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Poison-Based Taste Aversion Learning in Deer Mice (*Peromyscus maniculatus bairdi*)

Robert J. Robbins
Department of Zoology
Michigan State University

A series of experiments tested the ability of mice of the native genus *Peromyscus* to form learned taste aversions. It was found that (a) the mice acquired a strong aversion after a single flavor/toxicosis pairing, (b) naive mice drinking a LiCl solution apparently began to experience toxic effects within 90 sec after the beginning of consumption, (c) the mice acquired a total aversion after a single flavor/delayed illness pairing when high doses of toxin were employed, and (d) the aversion produced by a single flavor/delayed-illness pairing was specific to the flavor paired with illness and was dependent on the contingency between the flavor and illness. Although these responses are qualitatively similar to those reported for domestic rats, the mice formed considerably weaker aversions than those previously reported for laboratory rats tested with the same weight-specific doses of LiCl.

Although poison-based taste aversion learning (TAL) is being subjected to extensive investigation (see the bibliographies by Riley & Baril, 1976, and by Riley & Clarke, 1977), it has been studied thoroughly only in the laboratory rat. To be sure, the phenomenon has been demonstrated in many other taxa (see review by Gustavson, 1977), but many of the species tested have been so distant phylogenetically and ecologically that comparative interpretation of the results is difficult, and several of the species were either so large or so difficult to maintain that investigations involving large sample sizes and several control groups are uncommon. The interpretational difficulties inherent in comparisons over great phylogenetic distances have been emphasized by several authors (Denny & Ratner, 1970; Dewsbury, 1973; King, 1968; Lockard, 1971), and Bitterman (1976) has specifically criticized comparative taste aversion studies by asserting that "some experiments on conditioned [taste] aversion in animals other than rats . . . can hardly be called 'comparative' in any strict sense of the term" (p. 266).

The absence of systematic comparative studies in an area that has provided a challenge to traditional learning theory is particularly distressing, especially since one study (Wilcoxon, Dragoin, & Kral, 1971) showed that some specific, and theoretically important, attributes of poison-based aversion learning may vary from taxon to taxon. It is equally distressing that a phenomenon which may prove to be of great importance to a general ecological analysis of dietary selection has been studied primarily in a domesticated species. Thus, it seems that TAL could be productively investigated in nondomesticated species suitable both for large-scale laboratory studies and for systematic manipulation of their phylogenetic and ecological attributes. Barry (1975) discussed the many advantages of mice of the genus *Peromyscus* for laboratory studies, and Dewsbury (1973) specifically recommended *Peromyscus* for comparative studies. Indeed, the occurrence of *Peromyscus*

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Requests for reprints should be sent to Robert J. Robbins, Biology Research Center, Michigan State University, East Lansing, Michigan 48824.

as fifty or more species and hundreds of subspecies ranging across North America in habitats as diverse as deserts, grasslands, deciduous forests, arctic prairies, and tropical undergrowth (Baker, 1968; Hooper, 1968) makes them well suited for comparative work, since evolutionary convergence may be investigated by comparing species of different subgenera occupying the same habitat and adaptive radiation may be investigated by comparing subspecies occupying different habitats.

But before these extensive comparative studies are begun, it appears useful to investigate the basic attributes of TAL in a representative species. This should be done with the use of experimental designs similar to those already employed on the laboratory rat so comparisons may be readily made. Thus, this first article in a series of investigations of TAL in *Peromyscus* begins with the establishment of the phenomenon in a common grassland subspecies of deer mice, *Peromyscus maniculatus bairdi.*

Experiment 1

The first experiment determined whether phenomena related to TAL are present in *Peromyscus.* The animals were allowed to drink a novel toxic solution, and the subsequent acceptability of that, or a similarly flavored, solution was determined. The experiment was also designed to determine whether the animals distinguish between equimolar LiCl and NaCl solutions under the experimental conditions employed.

Method

All animals in this study were experimentally naive adult (100–160 days of age) male and female *Peromyscus maniculatus bairdi.* They were the first generation of laboratory-born offspring from original stocks captured on the Michigan State University campus and at a site about 10 miles (16 km) south of the campus (see Barry, 1975, for a detailed discussion on trapping and maintaining these animals for laboratory studies). During these studies the animals were housed either in a breeding room or in an experimental room. Both rooms were on the same 15:9 hr light/dark cycle. In the breeding room, mice were housed in plastic laboratory cages measuring 6 × 12 × 6 in. (15 × 30 × 15 cm) with wire lids. Wayne Breeder Blox and water were provided ad lib. All cages were provided with a bedding of woodshavings and with cotton nesting material.

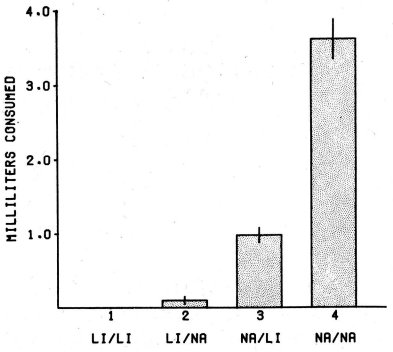

Figure 1. Mean sucrose consumption (±1 *SE*) of test groups in Experiment 1 on Day 12. (Salts given on Days 9 and 12 are shown below abscissa.)

Young mice were housed with their parents until weaning, then as littermates until the experimental procedures were begun.

At the beginning of the experiment, the animals were housed individually in cages equipped as indicated and were moved into the experimental room. Animals were randomly assigned to one of four treatment groups. Initially, n = 13 for each group, but differential mortality, apparently caused by the animals' inability to adjust to the restriction of fluid availability to 20 min per day, reduced the final numbers to 11, 12, 10, and 10 for Groups 1 to 4, respectively. All animals were placed on a restricted fluid-availability schedule, with water available only during a 20-min period (1300–1320) every day. After 8 days of water consumption on this schedule, the different treatment schedules were begun. For the purpose of ensuring equal consumption during the 20-min drinking period of Day 9, Groups 1 and 2 were offered only .75 ml of a .2 M. LiCl solution, and Groups 3 and 4 were offered only .75 ml of a .2 M NaCl solution. All animals consumed the full .75 ml. On Days 10 and 11, all groups were given water. On Day 12, Groups 1 and 3 were offered .2 M LiCl and Groups 2 and 4 were offered .2 M NaCl. This final drinking period was limited to 10 min since Nachman (1963) and Rusiniak, Garcia, and Hankins (1976) showed that for rats the onset of toxic effects from ingested lithium occurs 8–12 min after the beginning of a drinking bout.

During this and the subsequent experiments, fluid consumption was measured to .1 ml by providing the fluids in disposable 10-ml plastic syringes that had been modified into calibrated drinking tubes (following the method of Robbins, 1977a).

Results

The results of this experiment are given in Figure 1. Because of the unequal sample sizes in the different treatment groups and the pronounced heterogeneity of variance between treatment groups, significance was tested by making pair-wise comparisons with

Cochran's t' test (for details, see Snedecor & Cochran, 1967, pp. 114–116) for testing differences between samples with unequal variances. (Although multiple comparisons increase the experiment-wide likelihood of Type I error, this can be compensated for by placing more stringent requirements on the individual comparisons. In this case, with six comparisons, the requirement that each comparison be different at the $p \leq .001$ level yields an experiment-wide likelihood of Type I error of $p \leq .004$.) The t' tests showed that Groups 1 and 2 were not different from each other, t' (10, 11) = 1.732, but both groups were significantly different from groups 3 and 4, ($|t'|(\geq 9, 10) \geq 7.169$, $p \leq .001$). In addition, Groups 3 and 4 were significantly different from each other, $t'(9) = 9.108$, $p \leq .001$.

Discussion

The hypothesis that *Peromyscus* can form learned taste aversions is supported by the suppressed consumption on Day 12 of Group 1 (Li/Li) relative to group 3 (Na/Li). However, the hypothesis that equimolar LiCl and NaCl solutions are indistinguishable to *Peromyscus* is supported by the suppressed consumption of Group 2 (Li/Na) but is inconsistent with the significant difference between Group 3 (Na/Li) and Group 4 (Na/Na). It may be that the fluids are similar enough for the aversion to LiCl to be generalized to NaCl (as appears the case with Group 2) but dissimilar enough for a difference in preference to be evidenced by the previously nonpoisoned animals of Groups 3 and 4. Or, it may be that the fluids have similar tastes but the toxic effects of LiCl appear so rapidly with *Peromyscus* that consumption of the .2 M LiCl solution was terminated much earlier in the 10-min drinking period than was consumption of the .2 M NaCl. But, whatever the cause of this ambiguity regarding the equivalent taste of LiCl and NaCl, the data do indicate that *Peromyscus* can learn to avoid distinctly flavored fluids that have toxic effects.

Experiment 2

The equivalence of taste of equimolar LiCl and NaCl solutions to *Peromyscus* was unresolved in Experiment 1. However, the apparent inconsistency could be explained if the onset of toxic effects of LiCl occurred early in the 10-min test. This experiment examines the cumulative consumption of LiCl and NaCl by naive mice, to determine whether there is any indication that LiCl-induced toxicosis occurs rapidly after the beginning of consumption.

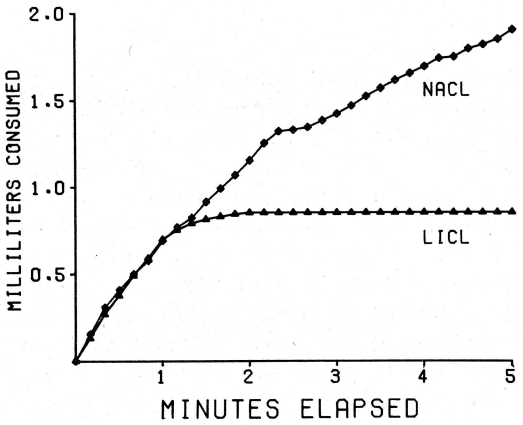

Figure 2. Mean cumulative consumption by animals drinking LiCl or NaCl solutions in Experiment 2. (The n = 13 for both groups.)

Method

The experimentally naive subjects (*P. m. bairdi*, as above) were housed individually in plastic cages and assigned randomly to one of two treatment groups (n = 13 for each). All animals were placed on the same restricted 20-min per day water-availability schedule employed in Experiment 1. For 8 days, tap water was offered to both groups. On Day 9, Group 1 was offered .2 M LiCl and Group 2 was offered .2 M NaCl. Each individual animal's consumption was monitored and recorded in 10-sec intervals for a total of 5 min (with Time 0 taken as the moment the animal first contacted the drinking spout).

Results

The results are shown in Figure 2. The mean cumulative consumption curves are virtually identical for the first 90 sec, then they begin to diverge rapidly, becoming significantly different at 2 min (t test, $p \leq .05$). The difference from 2 min to 5 min is striking—none of the LiCl animals drank any additional fluid during these last 3 min, whereas all the NaCl animals continued to drink throughout the final 3 min.

Discussion

These results are consistent with the hypothesis of equal acceptability but rapid onset of toxic effects. They also agree with the results of Experiment 1: In Experiment 1, animals freely drinking LiCl (Group 3 of Figure 1) consumed a mean of .98 (±.10) ml, whereas in this experiment, mean LiCl consumption was .85 (±.09) ml. (The free consumption of NaCl was almost 50% less here than in Group 4 of Experiment 1, but this is not unexpected as the present test was only 5 min long whereas that of Experiment 1 lasted 10 min.) Thus, it seems reasonable to postulate that the difference between Group 3 and Group 4 of Figure 1 could be due to this rapid rejection of LiCl rather than to an initially lower preference for the taste of LiCl.

Although these results are consistent with the notion of early toxicosis onset, they certainly do not establish that notion since they are equally consistent with the hypothesis of a difference in delayed aftertaste. However, it is established that some difference is detected by the mice very rapidly after they begin drinking. Indeed, it occurs so rapidly that future TAL studies on *Peromyscus* should not employ the ingestion of LiCl solutions, as this could easily lead to the confusion of learned effects with rapidly occurring direct effects.

Since similar studies have been performed on laboratory rats, it is possible to compare those findings with these of the present experiment: The cumulative consumption curves for *Peromyscus* (Figure 2) are generally similar in shape to those reported in rats by Nachman (1963) and by Rusiniak et al. (1976), but the onset of difference between LiCl and NaCl consumption occurs more rapidly in *Peromyscus* than in rats. Nachman (1963) provided a pair of mean cumulative drinking curves for rats drinking .12 M LiCl and .12 M NaCl which do not begin to diverge until 4 min have passed and in which the LiCl consumption does not cease until 8 min have elapsed. Similarly, Rusiniak et al. gave individual cumulative drinking curves for 7 rats drinking .12 M LiCl. Their results showed that the first rat stopped drinking after 6 min, whereas the median rat stopped at 10 min and one continued to drink throughout the 15-min period. The present work, on the other hand, found that 13 mice drinking .2 M LiCl all stopped drinking completely by 2 min after the onset of the exposure period.

This difference between rats and *Peromyscus* has several possible explanations. First, the concentrations of the two LiCl solutions were different. The rats were drinking a .12 M solution, whereas the *Peromyscus* were drinking a .2 M solution. Second, Rusiniak et al.'s rats had prior safe experience with an equimolar NaCl solution and thus might have been more likely to show a delayed reaction. Third, mice are considerably smaller than rats. If the onset of toxicosis in any way depends upon the rate at which lithium ions are distributed throughout the body, mice should show an earlier onset of symptoms since they are smaller and have a higher weight-specific cardiac output than the rats. Finally, although rats are at least 10 times heavier than the mice, they drank fluid at a rate only 3 times faster. Thus, they were acquiring their dose at a lower rate per unit of body weight than were the mice. It is clear that any combination of these factors could produce the observed difference.

Experiment 3

Although Experiment 1 indicated that *Peromyscus* learned to avoid a distinctly flavored toxic fluid after only one experience with their fluid, the results of Experiment 2 suggest that very little delay existed between the consumption of the fluid and the onset of toxic effects. The experimental designs employed in the first two experiments thus provided no evidence that the mice would form aversions if a delayed illness were paired with a distinctive flavor, nor did they test for the appropriate dosages necessary to produce such an aversion. Therefore, this experiment attempted to (a) determine whether adult *P. m. bairdi* form an aversion to a distinctly flavored fluid if consumption of that fluid is followed by a delayed lithium-injection-induced toxicosis and (b) determine how the aversion is affected by the dosage of injected toxin.

Method

The experimentally naive subjects (*P. m. bairdi*, as above) were housed individually in plastic cages and randomly assigned to 1 of 11 treatment groups ($n = 10$ for each group). All groups were assigned to have one experience with sucrose (20% w/v) followed by an injection of either a toxin or a control substance. The specific assignments were as follows: (a) no-injection control, (b) .3 mEq of LiCl per kilogram of body weight, (c) .3 mEq/kg NaCl, (d) 1.0 mEq/kg LiCl, (e) 1.0 mEq/kg NaCl, (f) 3.0 mEq/kg LiCl, (g) 3.0 mEq/kg NaCl, (h) 6.0 mEq/kg LiCl, (i) 6.0 mEq/kg NaCl, (j) 9.0 mEq/kg LiCl, and (k) 9.0 mEq/kg NaCl. The various dosages were obtained by varying the concentration of the solute rather than by varying the volume of the injection, which was held constant at .015 ml per gram of body weight.

Since *Peromyscus* often show a high mortality rate when restricted to 20 min of water availability per day, the mice in this experiment were placed on the following schedule: On Day 0, the animals were removed from their colony cages, where water had been available ad lib, and were placed in their experimental cages. At 1300 hours, their water was removed, beginning a 24-hr deprivation. At 1300 of Day 1, drinking tubes filled with water were placed on each of their cages, left for 20 min, then removed, and the amount consumed was recorded. Immediately after the recording of data, the tubes were refilled, replaced on the cages, and left in position for approximately 24 hr. At 1300 on Day 2, the tubes were removed and the consumption was recorded. This daily alternation of fluid availability/fluid deprivation was continued through the experiment. Note that this schedule provides a regular 20-min postdeprivation drinking period, suitable for taste-aversion-inducing manipulations, on every odd-numbered day and 24 hr of ad lib water consumption on every even-numbered day.

For the purpose of developing a regular drinking schedule in the animals, all groups were given water according to this schedule for 4 days. On Day 4, each animal was weighed. On Day 5, each animal was offered sucrose solution during the 20-min drinking period, then immediately injected ip with the assigned substance and dose. Fluid was withheld from the animals for 2 hr following the injections. Then, drinking tubes filled with water were placed on the cages and left for 22 hr. On Day 6, the drinking during the 22-hr period was recorded and the drinking tubes were removed from the cages. On Day 7, sucrose was offered to all animals during their 20-min drinking bout, after which the experiment was terminated.

Results

The results of this experiment, shown in Figure 3, indicate a marked difference between the groups injected with LiCl and those with NaCl. A two-way analysis of variance (Injectant × Dosage) on the data of the injected groups showed significance for both main effects and for the interaction: injectant, $F(1, 90) = 462.48$, $p \leq .001$; dosage, $F(4, 90) = 8.22$, $p \leq .001$; interaction, $F(4, 90) = 7.34$, $p \leq .001$. The t tests between the no-injection group and the NaCl-injected groups found no differences, $|t|(18) \leq 1.874$. Additional t tests found that the .3 mEq LiCl group was not different from the no-injection group $t(18) = 1.091$, while the 1.0 mEq LiCl group, $t(18) = 2.409$, $p \leq .05$, and the 3.0 mEq LiCl group, $t(18) = 5.231$, $p \leq .001$, were different from the no-injection group. Similarly, Cochran's t' test found that both the 6.0 mEq and the 9.0 mEq LiCl groups were different from the no-injection group, $|t'|(9) \geq 10.053$, $p \leq .001$.

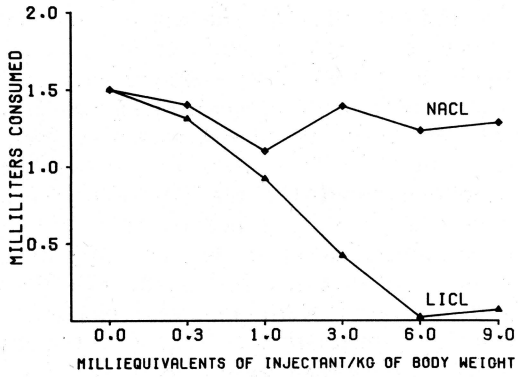

Figure 3. Mean sucrose consumption for all groups on the first test following a sucrose/injection contingency (Experiment 3).

Discussion

The results indicate that adult *P. m. bairdi* avoid drinking a sucrose solution after a single pairing of sucrose consumption with a delayed lithium-induced illness and that the degree of the aversion is influenced by the dosage of toxin administered.

Although the dose–response curve of Figure 3 is qualitatively similar to one reported for domestic rats (Nachman & Ashe, 1973), it differs quantitatively. Mice injected with .3 mEq LiCl/kg of body weight, for example, drank 87% as much as their noninjected controls, whereas rats at that dosage drank only 56% of the control amount. At 1.0 mEq/kg, mice drank 73%, whereas rats drank 17%. At 3.0 mEq/kg, mice drank 33%, whereas rats drank 0%. At

6.0 and 9.0 mEq/kg, the mice drank 0% (Nachman and Ashe did not test rats at these dose levels). These comparisons show a consistent displacement of the mouse and rat dose–response curves, which suggests that the mice form considerably weaker aversions than do the rats. However, there were some slight differences between the two experimental designs: (a) The rats were given a 15% sucrose solution, the mice 20%, and (b) the rats were injected immediately after a 10-min drinking period, the mice immediately after a 20-min drinking period. Since recent studies showed that the duration of conditioned stimulus (CS) presentation, the length of the CS/unconditioned-stimulus interval, and the CS intensity all affect the formation of taste aversions (Andrews & Braveman, 1975; Barker, 1976; Bond & Harland, 1975; Dragoin, 1971), these procedural differences might be responsible for the apparent difference. On the other hand, the displacement of the two curves may be due to a real difference, either physiological or behavioral, between domestic rats and *Peromyscus*.

In any event, the discovery of such a difference points up a hazard of comparative studies and serves to emphasize the usefulness of detailed studies, involving several control and experimental groups, on all species being considered. Had the present experiment on *Peromyscus* employed only the dosage used by Nachman and Ashe, for example, the ability of *Peromyscus* to form total aversions toward a flavor paired only once with delayed illness would have gone undetected, which would have suggested, perhaps, the erroneous conclusion that *Peromyscus* and rats differ qualitatively in their TAL acquisition abilities. Instead, the results of the present study indicate that the difference between rats and *Peromyscus* is simply quantitative.

Experiment 4

The previous experiment showed that mice which had experienced the taste of sucrose followed by a delayed lithium-induced illness subsequently avoided drinking a sucrose solution. This was taken as evidence that *Peromyscus* form learned taste aversions and that the strengths of these aversions are directly related to the dosage of toxin used to produce the illness. However, two alternative hypotheses could also explain the results of Experiment 3: (a) Exposure to lithium alone is sufficient to alter the animals' reaction to sucrose—the sucrose/lithium contingency is unnecessary—or (b) the apparent aversions are not specific to sucrose at all but rather represent a reduced tendency to drink *any* fluid presented at the appropriate temporal position in the experimental schedule. These objections are not raised lightly; some experimenters think that many of the findings on TAL derive primarily from inadequate controls, particularly for pseudoconditioning or sensitization (see Bitterman, 1975, 1976). Therefore, this experiment was designed in an effort to generate data bearing on the following questions: (a) Is the decrease in preference for sucrose shown to occur following lithium-induced toxicosis actually dependent on the sucrose/lithium contingency, or is it derived from the toxicosis alone? (b) Is the apparent aversion to sucrose specific to sucrose, or is it simply an aversion to drinking?

Method

The experimentally naive subjects (*P. m. bairdi,* as above) were housed individually in plastic cages and randomly assigned to one of four treatment groups (n = 10 for each group). For the purpose of developing a regular drinking schedule in the animals, all groups were given water according to the alternating fluid schedule of the previous experiment for 12 days. On Day 12, each animal was weighed. On Day 13, the different treatment procedures were begun: Group 1 (water/Li) was given water during its 20-min drinking period and immediately injected ip with a .6 M LiCl solution; Group 2 (water/Na) was given water during a 20-min drinking period and injected with a .6 M NaCl solution; Group 3 (sucrose/Li) was given a 20% w/v sucrose solution and injected with LiCl; and Group 4 (sucrose/Na) was given a 20% sucrose solution and injected with NaCl. The volume of the injections was adjusted so that each animal received 9.0 mEq of solute per kilogram of body weight. Additional drinking fluid was withheld from the animals for 2 hr following the injections. Then drinking tubes filled with water were placed on the cages for 22 hr. On Day 14, the drinking during the previous 22 hr was recorded and the drinking tubes were removed from the cages. On Day 15, water was offered to the animals during the 20-min drinking period and consumption was recorded. Then the tubes were refilled with water and replaced for 24 hr. On Day

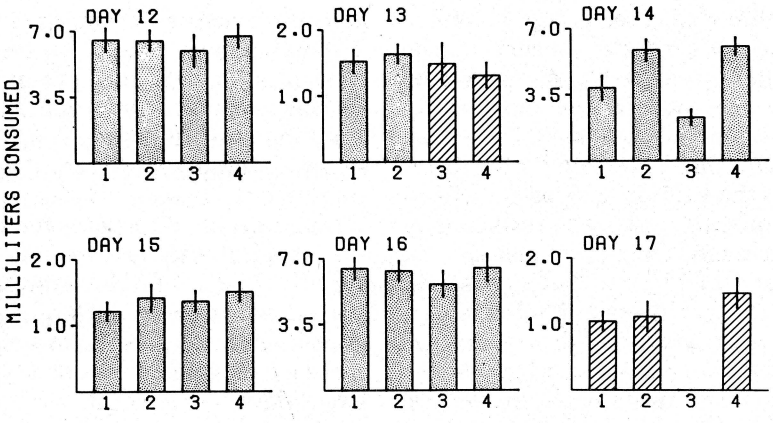

Figure 4. Mean fluid consumption (±1 *SE*) over 6 days in Experiment 4. (Stippled bars represent water consumption; striped bars represent sucrose consumption. After drinking on Day 13, Groups 1 and 3 were injected with LiCl and Groups 2 and 4 with NaCl.)

16, the tubes were removed and the consumption for the previous 24 hr was recorded. On Day 17, all groups were offered a 20% w/v sucrose solution and the amount consumed was recorded.

Results

The results of this experiment are given in Figure 4. A day-by-day consideration of the figure follows:

Day 12 gives the baseline 24-hr water consumption for all groups on the day before the initiation of the different treatment group procedures. Analysis of variance indicates that no significant differences exist.

Day 13 gives 20-min water consumption for Groups 1 and 2 and 20-min sucrose consumption for Groups 3 and 4. Again, analysis of variance (two way, Flavor × Injectant) indicates no differences. Note that immediately after this 20-min drinking period the animals were injected.

Day 14 shows the 22-hr water consumption for the period beginning 2 hr after the injections. Both lithium-injected groups (Group 1, water/Li, and Group 3, sucrose/Li) show significantly depressed consumption: injectant effect, $F(1, 36) = 29.759$, $p \leq .001$. Duncan's multiple-range test (Duncan, 1955) indicates no difference between Group 1 and Group 3 or between Group 2 and Group 4.

Day 15 gives the 20-min water consumption on the second day after the injections. Analysis of variance indicates no differences.

Day 16 gives the 24-hr water consumption recorded on the third day following the injections. Again, an analysis of variance shows no differences.

Day 17 gives the 20-min sucrose consumption for all groups. Group 3 (sucrose/Li) does not appear, as none of the animals in this group drank any sucrose. Thus, an obvious difference exists between Group 3 and the other groups: injectant effect and Injectant × Flavor interaction, $F(1, 36) \geq 15.614$, $p \leq .001$. Duncan's multiple-range test shows no differences among Groups 1, 2, and 4.

Discussion

On Day 17, sucrose was refused by Group 3 (which had lithium toxicosis contingently paired with sucrose ingestion) but not by Group 1 (which received lithium following water ingestion). This indicates that the aversion to sucrose shown by Group 3 was not the result of the lithium injection per se but rather was the result of the contingency between sucrose ingestion and lithium poisoning. On Days 15 and 16, no significant differences existed in water consumption among the groups. This indicates that the aversion produced by the sucrose/lithium contingency was specific to sucrose and not a generalized aversion to drinking. The fact

that both lithium-injected groups showed a significant decrease in water consumption on Day 14 is most reasonably explained by noting that the consumption on Day 14 represents water consumption during a period when the animals were under the direct influence of the lithium toxicosis. Observations of animals under the influence of lithium (Nachman, 1963; Radomski, Fuyat, Nelson & Smith, 1950; personal observations) indicate that these animals are particularly lethargic and do not drink or engage in other activities. However, whatever the source of this difference between the two lithium-injected groups and the two sodium-injected groups, the difference has completely disappeared by Day 15—the second day following the injection. Therefore, when these animals are used in experiments designed to measure the learned effects of lithium toxicosis, it seems reasonable that one should allow a day to elapse between the exposure to LiCl and the subsequent testing to be sure that the animals are not being tested while still under the direct effects of the toxicosis.

These results are essentially similar to those previously obtained with laboratory rats except that several studies (Carroll, Dinc, Levy, & Smith, 1975; Domjan, 1975, 1977; Kutscher & Wright, 1977; Mitchell, Kirschbaum, & Perry, 1975; Mitchell, Scott & Mitchell, 1977; Rozin, 1968; Rzoska, 1953) have indicated that with rats noncontingent toxicosis may lead to an unconditioned "enhanced neophobia" whereas the present study found that the noncontingently poisoned animals of Group 1 (water/Li) did not show an enhanced neophobia when they first encountered sucrose on Day 17. This may indicate a real difference between rats and *Peromyscus,* but it may also simply derive from procedural differences. In the present study, 3 days of water drinking occurred between the noncontingent toxicosis and the exposure to sucrose, and Carroll et al. (1975) specifically noted that "enhanced neophobia was not found when 2 days of water drinking were interposed between LiCl poisoning and saccharin testing" (p. 457).

In summary, the data indicate that (a) adult *P. m. bairdi* are capable of forming a learned aversion to sucrose after a single pairing of sucrose consumption with delayed lithium-induced illness, (b) this aversion is not simply the effect of lithium per se, and (c) this aversion is not a general aversion to drinking. Furthermore, the fact that the sucrose/lithium group formed an aversion to sucrose but the water/lithium group did not form an aversion to water indicates that in the experimental context, the aversion is specific to sucrose. However, the results do not allow a determination of whether the aversion is truly specific to sucrose or is instead a less precise aversion toward novel or sweet flavors in general.

General Discussion

These experiments have shown that TAL does occur in *Peromyscus* and that in them the very basic attributes of the phenomenon are qualitatively similar to those reported for domestic rats. In particular, Experiment 4 has confirmed that a total aversion may be formed following a single flavor/delayed illness pairing and that pseudoconditioning is not involved—thus providing at least a partial answer to Bitterman's (1975) challenge, "Problems of control abound in these aversion experiments, perhaps because they are not always uppermost in the minds of the investigators" (p. 708).

This establishment of TAL in *Peromyscus* opens the way for further investigations. Future studies might profitably be directed to several other aspects of TAL in *Peromyscus,* including the effects of flavor and flavor novelty upon aversion acquisition and extinction; sexual differences in aversion acquisition and extinction; age, subspecies, and strain differences in aversion acquisition; and the effects of deprivation level during testing upon aversion strength. In some of these areas, distinct qualitative as well as quantitative differences between the behavior of *Peromyscus* and that of domestic rats have already been found (Robbins, 1977b).

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