

Effects of Learned Flavor Avoidance on Grooming Behavior in Rats

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REIDINGER, R. F., JR. AND J. R. MASON. *Effects of learned flavor avoidance on grooming behavior in rats.* *PHYSIOL BEHAV* 37(6)925-931, 1986.—In Experiment 1, rats were conditioned to avoid saccharin in tapwater by pairing it with LiCl in carboxymethylcellulose (CMC) applied to the fur. Conditioned flavor avoidance (CFA) of saccharin was then assessed in drinking and grooming tests. In Experiment 2, rats were given saccharin CMC on their fur and NaCl in water (or vice-versa) as conditioned stimuli in a CFA paradigm. Two-choice tests (saccharin vs. NaCl) followed in drinking and grooming contexts. In Experiment 3, rats were given saccharin CMC on one flank and vehicle (CMC only) on the other. After grooming, animals were injected with LiCl and then given 2-choice tests, first between saccharin and water, then between saccharin-CMC and plain-CMC, and finally, between saccharin and water. Strong CFA was exhibited in drinking tests in all 3 experiments. This was not the case in grooming tests. Rats continued to groom when tastant was applied to only one flank (Experiment 1), and exhibited only weak CFA when a different tastant was applied to each flank (Experiments 2 and 3). We conclude that grooming can be directed to minimize the ingestion of noxious substances, but that such ingestion is not sufficiently reduced to affect the efficacy of grooming as a delivery method for unpalatable substances (e.g., rodenticides, chemosterilants). We speculate that grooming represents a weakness in rodents' defenses against dietary poisoning, and that it might be used to deliver toxicants as part of crop protection schemes that make use of CFA.

Grooming Taste Food aversion learning Rats Rodent control

“BAIT-SHYNESS” (defined here as the avoidance of a bait formulation following sublethal poisoning) is associated with the use of some rodenticides and chemosterilants. To circumvent this problem, we have probed for weaknesses in rodents' defenses against dietary poisoning [25]. Our investigations (e.g., [23]) have focused on conditioned flavor avoidance (CFA), since it appears particularly well-suited for protecting rodents during feeding and drinking. However, CFAs may be less well-adapted for protection during other activities such as grooming, nest-building, and gnawing, in which ingestion is concomitant, but minor. We have chosen to study grooming because it occurs frequently in the daily behavioral regime of rodents [5], and has been described as relatively stereotyped [5, 6, 8].

Already, evidence indicates that CFA is suppressed during autogrooming by pine voles (*Microtus pinetorum*, [14,21]). Such suppression is robust, and occurs when the material is applied to both flanks or to only one flank [21]. Conditioned flavor avoidance is expressed readily in drinking tests however, suggesting that the essentially unlearned behavior of grooming [5] is more persistent than the learned behavior of CFA [15]. Like voles, rats (*Rattus norvegicus*) can acquire CFA through pairings of flavor autogroomed from the fur and post-ingestional malaise [26]. CFAs are expressed subsequently in drinking tests. Whether rats con-

tinue to groom conditioned stimuli from the fur in the presence of CFA, however, has not been well-explored. Also largely uninvestigated is whether rats will ingest distinctively flavored ‘poison’ from the fur while grooming, and whether they will associate the groomed flavor or a flavor consumed in another context (e.g., drinking) with malaise. The present series of experiments were designed to address these questions.

In Experiment 1, rats were conditioned to avoid drinking saccharin by pairing it with an application of lithium chloride (LiCl) in carboxymethylcellulose (CMC) to the fur. Saccharin avoidance was then assessed in 2-bottle drinking tests (saccharin vs. tapwater), and in the grooming of saccharin-CMC from the fur. A major component of grooming (i.e., body washes [5,6]) was recorded to determine if the animals would shift grooming topographies to minimize ingestion of saccharin-CMC. In addition, the concentration of LiCl applied to the fur on the day of conditioning was varied parametrically in an attempt to produce CFAs of various strengths [1].

In Experiment 2, rats were given injections of LiCl following exposure to saccharin-CMC on the fur (grooming) and sodium chloride (NaCl) in tapwater (drinking) or NaCl-CMC on the fur (grooming) and saccharin in tapwater (drinking). Preference tests were then conducted in both drinking

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(saccharin vs. NaCl) and grooming (saccharin-CMC vs. NaCl-CMC) contexts. Such tests provided opportunities (a) to observe the effects of CFA on grooming, and (b) to assess the effects of conditioning context (drinking, grooming) on CFA expression.

In Experiment 3, rats were given saccharin-CMC on one flank and CMC alone on the other, and then LiCl or sham injections. Subsequently, all groups were given 2-bottle tests between saccharin and tapwater, then 2-choice grooming tests between saccharin-CMC and CMC alone, and finally, additional 2-bottle tests between saccharin and tapwater. This paradigm provided additional information about flavor-directed grooming, and an assessment of changes in CFA expression in drinking as a function of flavor exposure during interposed grooming trials.

GENERAL METHOD

Subjects

Naive adult male rats (Sprague-Dawley strain) were individually housed (cage dimensions: 17.7×24.2×17.7 cm) in a room with an ambient temperature of 20±4°C, and a 12:12 L/D cycle. All animals were given free access to food (Purina Lab Blox) and water for 2 weeks prior to the beginning of experiments.

Materials

Unless otherwise specified, the following stimuli were used: 0.0083 M sodium saccharin solution (0.20% w/v in tapwater); 0.15 M NaCl solution (0.88% w/v in tapwater); plain carboxymethylcellulose (CMC, 3.55% w/v in tapwater); 0.014 M saccharin-CMC (0.35% w/v saccharin); 0.26 M NaCl-CMC (1.54% w/v NaCl); 0.46 M LiCl-CMC (2.0% w/v LiCl); 1.15 M LiCl-CMC (5.0% w/v LiCl); and 2.31 M LiCl-CMC (10.0% w/v LiCl). Greater concentrations of saccharin and NaCl were mixed in CMC than in tapwater, since previous experiments with human subjects suggested the possibility of tastant masking by the gelatinous CMC [7,23]. Fluids were presented in 10-ml syringe-sipper tubes [27] on conditioning days and in 135-ml calibrated Richter tubes during 2-bottle drinking tests. Spouts of the drinking tubes were separated by about 10-cm when attached in pairs to the fronts of cages.

Procedure

The same adaptation regime was used before each experiment. On each of the 4 days immediately prior to treatment, each rat was water-deprived for 20 hr (1200–0800 hr), followed by free access to water presented in 2 drinking tubes for 1 hr. The drinking tubes were then removed, and access to water was followed by an application of 1 g of plain CMC to the left or right flank. After 30-min, the rats were given free access to water presented in 1 drinking tube for 2.5 hr.

Analyses

Consumption during 2-bottle tests, and the frequency and duration of grooming were assessed by analysis of variance (ANOVA). Bonferroni post-hoc *t*-tests [4,13] subsequently were used to isolate significant differences among means. Also, in Experiments 1 and 2, regression analyses [19] were performed to detect relationships between saccharin consumption and either the frequency or duration of grooming. However, these regression analyses failed to detect any sig-

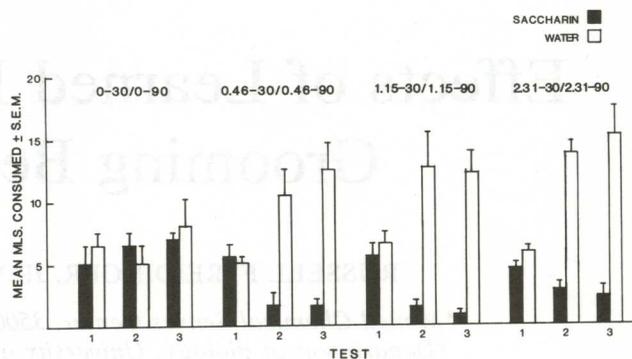


FIG. 1. Saccharin versus tapwater consumption exhibited in Experiment 1 2-bottle tests. Because the interval between 2-bottle tests and grooming had no significant effect, appropriate groups have been combined. Capped vertical bars represent standard errors of the means.

nificant relationships, and their results are not discussed below.

EXPERIMENT 1

METHOD

Procedure

Twenty-four rats (402–518 g) were randomly assigned to 8 groups ($n=3$ /gp). On 2 successive conditioning days, rats were given 1-hr 2-bottle preference tests between 0.0083 M sodium saccharin and tapwater. Thirty (groups 0-30, 0.46-30, 1.15-30, 2.31-30) or 90 (groups 0-90, 0.46-90, 1.15-90, 2.31-90) minutes after these 2-bottle tests, plain CMC or CMC containing various concentrations of LiCl were applied to the left flank of each animal. Plain CMC was applied to animals in the control groups (0-30, 0-90); 0.46 M, 1.15 M or 2.31 M LiCl-CMC was applied to animals in Groups 0.46-30 and 0.46-90, 1.15-30 and 1.15-90, and 2.31-30 and 2.31-90, respectively. For practical reasons, animals were not observed (see below) to assess whether grooming of LiCl-CMC was followed by symptoms of gastrointestinal malaise. On day 3, all groups were given a 2-bottle test between tapwater and 0.0083 M saccharin solution, without subsequent exposure to LiCl-CMC.

Individual grooming tests were conducted over the next 12 days (days 4–15, 2 rats/day). In these tests, rats were first given a 1-hr 2-bottle preference test between 0.0083 M saccharin solution and tapwater. Then they were placed in a viewing chamber for a 10-min period of adaptation. Following adaptation, 1.5 g of 0.014 M saccharin-CMC was applied to the left flank of each animal, and grooming was observed and recorded for 50 min.

In this and subsequent experiments, viewing was accomplished using a television camera and a remote videomonitor [26]. The order in which the rats were tested, and the right or left location of saccharin solution in 2-bottle tests were determined randomly.

Analysis

A 4-way ANOVA with repeated measures on 2 factors was used to assess consumption during 2-bottle tests. The independent factors were interstimulus interval (2 levels: 30

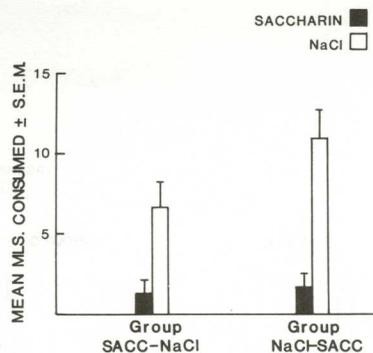


FIG. 2. Saccharin versus NaCl consumption exhibited in Experiment 2 2-bottle tests. Capped vertical bars represent standard errors of the means.

min, 90 min) and LiCl concentration in CMC (4 levels: 0.0, 0.46 M, 1.15 M, 2.31 M). The repeated factors were 2-bottle tests (3 levels) and stimuli (saccharin vs. tapwater). Two 2-way ANOVAs were used to assess the frequency and duration of grooming. The factors in these analyses were interstimulus interval (2 levels) and LiCl concentrations in CMC (4 levels). Two 1-way ANOVAs were used to assess the frequency and duration of grooming, *per se* (i.e., regardless of interstimulus interval or LiCl-concentration), among days.

RESULTS

Two-Bottle Tests

There were significant differences between consumption of saccharin and water in 2-bottle tests, $F(1,16)=10.7$, $p<0.01$. Also, there were significant 2-way interactions between drinking tests and saccharin versus tapwater, $F(2,32)=6.21$, $p<0.01$, and LiCl concentration and saccharin versus tapwater, $F(6,32)=5.1$, $p<0.01$. There were no other significant effects ($ps>0.10$).

Post-hoc analyses revealed that all groups except 0-30 and 0-90 preferred tapwater to saccharin ($ps<0.05$). However, such preferences were exhibited only during the second and third preference tests ($ps<0.05$). During the 2-bottle test prior to the first application of LiCl-CMC, all groups exhibited equivalent consumption of saccharin and tapwater. These data are displayed in Fig. 1. Because the interval between 2-bottle tests and grooming was not significant (see below), appropriate groups have been combined.

Grooming Tests

Analyses of the frequency and duration of grooming failed to reveal any significant differences between interstimulus interval or LiCl concentrations applied to the fur ($ps>0.10$). There were no significant differences in the frequency or duration of grooming, *per se*, exhibited across days ($ps>0.25$).

DISCUSSION

Rats exhibited avoidance of saccharin solution when 2-bottle preference tests were followed 30 or 90 min later by LiCl-CMC applied to the fur. While there were no significant effects of LiCl concentration, we inferred that avoidance was an expression of CFA for 2 reasons. First, animals

experienced the flavor of saccharin on 3 occasions, and thus neophobia [10] should have been minimized [11], although, perhaps, not eliminated. Second, avoidance was expressed only after application of CMC containing LiCl to the fur. On the first conditioning day (prior to any LiCl application) all groups exhibited equivalent consumption of saccharin and tapwater. Control groups (0-30, 0-90) exhibited equivalent consumption of saccharin and tapwater during all 3 2-bottle tests. Given that the "salty" taste of LiCl groomed from the fur was more closely associated with induced malaise than the "sweet" taste of saccharin, our results are consistent with the possibility that the taste of saccharin overshadowed [18] that of LiCl.

Opposite to the results obtained in drinking tests, we found that all groups groomed saccharin-CMC from their fur. There were no differences among groups either in the frequency or duration of body washes, and there was no relationship between grooming and CFA expressed in drinking. Unfortunately, no data were collected to indicate whether any of the LiCl-CMC groups exhibited relatively more grooming of the unsmeared flank than the flank to which saccharin-CMC had been applied. Nonetheless, the lack of effects probably does not reflect an inability to perceive 0.014 M saccharin in CMC. We have reported previously that rats given 0.014 M saccharin-CMC on their fur followed by an IP injection of 0.15 M LiCl exhibit strong CFAs in subsequent 2-bottle tests [26]. As with pine voles [21], it may be that exposure to the conditioned flavor stresses rats, and that stress, in turn, promotes grooming [9, 16, 21, 25]. Alternatively, differences between the conditioning context and test settings in the present experiment may have affected expression of CFA, especially if LiCl-CMC applied to the fur had produced only slight malaise (i.e., weak CFA). Archer *et al.* [2,3] have demonstrated that expression of CFA for saccharin is dependent on similarities between conditioning and testing. Specifically, the greater the dissimilarity between these settings, the weaker the expressed CFA. Applied to the present context, these findings imply that CFA expression is predictable in drinking (the conditioning context), but not in grooming, in which ingestion of the conditioned stimulus is concomitant but minor.

EXPERIMENT 2

In Experiment 1, rats were presented with 2-choice grooming tests in the sense that saccharin was applied only to the left flank of each animal. As noted above, LiCl-CMC rats may have exhibited relatively more grooming of the unsmeared than the smeared flank, although these data were not recorded. Experiment 2 was designed to provide explicit 2-choice grooming tests, in which the left and right flank of each animal were smeared with different stimuli. We reasoned that the 2-choice context might be more sensitive to expression of CFA, since CFA in drinking is more readily detected in 2-choice tests [12]. Rats were given injections of 0.15 M LiCl following exposure to 0.014 M saccharin CMC on the fur (grooming) and 0.15 M sodium chloride (NaCl) in tapwater (drinking), or 0.26 M NaCl-CMC on the fur (grooming) and 0.0083 M saccharin in tapwater (drinking). CFA was then assessed in both drinking (saccharin vs. NaCl) and grooming (saccharin-CMC vs. NaCl-CMC) tests. In addition to the opportunity to observe the effects of CFA on grooming in explicit 2-choice tests, Experiment 2 permitted opportunities (a) to assess the importance of conditioning context (drinking, grooming) on CFA expression, and (b) to determine

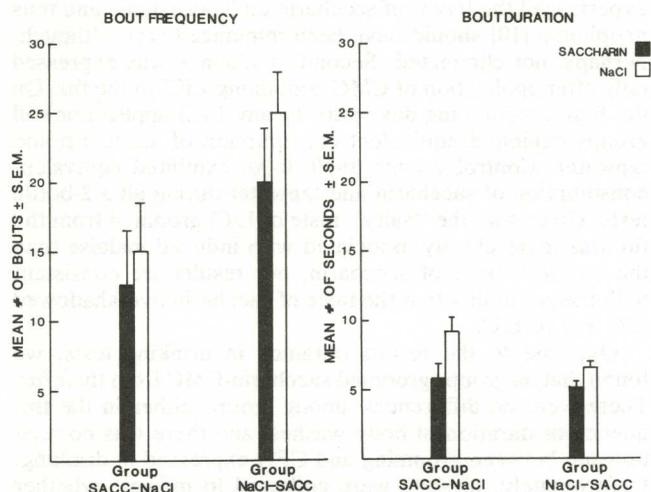


FIG. 3. Mean frequency and duration (sec) of saccharin-CMC versus NaCl-CMC grooming (body washes) exhibited in Experiment 2. Capped vertical bars represent standard errors of the means.

whether overshadowing occurred when flavors were confounded in drinking and grooming contexts.

METHOD

Eighteen rats (210–270 g) were randomly assigned to 2 groups (Sacc-NaCl; NaCl-Sacc; $n=9/\text{gp}$). On the day of conditioning, animals in Group Sacc-NaCl were given 2-ml of 0.0083 M saccharin solution to drink, and 1 hr later, 2 g of 0.26 M NaCl-CMC was applied to their left ($n=5$) or right ($n=4$) flanks. Grooming was permitted for 60 min, and then each rat was given an intraperitoneal (IP) injection of 0.15 M LiCl (100 mg/kg body weight). Group NaCl-Sacc rats were treated similarly, except that 0.15 M NaCl was presented in solution, while 0.014 M saccharin was presented in CMC. Two days later, CFA was assessed in 1-hr 2-bottle tests between 0.0083 M saccharin and 0.15 M NaCl.

One week later, rats were randomly selected (3 animals/day for 6 days) and placed in the viewing cage. After 10 min, one flank of each animal was smeared with 2 g of 0.014 M saccharin-CMC; 2 g of 0.26 M NaCl-CMC was applied to the other. Saccharin-CMC and NaCl-CMC applications were counterbalanced (left vs. right flank) across animals. The frequency and duration of body washes were then recorded for 50 min.

Analysis

A 2-way ANOVA with repeated measures on the second factor (stimuli: saccharin vs. NaCl) was used to assess drinking test results. Likewise, 2-way ANOVAs with repeated measures on the second factor (stimuli: saccharin-CMC vs. NaCl-CMC) were used to assess the frequency and duration of body washes.

RESULTS

Two-Bottle Tests

There was a significant difference between consumption of saccharin and NaCl, $F(1,16)=8.0$, $p<0.01$. Otherwise, there were no significant effects ($ps>0.10$). Examination of

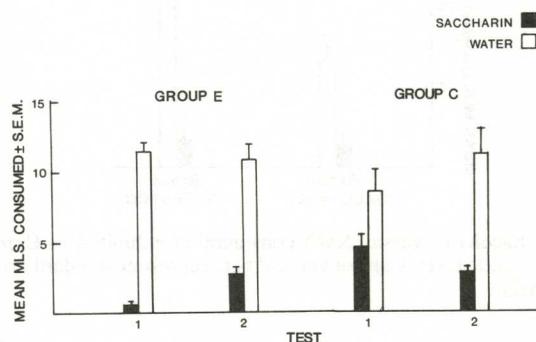


FIG. 4. Saccharin versus tapwater consumption exhibited in Experiment 3 2-bottle tests. Capped vertical bars represent standard errors of the means.

the data revealed that both groups consumed more NaCl than saccharin (Fig. 2).

Grooming Tests

Group NaCl-Sacc groomed more frequently than Group Sacc-NaCl, $F(1,16)=4.2$, $p<0.05$, although there was no interaction between groups and flavor-CMC stimuli ($p>0.10$). When grooming bout durations were examined, there were significant between groups differences, $F(1,16)=10.1$, $p<0.006$, and significant differences between saccharin-CMC and NaCl-CMC, $F(1,16)=5.0$, $p<0.04$. The 2-way interaction was not significant ($p>0.10$). Examination of the data revealed that Group Sacc-NaCl groomed for longer periods than Group NaCl-Sacc and that both groups exhibited longer grooming bouts directed at NaCl-CMC (Fig. 3).

DISCUSSION

Both groups avoided saccharin in 2-bottle tests, regardless of whether saccharin in drinking was followed by NaCl-CMC (Group Sacc-NaCl), or vice-versa (Group NaCl-Sacc). This result can be interpreted to reflect the relatively greater salience of saccharin as a stimulus. It can also be taken as consistent with previous reports that, when saccharin and NaCl are confounded in CFA, the flavor of NaCl is overshadowed [18]. We do not believe that the failure of Group NaCl-Sacc to exhibit NaCl CFA reflects a failure in avoidance acquisition. Rats will form CFAs toward NaCl when this tastant is presented in tapwater or in CMC on the day of conditioning [26].

That there were no differences in avoidance of saccharin between groups in the 2-bottle test is somewhat striking, insofar as Group Sacc-NaCl received saccharin in tapwater on the day of conditioning, while Group NaCl-Sacc received saccharin applied to the fur. Archer *et al.* [2] has reported that differences between conditioning and testing strongly influence expression of CFA. One plausible explanation for this discrepancy between Archer *et al.* [2] and the present study is that the former investigators evaluated the importance of exteroceptive cues (e.g., cage dimensions, bottle

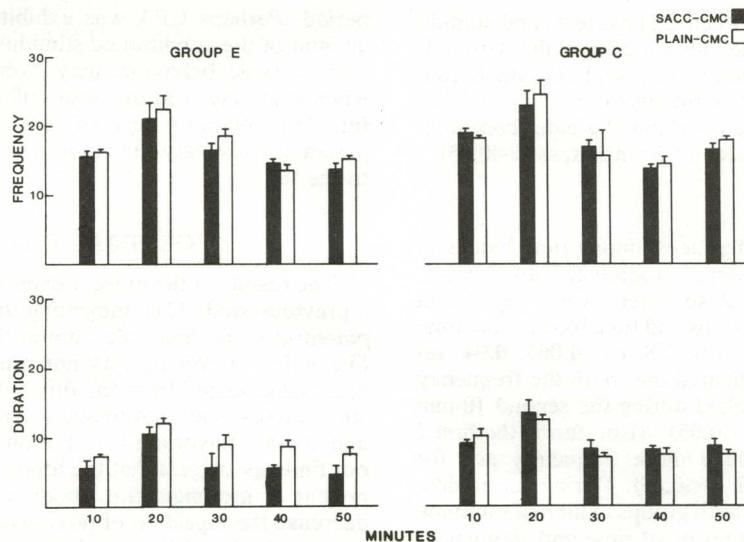


FIG. 5. Mean frequency and duration (sec) of saccharin-CMC versus plain-CMC grooming (body washes) exhibited in Experiment 3. Capped vertical bars represent standard errors of the means.

type), while the present study assessed changes in the mode of ingestion (drinking vs. grooming).

The results of grooming tests suggest that CFAs can be expressed when animals are presented with 2 flavors on their fur. However, such expression is relatively weak, in that (a) grooming of the conditioned stimulus is merely reduced and not abolished, and (b) CFA is reflected only in bout durations but not frequencies. In addition, overall grooming by Groups NaCl-Sacc and Sacc-NaCl was similar (i.e., the former animals groomed more frequently, but the latter groomed for longer durations). These observations support our conclusion in Experiment 1 that grooming behavior is not easily modified by CFA. As such, grooming may represent an important, exploitable weakness in rodents' defenses against dietary poisoning.

EXPERIMENT 3

Experiment 3 was performed to assess whether rats would express saccharin CFAs in 2-choice grooming tests between saccharin-CMC and plain-CMC (neutral-tasting to humans, [26], personal observation). Our aim was to determine whether the strength of CFA expression in grooming was influenced by the quality of the alternative stimulus in 2-choice tests. Rats were given saccharin-CMC on one flank and plain-CMC on the other, followed by LiCl or sham IP injections. Subsequently, both groups were given first a 2-bottle test (0.0083 M saccharin vs. water), then a 2-choice grooming test (0.14 M saccharin-CMC vs. plain-CMC), and finally, another 2-bottle test (0.0083 M saccharin vs. water). In addition to assessments of CFA in grooming, this paradigm permitted an evaluation of saccharin CFA in drinking before and after exposure to saccharin-CMC during interposed grooming trials.

METHOD

Procedure

Sixteen adult male Sprague-Dawley rats (200–280 g) were

assigned to 2 groups ($n=8/gp$). On the day of conditioning, both groups (E, C) were given 0.014 M saccharin-CMC on one flank and plain-CMC on the other. Equal numbers of animals in both groups were smeared with saccharin-CMC on the left and right flanks. After 1 hr, the animals in Group E were given IP injections of 0.15 M LiCl (100 mg/kg body weight). The animals in Group C were given sham injections (i.e., the needle was inserted into the abdomen but withdrawn without injection). Following treatment, all animals were given water and food ad lib for 2 days. Water deprivation was reinstated on the second recovery day during the last hour of light.

On the third post-treatment day, both groups were given 1-hr 2-bottle tests between 0.0083 M saccharin and tapwater. Over the next 4 days, all animals were given 50-min 2-choice grooming tests ($n=4$ animals/day) between 0.014 M saccharin-CMC and plain-CMC. The order in which animals were tested was counterbalanced between groups. On the day following the last grooming test, all animals were given an additional 1-hr 2-bottle test between 0.0083 M saccharin and water.

Analysis

A 3-way ANOVA with repeated measures on 2 factors was used to assess 2-bottle tests. The independent factor was groups (2 levels), while the repeated factors were tests (2 levels) and stimuli (saccharin vs. water). Grooming was assessed in a 3-way ANOVA with repeated measures on 2 factors. The independent factor in this analysis was groups (2 levels), while the repeated factors were time (5 levels; grooming tests partitioned into 10-min blocks) and stimuli (saccharin-CMC versus plain-CMC).

RESULTS

Two-Bottle Tests

There was a significant difference between tests, $F(1,14)=7.0$, $p<0.02$, a significant 2-way interaction between groups and stimuli, $F(1,14)=10.0$, $p<0.01$, and a sig-

nificant 3-way interaction between groups, tests and stimuli, $F(1,14)=10.8, p<0.01$. Post-hoc tests indicated that Group C consumed more saccharin than water, while Group E consumed more water than saccharin ($ps<0.05$; Fig. 4). Between test sessions, both groups exhibited greater consumption of saccharin during the second 2-bottle test ($p<0.05$).

Grooming Tests

There were significant differences among time blocks in both the frequency and duration of grooming, $Fs(4,56)=3.1, 3.2, ps<0.02$, respectively. Also, there were significant 2-way interactions between groups and time blocks, and time blocks and stimuli, $Fs(4,56)=4.6, 2.8, ps<0.003, 0.04$, respectively. Post-hoc tests indicated that both the frequency and duration of grooming peaked during the second 10-min block of the grooming trial ($p<0.05$). Also, during the first 2 time blocks, Group C groomed more frequently and for longer periods than Group E ($p<0.05$). During the middle time blocks (30-min, 40-min), both groups exhibited the same amount of grooming, both in terms of time and frequency. During the final 10-min period, Group C exhibited more frequent and longer bouts of grooming ($ps<0.05$) than Group E. Also, during the last two time blocks, Group E exhibited relatively longer bouts of grooming directed at the flank smeared with plain-CMC ($ps<0.05$). During all time blocks, Group C groomed saccharin-CMC and plain-CMC for equivalent durations (Fig. 5).

DISCUSSION

Saccharin grooming followed by LiCl injection was sufficient for acquisition of CFA (later expressed in drinking). In addition, exposure to saccharin during interposed grooming trials was sufficient for some extinction of CFA (i.e., Group E exhibited significantly greater saccharin consumption during the second 2-bottle test).

Conditioned flavor avoidance also was expressed in 2-choice grooming tests between saccharin-CMC and plain-CMC. We propose that avoidance may have been expressed in 2 ways. First, control (C) animals groomed more frequently and for longer periods of time than experimental (E) animals. Second, Group E exhibited relatively longer bouts of grooming toward plain-CMC. It is important to note, however, that differential (stimulus-directed) grooming was expressed only in terms of bout durations. This result is consistent with the results of Experiment 2. Overall, Experiments 2 and 3 suggest that CFA expression in grooming is weak, relative to expression in drinking.

The findings (a) that grooming peaked during the second 10-min block, and (b) that differential grooming was exhibited by the experimental group only during the final 2 time blocks, are not readily explained. One hypothesis, however, is that the expression of CFA in grooming may have depended, in part, on the amount of stimuli present on the fur. Casual observation suggested that much of the material applied to the fur had been consumed during the first 10-min

period. Perhaps CFA was exhibited only when a minimal amount of the conditioned stimulus remained. Grooming, as a stereotypic behavior, may override expression of CFA when relatively large quantities of material are present on the fur. One obvious test of this possibility would be to parametrically vary the amount of stimulus material applied to the fur.

GENERAL DISCUSSION

The results of the present experiments are consistent with a previous study [21], indicating that rodents (i.e., *Microtus pinetorum*) continue to groom in the presence of CFA. Unlike voles, however, rats not only perceive the flavor of material groomed from the fur, but can exhibit CFA toward such flavors in autogrooming when the conditioned stimulus and another flavor are smeared on opposite flanks. As such, our findings suggest that the topography of at least one component of grooming (i.e., body washes) can be shifted to decrease the ingestion of noxious and potentially toxic substances. Redirected grooming is unlikely to compromise the potential efficacy of this behavior as a means for delivery of chemical agents, however, in that (a) rats continue to groom conditioned stimuli from their fur when tastant is applied to only one flank, and (b) expression of CFA in 2-choice grooming tests is relatively weak, and directed grooming is expressed mainly (if not solely) in terms of bout durations. While the strength of CFA expressed in grooming may depend on the quantity of material applied to the fur (Experiment 3), we propose that grooming may provide a means of delivering control compounds (e.g., rodenticide, chemosterilant) to rodent pests regardless of the compound's palatability or potential for causing bait-shyness ([17,20]; see also [24,26]).

An additional implication of the present experiments for rodent control can be drawn from the observation that saccharin presented in drinking appears to overshadow NaCl presented in grooming. In principle, we speculate that overshadowing might be implemented as means of crop protection. In the simplest case, rodent pests might acquire CFA to a crop if the flavor of the crop overshadows the flavor of a toxicant ingested while grooming [26]. To abet CFA acquisition, one might treat a crop with a distinctive flavor, or use toxicants which are less salient than the crop. One could examine the flavor characteristics of toxicants that are routinely sprayed on crops via generalization of CFA [22] to determine if they might be exploited in this manner.

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