tray. Second, the length of the CS-US interval does not explain the development of post-pellet misbehavior or the increased interaction with the bearing following extinction in Experiments 1 and 2. A more precise resolution of the relative importance of CS-US interval and competition from responses elicited by food delivery will require independent manipulation of the length of the CS, a difficult task in the present paradigm.

Response contingencies. Response contingencies also affected misbehavior. An omission contingency for contact decreased the duration, complexity, and frequency of pre-pellet misbehavior, though the effect emerged more slowly and was less complete for animals that previously had shown considerable pre-pellet misbehavior. The omission contingency also entirely eliminated post-pellet misbehavior. Apparently, inhibiting pre-pellet interaction with the ball bearing inhibited post-pellet interaction as well.

Some response-related contingencies had little effect. A contingency that delayed the delivery of food until the animal stopped interacting with the bearing and allowed it to exit did not eliminate pre- or post-pellet misbehavior (Experiments 1, 2, 4, and 5), though it usually reduced its average duration relative to baseline (Experiments 2, 4, and 5). A contingency that delayed the beginning of the intertrial interval until the bearing left was not successful in eliminating post-pellet misbehavior in any experiment.

One contingency was very effective in producing misbehavior. Requiring the subjects to contact the ball bearing to obtain food produced consistent pre-pellet interaction with the ball bearing regardless of the animal's history. Experienced rats, naive rats, and rats previously showing goal-directed misbehavior reliably dug, scooped, and carried the ball bearing under a response contingency that required only contact. Animals that were not interrupted by the delivery of food increased pre-pellet chewing and retrieving. Animals that were interrupted by food delivery usually increased post-pellet chewing and retrieving, instead. Previous experience with bearing interaction increased speed of acquisition of misbehavior under the operant contingency and increased the extent and persistence of post-pellet misbehavior.

In short, the extent, topography, and type of misbehavior were modified by both stimulus and response contingencies. In comparison with the results of the Pavlovian procedure, required contact with the bearing increased the stereotypy, reliability, and complexity of misbehavior. However, mis-

behavior was not solely or simply determined by type of contingency. Both contingencies produced fundamentally similar interactions with the ball bearing, though the precise form and development of misbehavior varied with the timing of food delivery relative to the programmed presentation of the bearing.

Given the similarities in misbehavior under Pavlovian and operant procedures, it may be tempting to some investigators to attribute all misbehavior to the effect of response contingencies. In fact, at the end of Experiments 1 and 2, there was a clear though delayed conjunction between manipulating and releasing the ball bearing and the delivery of food. However, this conjunction appears more the result of the development of misbehavior than its key causal factor. In initial conditioning trials, a conjunction between contacting the bearing and food delivery existed only on the small number of trials in which the animal happened to contact the bearing. There was a much more frequent conjunction between approaching the food tray or moving about the chamber and food delivery. Further, the same conjunction between contact and food was present for both paired groups in Experiment 1, but only one group developed pre-pellet misbehavior. Lastly, the dominant response-food conjunction at asymptote did not involve contacting the ball bearing but committing to the food tray. Since this commitment occurred on both contact and non-contact trials, misbehavior should have been minimized in favor of commitment. We discuss several other objections to an operant conditioning interpretation under the section on theoretical accounts.

Sequencing of Behavior

Figure 11 presents an idealized picture of the relation among the different forms of misbehavior shown in these experiments. Not all sequences of behavior shown by the subjects are represented. Pairing the ball bearing with food in a Pavlovian or operant contingency produced a conditioned reaction of either misbehavior or goal-directed behavior. The former occurred when response-independent food delivery interrupted the

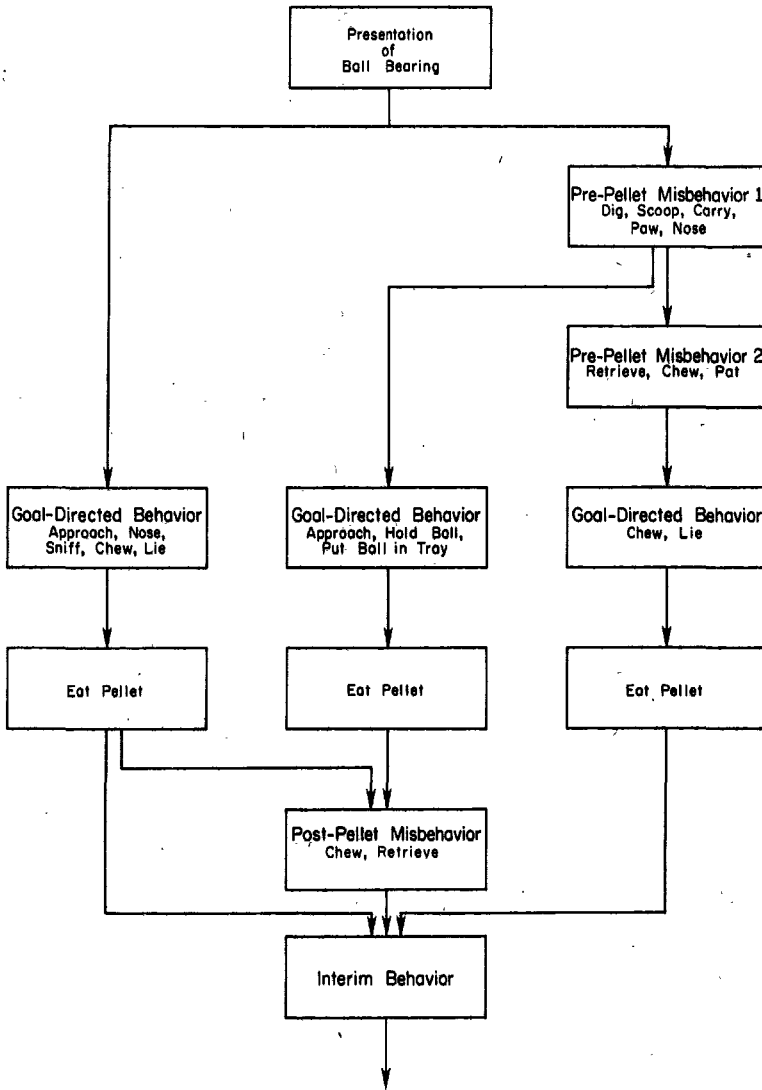


Figure 11. A schematic of the sequences of behavior typically following presentation of the ball bearing.

beginning of misbehavior.² The latter usually occurred when there was no interruption of initial contact with the bearing, or when contact with the bearing was required. If goal-directed behavior occurred, subjects often showed post-pellet misbehavior.

Pre-pellet contact with the ball bearing was usually of two sorts, minimal contact (and sometimes carry) and more extensive contact often with chewing. Minimal contact most often occurred when animals were required to contact the bearing and food was

delivered immediately. Animals under these conditions frequently showed post-pellet misbehavior, as though the pre-pellet contact had been postponed until the pellet was obtained. More extensive pre-pellet contact occurred in animals that were not interrupted by immediate food delivery. When

² Unpublished data (1977) from our laboratory suggests that increased pretraining with food delivery prior to pairings of the bearing and food also blocked behavior directed at the bearing in favor of behavior directed at the food tray.

given the opportunity, these animals did not engage in post-pellet misbehavior.

Definition and Study of Misbehavior

The Brelands (1961, 1966) defined misbehavior as (a) unnecessary, instinctive, pre-food behavior that (b) interrupts a chain of learned operant behavior leading to food and (c) delays or prevents the receipt of food. Our research indicates that this is too limiting a definition to guide research into the nature and determinants of misbehavior. First, the presence of a learned operant chain leading to food does not appear to be necessary for misbehavior to develop. Second, post-food behavior highly similar to pre-food misbehavior arises if pre-food behaviors are interrupted by food delivery and an opportunity is provided to interact with the token following receipt of food. Presumably the Breland's pig would have returned to interact with its token if food delivery had interrupted its rooting and tossing.

Third, that misbehavior delays or prevents reward does not appear to be a primary characteristic of the behavior itself but is rather a function of the procedure used to test for misbehavior. The fundamental behaviors involved are elicited by pairing a stimulus with reward, and they are expressed in the absence of competition with behaviors elicited by the delivery of food. Whether these behaviors have any effect on obtaining reward depends on their relation to the response requirements imposed by the experimenter. If the behaviors elicited by pairing are compatible with the required response, misbehavior should facilitate learned performance. If the behaviors elicited compete with the required response, misbehavior should inhibit learned performance. If the behaviors elicited are independent of the required response but not incompatible with it, misbehavior may have no effect on learned performance. The potential complexity of these outcomes suggests to us that research on misbehavior should focus on the determinants of its form and elicitation, and only secondarily on its role in delaying or preventing reward.

The definition of misbehavior is not the only factor limiting research. Another is the

procedural importance of allowing the animal control of the misbehavior object. As noted above, such a procedure limits the experimenter's ability to manipulate the interval between CS offset and US onset. Perhaps more important, the ability of the subject to prolong access to the misbehavior object means that the timing and conjunctions of stimuli, responses, and rewards cannot be controlled as completely as in the precise paradigms popular with researchers. Specifically, this flexibility means that some aspects of experimental parameters usually considered independent variables (e.g., point of presentation of reward, overlap of CS and US) must be treated as dependent variables.

A third factor potentially limiting research is the variation in misbehavior. Each subject has its own unique style and may show several alternative patterns under similar stimulus conditions. However, these same characteristics appear in more common circumstances as well. Rats contact bars and pigeons peck keys with individual style and variable patterns. In both cases the subject's behavior can be made more orderly by imposing explicit response contingencies, precisely controlling presentation of the CS, and measuring only abstract qualities of behavior (e.g., microswitch closures). However, in our opinion a major point in the study of misbehavior is to provide the subjects enough freedom to tell us something of their nature and ecology.

Despite the complexities of research on misbehavior, we think the above experiments demonstrate a control of independent variables and a consistency of behavior adequate to test different hypotheses of misbehavior. More important, the careful study of misbehavior may be an important step in the analysis of learning. Most research strives to control or eliminate misbehavior and ignores that which cannot be prevented easily. The result is a study of learning that forces phenomena into the particular conceptual structures favored by the experimenter. By focusing on misbehavior, behavior that does not fit within the common conceptual structures, we are likely to discover more about the organization underlying learning than is revealed in more completely controlled situations (Timberlake, in press).

Theories of Misbehavior

In agreement with Boakes et al. (1978) and others, we found that misbehavior was related to Pavlovian conditioning in several ways: (a) It occurred as the result of pairings between a CS (the ball bearing) and a US (food). (b) It often interfered with, rather than facilitated, obtaining the US. (c) In a broad sense, it was related to behaviors directed at the reward.

However, there are many difficulties with treating misbehavior as a phenomenon of Pavlovian conditioning. First, the topography and types of misbehavior were more varied than are typically reported in Pavlovian conditioning. Misbehavior could be directed at different stimuli and could occur before or after the delivery of reward. There were at least a dozen easily identifiable topographies of behavior. Second, the control of misbehavior by stimulus timing was considerably different and more complex than is typical of Pavlovian conditioning. Pre-pellet misbehavior was facilitated by conditions opposite to those that facilitate most traditional examples of Pavlovian conditioning. Misbehavior was maximal with longer delays between onset of the CS and onset of the US, and with nonoverlapping CS and US (trace conditioning). Post-pellet misbehavior was facilitated by more typical conditions, but it occurred after the delivery of food.

Third, the specific behaviors directed at the ball bearing were never directed at food, and vice versa. The rat did not scoop the pellet with its paws, run about the cage with it, chew it while turning it, place it in the food hopper, retrieve it, pat it, or chase it. These behaviors resembled appetitive behaviors that rats are capable of directing toward food-related objects but were never directed at the pellets in the present circumstances. If we view these results as an example of stimulus substitution, we must develop a scheme that correctly categorizes natural appetitive behaviors and their eliciting stimuli prior to the experiment (Timberlake, in press). Such a scheme would be extremely useful, but we prefer not to extend the term "stimulus substitution" to refer to the appearance of these behaviors.

Holland (1979) recently proposed a broader account of Pavlovian conditioning that has relevance to the present data. According to Holland (1977, 1979, 1980a, 1980b), behavior directed at the CS resembles unlearned orienting behavior at the beginning of the CS and behavior related to the US near the offset of the CS. If it is reasonable to stretch the concept of the orienting reaction to include behaviors directed to the CS when presented alone, then the present data show some support for this view. However, there were changes in the complexity of the behavior (e.g., the development of digging, patting the bearing under one paw, and retrieving) and in the distribution of behavior under the contingency, which resembled neither baseline orienting behavior nor behavior related to the food. Further, some of the last behaviors directed at the ball bearing actually resembled feeding behavior the least. As previously noted, the animals never patted or retrieved the pellet.

Another possible explanation for misbehavior within a Pavlovian framework is that it is an example of autoshaping or sign tracking (Hearst & Jenkins, 1974). Pre-pellet misbehavior resembles autoshaped behavior in that the animals approached and contacted a cue paired with reward. However, the optimal stimulus conditions for interaction with the ball bearing may not be those that are optimal for eliciting common autoshaped responses. Further, the sign-tracking explanation of autoshaping has little or nothing to say about post-pellet misbehavior, the variation in pre-pellet misbehavior with changes in stimulus conditions, or the topography and complexity of the misbehavior. In brief, it is quite possible that misbehavior and autoshaped behavior belong to the same class of activities, but the sign-tracking explanation applies only to a subset of such a class (see Timberlake, in press).

Misbehavior also shares several characteristics with operant conditioning. It occurs and is modified by specific response contingencies, and it may facilitate, or at least not interfere with, obtaining food. In Experiment 5, dashing from contact with the bearing to the food tray is the fastest way of obtaining food, though it is hard to explain

why rats persist in digging the bearing out of the entrance, thereby often slowing its entry, and in carrying the heavy bearing in their mouth to the food tray.

There are other problems with operant explanations. First, the topography of misbehavior was entirely too reliable to have been produced simply by chance association of response and food (Staddon & Simmelhag, 1971). Further, misbehavior under a contingency was not equivalent in topography to behaviors directed toward the ball bearing prior to the contingency. Second, food delivery contingent on behavior such as releasing the ball bearing, or not contacting the ball bearing, at best only slightly facilitated these behaviors. Third, animals receiving food during the programmed presentation of the ball bearing interacted with the ball bearing after eating rather than before, even though this interaction delayed the start of the next trial. Fourth, maximum misbehavior appeared to occur under maximum delay of reward (though the delays used were not large). Fifth, increased stereotypy of behavior occurred in the absence of a specific response contingency. Sixth, several aspects of misbehavior, once acquired, showed considerable resistance to change by other contingencies.

Seventh, most misbehavior did not appear to arise out of an operant chain by instinctive drift, but rather, any behavior chains involving the bearing began with components of misbehavior. Instead of misbehavior displacing efficient operant behavior, aspects of misbehavior were modified in the direction of greater efficiency by the effects of response contingencies. Eighth, a careful analysis of response-reward conjunctions suggested that animals run under the Pavlovian procedures should not have developed or maintained misbehavior. Most of the initial conjunctions of responses and reward involved behavior directed toward the food tray or the chamber, not behavior directed toward the ball bearing. At asymptote nearly all response-reward conjunctions were between committing to the food tray and receipt of food.

The most satisfactory explanation of the misbehavior we obtained is provided by the appetitive structure approach (Timberlake,

in press). In this view, pairing the ball bearing with food elicited a complex set of natural appetitive behaviors related to obtaining and handling food, (e.g., digging, carrying, chewing, retrieving). This underlying appetitive structure provided the basis for the behaviors common to both Pavlovian and operant contingencies. The variation in expression of appetitive behaviors depended on the nature of the contingency and the resultant competition for expression with other behaviors. In other experiments, the conditioned appetitive behaviors varied with the eliciting characteristics of the predictive stimulus (Timberlake, in press; Timberlake & Grant, 1975).

Given these results and the appetitive structure hypothesis, misbehavior may not be a peculiar aberration but a particularly clear expression of the species-characteristic organization of stimuli and responses that probably underlies most learning. This organization has been slighted in past accounts because (a) the apparatus and stimuli used were designed to minimize easily recognized contributions of species-characteristic processing and responses (Timberlake, in press); (b) experimental procedures and measures in Pavlovian and instrumental conditioning have minimized the opportunity to observe misbehavior while preserving those aspects of the situation that produce reliable results; (c) the concept of reinforcement has explained the efficiency of an animal's learned behavior in appealing rational-mechanical terms, with few possibilities of contradiction. Exceptions to efficient behavior therefore have generally been attributed to mental or physical limitations or to pathology (e.g., Bitterman, 1965).

If we accept the notion that a characteristic organization of stimulus reception and behavior underlies all learning, it suggests that conditioning paradigms do not define different kinds of learning but simply modify and measure different aspects of the expression of this basic organization. Misbehavior is produced by using those stimuli and contingencies that control behaviors obviously typical of the animal's natural repertoire, but in the absence of the normal payoff for such behaviors. More traditional learned behavior may be produced by using stimuli,

responses, and procedures that elicit less distinctive bits of the animal's natural repertoire, and in the presence of an appropriate payoff.

Reference Note

1. Timberlake, W. Personal observation, 1977.

References

- Bitterman, M. E. The evolution of intelligence. *Scientific American*, 1965, 212, 92-100.
- Boakes, R. A. Performance on learning to associate a stimulus with positive reinforcement. In H. Davis & H. M. B. Hurwitz (Eds.), *Operant-Pavlovian interactions*. Hillsdale, N.J.: Erlbaum, 1977.
- Boakes, R. A., & Jeffery, G. Automodellaggio e mal-comportamento. *Ricerca di Psicologia*, 1979, 10, 53-68.
- Boakes, R. A., Poli, M., Lockwood, M. J., & Goodall, G. A study of misbehavior: Token reinforcement in the rat. *Journal of the Experimental Analysis of Behavior*, 1978, 29, 115-134.
- Breland, K., & Breland, M. The misbehavior of organisms. *American Psychologist*, 1961, 16, 681-684.
- Breland, K., & Breland, M. *Animal behavior*. New York: Macmillan, 1966.
- Cowles, J. T. Food tokens as incentives for learning by chimpanzees. *Comparative Psychology Monographs*, 1937, 14 (5, Serial No. 71).
- Hearst, E., & Jenkins, H. M. *Sign tracking: The stimulus-reinforcer relation and directed action*. Austin, Tex.: The Psychonomic Society, 1974.
- Holland, P. C. Conditioned stimulus as a determinant of the form of the Pavlovian conditioned response. *Journal of Experimental Psychology: Animal Behavior Processes*, 1977, 3, 77-104.
- Holland, P. C. Differential effects of omission contingencies on various components of Pavlovian appetitive conditioned behavior in rats. *Journal of Experimental Psychology: Animal Behavior Processes*, 1979, 5, 178-193.
- Holland, P. C. CS-US interval as a determinant of the form of Pavlovian appetitive conditioned responses. *Journal of Experimental Psychology: Animal Behavior Processes*, 1980, 6, 155-174. (a)
- Holland, P. C. Influence of visual conditioned stimulus characteristics on the form of Pavlovian appetitive conditioned responding in rats. *Journal of Experimental Psychology: Animal Behavior Processes*, 1980, 6, 81-97. (b)
- Jenkins, H. M., Barrera, C., Ireland, C., & Woodside, B. Signal-centered action patterns of dogs in appetitive Pavlovian conditioning. *Learning and Motivation*, 1978, 9, 272-296.
- Jenkins, H. M., & Moore, B. R. The form of the auto-shaped response with food or water reinforcers. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 163-182.
- Karli, P. The Norway rat's killing response to the white mouse: An experimental analysis. *Behaviour*, 1956, 10, 81-103.
- Meltzer, D., & Brahlek, J. A. Conditioned suppression and conditioned enhancement with the same positive UCS: An effect of CS duration. *Journal of the Experimental Analysis of Behavior*, 1970, 13, 67-73.
- Pavlov, I. P. *Conditioned reflexes* (G. V. Anrep, trans). London: Oxford University Press, 1927.
- Skinner, B. F. *The behavior of organisms; an experimental analysis*. New York: Appleton-Century-Crofts, 1938.
- Skinner, B. F. *Contingencies of reinforcement: A theoretical analysis*. New York: Appleton-Century-Crofts, 1971.
- Skinner, B. F. Herrnstein and the evolution of behaviorism. *American Psychologist*, 1977, 32, 1006-1012.
- Staddon, J. E. R., & Simmelhag, V. L. The "superstition" experiment: A reexamination of its implications for the principles of adaptive behavior. *Psychological Review*, 1971, 78, 3-43.
- Timberlake, W. The functional organization of appetitive behavior: Behavior systems and learning. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behavior: Vol. 3. Biological factors in learning*. Chichester, England: Wiley, in press.
- Timberlake, W., & Grant, D. L. Autoshaping in rats to the presentation of another rat predicting food. *Science*, 1975, 190, 690-692.
- Williams, D. R., & Williams, H. Auto-maintenance in the pigeon: Sustained pecking despite contingent non-reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 511-520.
- Wolfe, J. B. Effectiveness of token rewards for chimpanzees. *Comparative Psychology Monographs*, 1936, 12(5, Serial No. 69).
- Woodruff, G., & Starr, M. D. Autoshaping of initial feeding and drinking reactions in newly hatched chicks. *Animal Learning & Behavior*, 1978, 6, 265-272.
- Woodruff, G., & Williams, D. R. The associative relation underlying autoshaping in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1976, 26, 1-13.

Received April 7, 1981 ■