

# Hurdle-jump responding in the rat as a function of conspecific odor of reward and nonreward

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A hurdle-jump escape response was employed to assess the laboratory rat's aversion or attraction to different types of conspecific odor. Odorant donor subjects received 112 runway acquisition trials on a continuous reward schedule followed by 32 extinction trials, 112 acquisition trials on a 50% schedule of reward and nonreward followed by 32 extinction trials, or 144 "neutral" trials with no reward in the alley. Different groups of test subjects escaped from odor excreted by odorant subjects on (a) nonrewarded acquisition and extinction trials, (b) rewarded trials during continuous reinforcement, (c) rewarded trials during partial reinforcement, or (d) neutral trials; others escaped from a clean box. The principal findings were: (1) significant aversion to "odor of nonreward" appeared after the donor odorants had received 12 exposures to reward; (2) production of odor of nonreward by odorant subjects changed as a function of training experience with reward; (3) after repeated exposure to odor of nonreward, the escape response habituated; (4) greater or different odor excretion in extinction resulted from subjects trained on a continuous reward schedule than on a partial reward schedule. Relationships of the data to frustration theory were discussed, assuming that inferred differences in production of odor reflect differences in frustration reaction.

Encountering nonreward in the presence of stimuli previously associated with reward has been identified as a treatment that produces a distinctive odor in rats (Collerain & Ludvigson, 1972; Mellgren, Fouts, & Martin, 1973; Morrison & Ludvigson, 1970; Pratt & Ludvigson, 1970), and some work has suggested that reward training also produces a distinctive odor (Mellgren et al., 1973). A recent study from our laboratory investigated the effect of "odor of nonreward" or "frustration odor," i.e., odor accompanying frustrative nonreward, on reactions of rats encountering this odor in the absence of any reward contingency (Collerain & Ludvigson, 1972). Certain previous data (McHose & Ludvigson, 1966; Pratt & Ludvigson, 1970; Wasserman & Jensen, 1969) have suggested that frustration odor might be unconditionally aversive or fear-eliciting, and the results of the Collerain and Ludvigson study were generally consonant with this suggestion because significant withdrawal or "avoidance" of frustration odor was observed. This reaction appeared at the outset of testing, indicating that excretion of the aversive scent may occur after as few as 2-4 exposures to reinforcement. Particularly interesting was the observation that the avoidance of frustration odor

diminished later in training, leading to the speculation that either the odor-donor animals excreted less scent on later trials or that habituation occurred in the test subjects. Although the latter explanation was favored on the basis of inferences from other experiments, one purpose of the present study was to resolve this question. A second purpose was to gather further data on the rapidity with which the inferred production of frustration odor develops with training. A third impetus for the present work was the conjecture that placing a rat into an odor-containing chamber and measuring the speed of escape to another chamber might yield a sensitive index of the motivational effects of odor, just as similar techniques have proved useful in assessing motivational effects of conditioned fear and frustration. This experiment employed a hurdle-jump escape task. Odorant donor subjects experienced different types of goal events in a straight runway. Escape test subjects were placed into the goalbox of the runway (which served as the start section of the hurdle-jump apparatus) and were allowed to escape from any odor excreted by the odorant subjects. The main experimental strategy was to test naive subjects after different amounts of training for odorant subjects.

## METHOD

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### Apparatus

The apparatus was 7-ft (2.31-m) alley, 3 in. (.08 m) wide  $\times$  3 $\frac{3}{4}$  in. (.10 m) high, consisting of two functional parts referred to as the runway and hurdle-jump sections. The runway section of the apparatus consisted of a 12-in. (.30-m) startbox, 45-in. (1.14-m) runway, and 11-in. (.28-m) goalbox. The runway was

white throughout with a Plexiglas top. Raising the startbox gate activated a microswitch and started Clock 1. Interruption of photobeams 6 in. (.15 m) and 49 in. (1.24 m) from the gate allowed measurement of start and run times. A goalbox door prevented retracing. A removable white goal cup was present on all running trials.

The hurdle-jump section of the alley consisted of a startbox (which was the goal section of the runway) and an 11-in. (.28-m) goalbox. The start and goal sections were separated by a door which rested on a 1-in.-high (.03-m-high) hurdle. Raising the door activated a microswitch and started a timer. Breaking a photo-beam located 6 in. (.15 m) from the door stopped the timer, thus providing a hurdle-jump latency.

To provide a clean box after each escape trial, disposable white cardboard inserts that covered the floor and side walls were placed into the start and goal sections of the hurdle-jump apparatus. A clean floor surface in the alley was obtained by the use of 3-in.-wide (.08-m-wide) adding machine paper, a roll of which was affixed to the goal end of the alley so as to permit it to be drawn through slits just above the floor of the apparatus at each end. An exhaust fan was attached to the rear of the alley and activated for 30 sec after each trial.

**Subjects**

The subjects were 230 naive male albino rats purchased from the Holtzman Company, Madison, Wisconsin. They were approximately 80 days old at the beginning of the experiment. Two types of subjects were employed (cf. Table 1). Odorant animals traversed the runway and experienced different reinforcement conditions in the goalbox (the startbox of the hurdle-jump). Escape subjects were allowed to escape from the goalbox previously occupied by the odorant subjects. On the first day of the experiment, all odorants were placed on a food-deprivation regimen of 11 g of Purina Lab Chow per day. Escape subjects were placed on a similar regimen 1 week before their participation in the experiment.

**Odorant Preliminary Training**

All odorant subjects (N = 120) were handled and habituated to the apparatus on the 5th and 6th days of the study. On each of these days, the subjects received two 5-min runway explorations and 10 45-mg Noyes food pellets in the home cage.

**Odorant Conditions**

Acquisition (Training Day 1) began on the 7th day of the study. Odorant subjects were randomly assigned to one of four groups. As indicated in Table 1, two of these groups (O-P1 and O-P2) received 112 partially rewarded running trials (8 per day) according to a double-alternation schedule of reward and nonreward. Reward on a given trial consisted of 30 sec access to 45-mg Noyes pellets. Goalbox confinement duration on nonrewarded trials was 30 sec. Another odorant group (O-C) received continuously rewarded running trials during acquisition. Reward magnitude for Group O-C was the same as that for Groups O-P1 and O-P2. A fourth odorant condition, a "neutral" nonreward group (Group O-n), received the same training as other odorants, except that they never received reward, receiving instead "neutral" nonreward on all trials. Following acquisition training, all odorant groups received 32 extinction trials (8 per day), each with 30 sec of goalbox confinement, as in acquisition.

**Preliminary Training for Escape Subjects**

Just before testing, escape subjects received habituation to the hurdle-jump apparatus. That is, on the 5th and 6th days, a portion of the escape animals (Groups RP, NP(T), NP(E), RC, n, and c) received on each day one placement in the start and one in the goal section of the hurdle-jump apparatus with the door separating the sections closed. A second portion, Group NP(M), received this treatment on the 9th and 10th days (Training Days 3-4) of the experiment; a third portion, Group NP(L), received it on Training Days 11-12; and another portion, Groups NP(X), NC(X), and n(X), on Training Days 13-14.

**Table 1**  
Treatments for Groups on Each of Eight Trials Within a Day During Odorant Acquisition and Extinction, Wherein Odorants Received Reward (R), Frustrative Nonreward (N), or Neutral Nonreward (n), and Escape Groups Received Tests (t)

Groups		Training Days				Extinction Days	
Odorant	Escape	1 & 2	3 & 4	5 & 6	...13 & 14	15 & 16	17 & 18
O-P1		NNRRNNRR	RRNNRRNN	NNRRNNRR	..NNRRNNRR	NNNNNNNN	NNNNNNNN
	RP	tt tt	tt tt	tt tt	... tt tt	tt tt	tt tt
	NP(T)	tt tt	tt tt	tt tt	... tt tt	tt tt	tt tt
O-P2		NNRRNNRR	RRNNRRNN	NNRRNNRR	..NNRRNNRR	NNNNNNNN	NNNNNNNN
	NP(E)	tt tt					
	NP(M)			tt tt			
	NP(L)				tt tt		
	NP(X)					tt tt	tt tt
O-C		RRRRRRRR	RRRRRRRR	RRRRRRRR	..RRRRRRRR	NNNNNNNN	NNNNNNNN
	RC	tt tt	tt tt	tt tt	... tt tt		
	NC(X)	tt tt	tt tt	tt tt	... tt tt	tt tt	tt tt
O-n		nnnnnnnn	nnnnnnnn	nnnnnnnn	..nnnnnnnn	nnnnnnnn	nnnnnnnn
	n	tt tt	tt tt	tt tt	... tt tt		
	n(X)	tt tt	tt tt	tt tt	... tt tt	tt tt	tt tt
	c	tt tt	tt tt	tt tt	... tt tt	tt tt	tt tt

Note—The initial "O" in a group designation indicates an odorant group; all other groups are escape groups. The first letter of an escape group indicates the type of treatment from which the subject escaped, reward (R), frustrative nonreward (N), neutral nonreward (n), or clean (c). The letter P or C of an escape group designates the type of treatment given the paired odorant subjects during acquisition, partial or continuous reward. Letters in parentheses indicate when testing occurred: early (E), middle (M), or late (L) acquisition; throughout training (T); or in extinction (X). "◁" shows group subdivision; "... " indicates continuation of treatment or test.

### Escape Conditions

Odorant Group O-P1 was associated with two escape groups throughout the 112 odorant acquisition trials. Group RP escaped following Group O-P1's rewarded trials and Group NP(T) escaped following its nonrewarded trials. Group RP and NP(T), as well as all other escape groups throughout the study, received four escape trials per day.

Escape trials after nonrewarded trials of Group O-P2 were provided for certain other escape groups. Group NP(E) escaped after Runway Trials 1, 2, 5, 6, 9, 10, 13, and 14 on Days 1-2. Group NP(M) escaped after Trials 33, 34, 37, 38, 41, 42, 45, and 46 on Days 5-6; and Group NP(L) escaped after Trials 97, 98, 101, 102, 105, 106, 109, and 110 on Days 13-14.

In addition to subjects (RP) that escaped after rewarded trials of Group O-P1, a second group (RC) escaped from a goalbox previously occupied by members of Group O-C. The daily schedule (i.e., position with respect to the eight trials of an odorant) of escape trials for half the subjects of Group RC was the same as for Group NP(T), and the schedule for the other half of the subjects was the same as for Group RP.

Control conditions involved subjects (Group n) that escaped from a goalbox visited by "neutral" odorants (Group O-n) and subjects (Group c) that escaped from a "clean" box. As with Group RC, escape trials were given so as to equate test conditions as much as possible among groups. Thus, half the subjects of Groups c and n received tests according to the schedule for Group NP(T) and half according to the schedule for Group RP.

During odorant extinction, Group NP(T) continued to be exposed to the goalbox previously occupied by Group O-P1; Group NP(X) was exposed to that occupied by O-P2, Group NC(X) to that occupied by O-C, and Group n(X) to that occupied by Group O-n. Group c continued to escape from a clean box. All escape groups continued to receive four tests per day in the manner of the acquisition schedules.

### General Procedure

Escape subjects were paired with odorant subjects such that a given escape subject always escaped from a goalbox visited by a given set of three odorant animals, which always received their trials in the same order. On a runway trial, an odorant subject was placed into the runway startbox facing the start gate, which was raised 1 sec later. On a hurdle-jump trial, an escape subject was placed into the hurdle-jump startbox facing away from the start gate, and the gate was raised 1 sec later. After crossing the hurdle, an escape subject was confined for 10 sec in the hurdle-jump goalbox. Nothing was done to the hurdle-jump apparatus between odorant runway trials and an escape trial except for removal of the food cup and any visible food crumbs. Following an escape trial, the cardboard inserts in the start and goal areas of the hurdle-jump were replaced with clean ones and the air was exhausted for 30 sec with a fan located at the end of the alley. In addition, a clean floor was obtained by pulling fresh paper onto the floor of the runway.

The subjects were run in 10 squads with each odorant condition present within a squad. All subjects in a squad received Trial 1 of the day before any received Trial 2, etc. Daily order of running within a squad was balanced across squads such that subjects in a given condition occupied the same ordinal position twice. For example, the Group O-P2 subjects and the associated escape animals ran first in the day in two squads, second in two squads, third in two squads, etc.

Start and run measures were recorded for each odorant subjects on each trial. A latency was recorded on each trial for escape animals.

## RESULTS

The unit of the analyses performed on escape data was the mean of a subject's speeds in a doublet of trials or "trial block," e.g., Trials 1-2, 5-6, 9-10, etc.,

for Group NP(T) and Trials 3-4, 7-8, 11-12, etc., for Group RP. The results are discussed below as they pertain to specific a priori questions.

### Initial Aversion to Odor of Nonreward

The first question concerned the point at which odor of nonreward was initially aversive, as suggested by faster speeds for subjects that escaped from odor of nonreward in comparison with the clean baseline (cf. Figure 1). Group NP(T) escaped from odor of nonreward throughout acquisition, and Group NP(E) received identical escape tests during the first four trial blocks. Over these first blocks, then, the groups were combined and compared with the overall acquisition mean for Group c; similarly, Group NP(T) alone was compared with Group c beyond the fourth trial block. Group c's overall mean was deemed a reasonable baseline, since prior analyses had indicated that Group c did not significantly change over acquisition trials,  $F(27, 234) < 1$ . Using as a criterion of aversion significant differences on two successive trial blocks, the first block on which the criterion was met was Trial Block 6,  $t(19) = 3.10$ ,  $p < .01$ . Thus, evidence of aversion appeared somewhat later than in our prior study (Collerain & Ludvigson, 1972), not until the associated odorants had received 12 exposures to reward.

### Odor of Nonreward as a Function of Experience with Partial Reward

Another major question was whether production of odor of nonreward changes as a function of the amount of partial reward training. To answer this question, naive escape subjects, Groups NP(E), NP(M), and NP(L), were introduced to the odor of nonreward at early, middle, and late portions of the training of the partially rewarded odorant subjects. Differences among these groups would suggest quantitative and/or qualitative differences in odor production. Group trends presented in Figure 2 indicate that escape speeds for Groups NP(E), NP(M), and NP(L) increased over trials, and analysis of the data for these three groups revealed significant effects of groups,  $F(2,27) = 12.38$ ,  $p < .01$ ; trials,

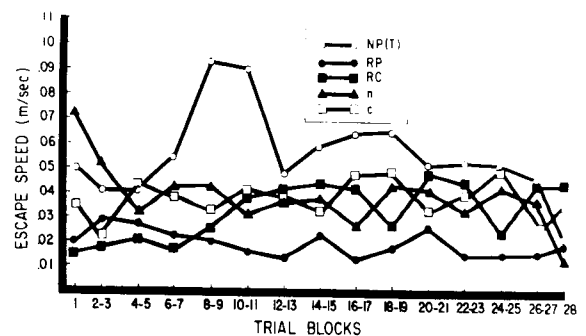


Figure 1. Mean escape speed during odorant acquisition for Groups NP(T), RP, RC, n, and c in blocks of two trials.

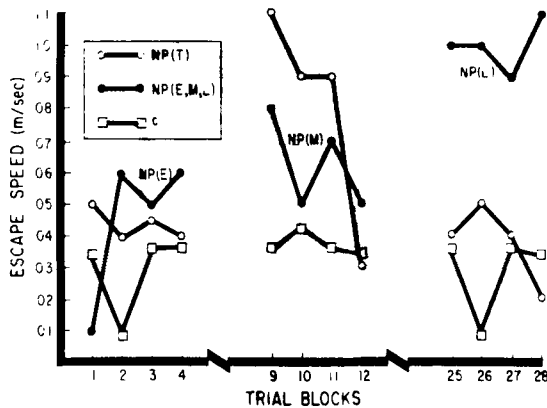


Figure 2. Mean escape speed during odorant acquisition for Groups NP(T), NP(E), and c on Trial Blocks 1-4; Groups NP(T), NP(M), and c on Trial Blocks 9-12; and Groups NP(T), NP(L), and c on Trial Blocks 25-28.

$F(3,82) = 3.95, p < .05$ ; and Groups by Trials,  $F(6,82) = 3.08, p < .05$ . The groups effect supports the conclusion that odor excretion changed as a function of amount of partial reward training, with perhaps the simpler inference being that odor production increased with training, as opposed to an interpretation in terms of qualitative changes.

**Habituation to Odor of Nonreward**

A question related to the one above concerns whether or not aversion to odor of nonreward habituates after repeated exposure to the scent. Evidence for the notion that responding to odor of nonreward does habituate can be seen from the NP(T) vs. NP(M) and NP(T) vs. NP(L) comparisons also profiled in Figure 2. Groups by Trials analyses of variance revealed that mean escape speeds for Groups NP(T) and NP(M) were not significantly different,  $F(1,18) = 1.14$ , through the groups displayed different trends,  $F(3,54) = 23.00, p < .01$ . However, speeds for NP(L) were significantly faster than those of NP(T),  $F(1,18) = 8.37, p < .01$ . The nonsignificant difference obtained between Groups NP(T) and c on Trial Blocks 25-28,  $F(1,18) = 2.11$ , also supports the habituation hypothesis in that the NP(T) subjects, after repeated exposure to the scent, did not respond significantly faster than the clean baseline condition.

The effects of response habituation to odor of nonreward can also be noted in the rapid escape speed of Group NP(X) as compared with NP(T) during odorant extinction (cf. Figure 3). A Group by Trials analysis of variance comparing Groups NP(T) and NP(X) revealed significant effects of groups,  $F(1,18) = 8.00, p < .05$ ; trials,  $F(7,126) = 7.00, p < .01$ ; and Groups by Trials,  $F(7,126) = 9.00, p < .01$ . The fact that speeds for Group NP(T) were virtually identical to those of Group c during odorant extinction further indicates that habituation was essentially complete.

**Escape During Odorant Extinction**

Turning to a more general analysis of escape performance during extinction of the odorants' running response, an overall analysis of variance comparing Groups NC(X), NP(X), n(X), and c revealed significant effects of groups,  $F(3,36) = 11.36, p < .01$ ; trials,  $F(7,253) = 10.63, p < .01$ ; and Groups by Trials,  $F(21,253) = 4.54, p < .01$ .<sup>1</sup> Follow-up analyses revealed that subjects that escaped from odors excreted by animals that had received, during acquisition, either a continuous or a partial reinforcement schedule escaped significantly faster than did the clean-control subjects,  $F(1,18) = 10.13$  and  $5.69, p < .01$  and  $.05$ , respectively. Of special interest was the superior escape responding demonstrated by NC(X) relative to NP(X), which was also statistically reliable,  $F(1,18) = 6.62, p < .05$ . This indicates that subjects trained on a continuous reward schedule excreted a more aversive, perhaps a greater amount, of odor of nonreward during extinction than did subjects trained on a partial reward acquisition schedule.

**"Neutral" Odor**

The present data offer, perhaps, some support for the conclusion that the "neutral" odor had transitory motivational properties, although a Groups by Trials analysis of variance comparing Groups n and c over all of acquisition revealed no significant effects. Groups n and c were compared during the initial test trials because of the a priori suspicion that odorant fear of the novel environment might lead to an early, but perhaps short-lived, aversion in escape subjects. Significant aversion (relative to the clean condition, see Figure 1) occurred on Trial Blocks 1-3,  $t(9) = 3.66, p < .05$ ; this effect disappeared by Trial Block 4 i.e., after six exposures to neutral odor,  $t(9) = 1.86$ ,

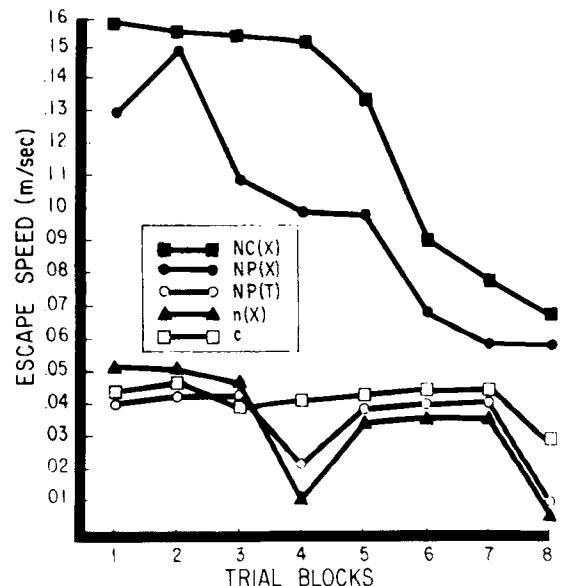


Figure 3. Mean escape speed during odorant extinction for Groups NP(X), NP(T), NC(X), n(X), and c in blocks of two trials.

$p < .10$ . A second test relevant to this conclusion was possible, since Group n(X) also escaped from neutral odor but only during the odorant extinction phase after the odorant animals, Group O-n, had experienced 112 neutral trials. Surely any fear reaction to novelty would have long passed after that number of trials, leaving a "purer" neutral odor. A visual comparison of the functions of Group n in Figure 1 and Group n(X) in Figure 3 suggests, consonant with the conclusion, that the former, but not the latter, group displayed an initial elevation, and comparison of these groups via *t* test revealed a significant difference on the first trial block,  $t(9) = 4.10, p < .01$ .

### Odor of Reward

Some evidence for the existence of an odor of reward can be seen from further inspection of Figure 1, principally in the data of Group RP, which shows consistently slow escape speeds while RC responds at the level of the clean control except during the initial trials.

Following prior overall analysis which had indicated significant differences, Groups RP and c were found to differ significantly,  $F(1,18) = 6.94, p < .05$ . Similarly, in a comparison of Groups RP and RC, the Groups by Trials interaction was significant,  $F(27,486) = 2.00, p < .01$ . Taken together, the observations suggest that both Groups RP and RC were initially attracted to odor of reward, and that that reaction persisted in Group RP.

### Odorant Acquisition and Extinction

The data from the odorant subjects are of importance merely as assurance that the inferred test odors generated by these subjects came from animals behaving in a manner typical of those exposed to the treatments received. As may be seen in Figure 4, the start speeds of the partially rewarded animals crossed those of the continuous animals, similar to many previous observations (e.g., Goodrich, 1959), and the extinction curves diverged in a manner characteristic of the partial reinforcement effect (PRE). In the run speed data (not presented), the partial group remained clearly below the continuous group throughout acquisition, again a typical finding, and a PRE was even more clearly evident in extinction as the curve for the partial group crossed that of the continuous group. Given the large numbers of subjects in these groups, these effects were statistically highly significant.

## DISCUSSION

The present study provides additional substantial evidence that rats, when experiencing frustrative nonreward, excrete an odor that causes conspecifics to escape it. It extends our previous work (Collerain

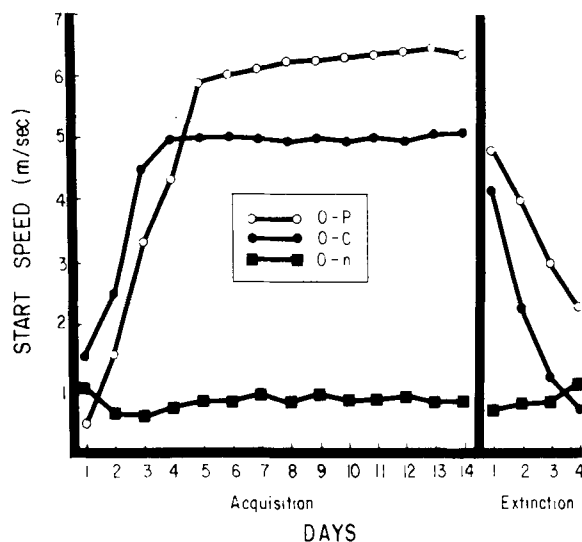


Figure 4. Mean start speed per day during acquisition and extinction for Groups O-P, O-C, and O-n.

& Ludvigson, 1972) showing withdrawal from frustration odor in a T-maze. It also directly corroborates the finding of Mellgren et al. (1973) of heightened escape speed from frustration odor.

Whether or not the inference of "aversiveness" is justifiably attributable to frustration odor depends on one's criteria for such an inference. If one accepts as sufficient the observation that the odor enhances escape and withdrawal reactions, then the inference seems justifiable. However, if one insists, as some do, that the odor motivates the learning of a new response that removes odor, then the inference is not so clear. While it is true that Group NP(T) displayed an increase in escape speed over the first eight trial blocks (cf. Figure 1), a comparison of Groups NP(E), NP(M), and NP(L) in Figure 2 indicates that the odor changed over training, thus enhancing the initial escape response of naive subjects. Therefore, the increase for Group NP(T) could merely represent an enhancement of an escape response already in the subjects' repertoires. Furthermore, although escape speeds for NP(T) exceeded those for NP(M), as would be expected if the former had profited from the prior training by learning to escape (cf. Figure 2), this difference was not statistically significant.

Regarding the question of the rapidity with which odor of nonreward develops, the present study suggests that as many as 12 rewarded trials are necessary for an aversive odor, as indexed by stable escape responding. In contrast, Collerain and Ludvigson (1972) found significant withdrawal after odorant subjects had had only 2-4 rewarded placements. This discrepancy might be attributable to the different responses required of test subjects, since rapid execution of the escape response might depend more on learning than might withdrawal. Alternatively, the different odor-producing operations might

be implicated. Odorant subjects in the present study were required to run in a long alley to receive reward or nonreward. In contrast, odorants in the previous experiment were merely placed into baited or unbaited goalboxes. Goalbox placement, as compared with a long instrumental response, might hasten the acquisition of anticipatory reward and, thus, according to frustration theory (Amsel, 1958), the occurrence of frustration-produced odor.

As to the questions of whether aversion responses to odor of nonreward habituate and whether odor production changes with training, the present results clearly implicate both phenomena. Production of odor of nonreward appears to change as a function of partial reward training through at least 112 trials. On the other hand, responding habituated to the scent, with a substantial reduction in escape after 22 exposures and a complete return to baseline after some 40-50 exposures. In the light of these results, the data of Collerain and Ludvigson (1972) showing a disappearance of withdrawal responding after 12-16 exposures can be interpreted as further evidence of habituation. It may be noted that having established that responding habituates, these data do not permit a choice among possible mechanisms of habituation, e.g., whether habituation results from "loss of aversiveness" or control of response by the scent, or whether it is simply an increased refractoriness of the response without any change in the significance of the stimulus.

Certain aspects of the present data bear on Amsel's (1958) frustration theory assuming that frustration odor accompanies the hypothetical reaction of primary frustration and that a faster escape response to the odor is indicative of greater frustration reaction in the odorant animals. One implication arises from the inferred increase in aversiveness in the odor of nonreward as a function of training [cf. Groups NP(E), NP(M), NP(L), and NP(X)]. This increase is consonant with the basic assumption that the magnitude of the frustration reaction is an increasing function of the strength of reward expectancy ( $r_R$ ), assuming  $r_R$  continues to gain strength through at least 56 rewarded trials.

A second relevant observation is the faster escape speed demonstrated by Group NC(X) relative to NP(X) during odorant extinction (Figure 3), indicating a more aversive frustration odor and, by assumption, a greater frustration reaction in the odorant animals. While the theory does not greatly concern itself with the magnitude of the frustration response itself during extinction, emphasizing instead a counterconditioning process, the observation is generally consonant with the theory. Frustration during extinction would presumably not be as great following partial reinforcement as it would following continuous reinforcement because reward ex-

pectancy should be less, given its history of fewer rewards and extinction trials inherent in the partial schedule.

In contrast to the above agreements, there is one respect in which the present early-trial findings raise questions for Amsel's (1958) frustration theory. According to the theory, expectation of reward must reach a certain strength before nonreward becomes frustrating. Reports of a partial reinforcement effect after as few as 2-4 acquisition trials ("limited training PRE") have been troublesome for the theory (McCain, 1966), leading to the position (Amsel, Hug, & Surrige, 1968) that one trial with a multiple-pellet reward develops sufficient reward expectancy for the arousal of primary frustration. The present data are not supportive of this notion in that odorants received approximately 12-14 exposures to a multiple-pellet reward before clear evidence of frustration arousal, i.e., "frustration odor," was seen. These results are also at variance with those of Brooks (1969), who reported enhanced escape from an empty box after only 6-30-sec exposure to wet mash.

The present data do, however, support the view that there is emotional arousal on early trials resulting from mere exposure to the empty goalbox. Significant aversion was demonstrated by Groups n, NP(T), and, following the first trial block, NP(E); in contrast, n(X) displayed no aversion to "well-habituated" neutral odor and nor did RP or RC demonstrate an initial aversive reaction. This early, transient aversion appears to have resulted from fear arousal on the part of the associated odorants. Hence, emotional arousal could be present on early runway trials, but this arousal is more likely attributable to fear than to frustration. This finding regarding initial emotionality should, however, be treated cautiously for two reasons: the effect appears fairly unstable and Collerain and Ludvigson (1972) found no initial withdrawal from neutral odor.

Turning to questions concerning a possible "odor of reward," i.e., odor emitted by a rat as a consequence of receiving reward, the present study, in contrast to previous work from this laboratory (Collerain & Ludvigson, 1972; Morrison & Ludvigson, 1970), would seem to provide evidence for the existence of such an odor and its "attractive" nature, since Group RP was slower to leave the odor-containing box than either Group c or Group n throughout acquisition and Group RC was slower during the first nine trial blocks. Although the nature and function of this odor remain to be clearly identified, the observation that reward and neutral odors are different argues against the view that reward odor is merely scent that regularly accompanies the animal or vestigial food odor. In addition, this difference suggests certain inferences regarding both production of reward odor and habituation to it.

Clearly, the persisting attraction displayed by Group RP is most parsimoniously explained by assuming that production remained constant and no habituation occurred. The disappearance of attraction in Group RC, then, would appear to result from diminished production of reward odor by the odorants, since there is no reason to posit differential habituation for Groups RP and RC, assuming that the nature of the reward odor is the same from Groups O-P and O-C. Why Group O-P, but not Group O-C, continued to produce reward odor is not known, but it is possible that the contrasting experience of nonreward maintained it.

Finally, it may be noted that the data of Groups RP and RC are not encouraging for the hypothesis of Mellgren et al. (1973) that reward in the context of a partial reinforcement schedule might produce a "mixed" (frustration and reward) and less discriminable odor than continuous reinforcement. This hypothesis was based on the observation that differences in one study from odors from rats on continuous reward as against extinction-following-continuous-reward were greater than differences in another study from odors from nonrewarded trials as against rewarded trials of a single group of partially rewarded rats. According to this hypothesis, one would have expected the evidence for a reward odor to be stronger in Group RC than in Group RP.

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#### NOTE

1. Since Groups NC(X), NP(X), and n(X) received tests for the first time during odorant extinction while Group c received tests from the outset of odorant acquisition, the data of Group c for these analyses came from the first eight trial blocks of odorant acquisition, thus equating the groups on prior experience with the tests.

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