The effect of nonnutritive satiation on the learning of a flavor preference by rats

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On each day of training in Experiment 1, hungry rats were given one flavored saccharin solution followed by a differently flavored saccharin solution. The rats drank more of the first flavor during training, but preferred the second flavor in a subsequent choice test. In Experiment 2, the two flavored saccharin solutions were provided on alternate days, with one flavor being preceded by nothing and the other flavor by plain saccharin. The rats drank more of the flavor preceded by nothing during training, but preferred the other flavor in a subsequent choice test. These results suggest that a state of nonnutritive satiation can reinforce a flavor preference.

Satiation with food is well known to reduce eating and has also been shown to reduce the reinforcing effect of food upon instrumental responses (Capaldi, 1971; Kurtz & Jarka, 1968). The effects of satiation upon the learning of flavor preferences, however, are surprisingly equivocal.

Revusky (1967) has reported effects with flavor preferences similar to effects observed with instrumental responses. He offered rats one type of food when they were hungry and another type of food when they were nearly satiated and found that in a subsequent choice test they preferred the food that had been eaten when they were hungry. In later experiments, Revusky (1968, 1974) also obtained the same results with thirst; that is, rats preferred a solution consumed when they were thirsty to one consumed when they were nearly satiated with water. Revusky interpreted his results in terms of delayed nutritional aftereffects of the substance consumed, aftereffects that became more rewarding as deprivation increased. Thus, food consumed when rats are deprived will be preferred, since such food is associated with greater reinforcement.

LeMagnen (1957), however, has reported exactly the opposite results: his rats preferred a flavored food consumed when they were relatively satiated to one consumed when hungry. Moreover, Capaldi and Myers (1982) have recently replicated, under different conditions, the results of both Revusky and LeMagnen. They conclude that the likelihood of replicating Revusky's finding is increased by mixing the flavors in nutritive solutions, giving the flavored solutions shortly before and after the maintenance

meals during training, and testing the rats when they are hungry. Conversely, the likelihood of replicating LeMagnen's result is increased by mixing the flavors in nonnutritive (saccharin) solutions, separating the flavored solutions from the maintenance meals during training, and testing the rats when they are satiated. The effect of nutritive solutions is consistent with Revusky's theory of postingestive reinforcement, but the occurrence of LeMagnen's results under some conditions suggests the existence of other factors as well.

Further information about these other factors might be gained by investigating other methods of satiation. All the experiments with hungry rats described so far have used nutritive food to control the rats' state of deprivation and satiation, although Capaldi and Myers mixed their flavors with non-nutritive as well as nutritive solutions. There are at least two ways to produce nonnutritive satiation. First, Miller (1955) found that consumption of saccharin reduced subsequent consumption of saccharin, dextrose, milk, lab chow, or fat; he attributed this result to oropharyngeal factors, since tube feeding with saccharin had no effect. Miller (1957) suggested that saccharin consumption reduced hunger. Other possible explanations include glycemic effects of the sort studied by Deutsch (1974) and sensory satiation of the sort invoked to explain spontaneous alternation.

More direct evidence of sensory satiation comes from the second method of nonnutritive satiation. Morrison (1974) and Holman (1973) found that consumption of one arbitrary flavor selectively reduced the subsequent consumption of that flavor compared with another. In his study of the reinforcing effects of this type of satiation, Holman (1980) found that satiation with one flavored solution and not another during training had no effect upon preferences be-

This research was supported by UCLA Academic Senate Research Grant 2386. Reprints can be obtained from Eric W. Holman, Department of Psychology, University of California, Los Angeles, California 90024.

tween flavors associated with these solutions. It is not yet known, however, whether this negative result is characteristic of nonnutritive satiation, sensory satiation, or Holman's specific procedure.

The present experiments were therefore conducted using saccharin to provide alternative tests of non-nutritive satiation. In the first experiment, hungry rats were given one flavored saccharin solution followed by a differently flavored saccharin solution on each day of training. Thus, they were satiated with the first solution when they drank the second.

EXPERIMENT 1

Method

Subjects. The subjects were 12 naive female Sprague-Dawley rats obtained from Simonsen Laboratories, Gilroy, California, and weighing 241-271 g.

Materials. The two solutions used contained .16% sodium saccharin dissolved in water and flavored with 2.0% Crown Colony almond or banana extract. The solutions were presented to the rats in graduated test tubes with drinking spouts, which were attached to the rats' home cages.

Procedure. The rats were housed in individual cages, with constant temperature and illumination, and were handled daily. They were kept hungry, but presumably not thirsty, because Mook and Kenney (1977) had concluded that rats prefer saccharin solutions because of hunger rather than thirst. Two weeks before the experiment, the rats were put on a deprivation schedule for reduction to 85% of their ad-lib weights. Thereafter they were restricted to about 12 g of food daily, to maintain their weights at a constant level. Water was continuously available except when the solutions were presented. To reduce neophobia, the rats were given 20 ml of .16% saccharin solution for 10 min daily for 10 days before the experiment.

The experiment itself consisted of 6 training days followed by a test day. On each training day, half of the rats (Group A) received 40 ml of the banana-flavored solution, then water, and then 40 ml of the almond-flavored solution, each for a period of 10 min. The other half of the rats (Group B) received the same solutions but in the reverse order. To prevent association of food with the flavored solutions, the rats were fed 3 h after training. Two test periods were conducted in line with the training procedure. The rats were offered 40 ml of each solution side by side for 10 min, then water for 10 min, and then 40 ml of each solution again for 10 min.

All statistical tests in this and the next experiment were analyses of variance. The dependent variable was amount consumed; the factors were groups, flavors, and training days or test periods; the rejection criterion was $p < .05$.

Results

Mean daily consumption of plain saccharin during the 10 familiarization days before training was 6.7 ml. Table 1 shows the mean daily consumption of the two flavored solutions by the two groups during training and during the two tests. During training, the rats consumed significantly more of the solution offered in the first 10-min period than of the solution offered in the second 10-min period [$F(1,10) = 9.02$], indicating satiation. During the test, however, the rats consumed significantly more of the solution previously offered in the second 10-min period than

Table 1
Mean Daily Consumption (in Milliliters) During
Training and Tests in Experiment 1

	Solution	Group A	Group B
Training	Almond	9.8	9.5
	Banana	10.3	7.7
Test 1	Almond	9.0	4.2
	Banana	4.2	7.3
Test 2	Almond	7.8	4.5
	Banana	3.0	6.5

Note—During training, Group A received almond after banana and Group B received banana after almond.

of the solution previously offered in the first 10-min period [$F(1,10) = 18.85$]. Neither this preference ($F < 1$) nor total consumption [$F(1,10) = 1.99$] differed between the two test periods. The results therefore show that hungry rats, when given two consecutive saccharin solutions, come to prefer the one consumed while they are satiated with saccharin to the one consumed while not satiated.

EXPERIMENT 2

The fact that in the first experiment the two flavored solutions occurred close together in time introduces the possibility that the results may partly be due to some association between the flavors. Experiment 2 was therefore conducted to eliminate any possible interaction between the two flavored solutions because of their consecutive presentation. The flavors were presented on alternate days preceded in one case by plain saccharin.

Method

Subjects. The subjects were 12 naive female rats weighing 283-343 g; they were of the same strain and stock as in Experiment 1.

Materials. The two flavored solutions were the same as in Experiment 1, and the third solution was plain .16% saccharin.

Procedure. With the exception of the training procedure, the rats were fed, watered, and treated as in Experiment 1. The experiment itself consisted of 12 training days followed by a test day. On odd-numbered days, half of the rats (Group A) received 40 ml of plain saccharin solution for 10 min followed by water for 10 min and then by 40 ml of almond-flavored solution for 10 min; the other half of the rats (Group B) received 40 ml of almond-flavored solution for 10 min preceded by nothing. On even-numbered days, the Group B rats received 40 ml of plain saccharin for 10 min, followed by water for 10 min and then by 40 ml of banana for 10 min; the Group A rats received only 40 ml of banana for 10 min preceded by nothing. Thus, all the rats consistently had one flavored solution after plain saccharin and the other flavored solution after nothing. Two tests were again conducted in line with the training procedure. The two flavored solutions were twice offered side by side for 10 min, separated by 10 min of water presentation.

Results

Mean daily consumption of plain saccharin during familiarization was 7.7 ml. Table 2 shows the mean

Table 2
Mean Daily Consumption (in Milliliters) During
Training and Tests in Experiment 2

	Solution	Group A	Group B
Training	Plain	10.6	8.7
	Almond	9.1	10.4
	Banana	12.1	8.1
Test 1	Almond	12.0	7.8
	Banana	6.8	7.7
Test 2	Almond	6.7	4.3
	Banana	5.7	7.7

Note—During training, Group A received almond after plain saccharin and banana after nothing and Group B received banana after plain saccharin and almond after nothing.

daily consumption of the solutions by the two groups during training and tests. During training, the rats consumed significantly more of the flavored solution preceded by nothing than of the one preceded by plain saccharin [$F(1,10)=28.30$]. As in Experiment 1, the consumption pattern was different during the test, with the rats consuming significantly more of the flavored solution previously consumed after plain saccharin than of the flavored solution previously consumed after nothing [$F(1,10)=12.31$]. This preference did not differ between the two test periods ($F < 1$), although total consumption was significantly greater in the first test period [$F(1,10)=52.09$]. The results of this experiment essentially replicate those obtained in Experiment 1 and show that the results of the previous experiment cannot be attributed to an interaction between the flavors during their consecutive presentations, since in the present experiment the two flavors were presented on alternate days.

GENERAL DISCUSSION

In both of the present experiments, rats preferred a flavor previously consumed when they were satiated with saccharin to a flavor previously consumed when not satiated. As Capaldi and Myers (1982) pointed out, the preferences demonstrated in experiments of this sort are relative, rather than absolute. The data do not distinguish a preference for the flavor consumed when the rats are satiated from an aversion for the flavor consumed when not satiated. Consistent with previous findings, however, the rats in the present experiments increased their consumption of saccharin during the familiarization trials before training, which indicates that any aversion caused by drinking saccharin when hungry was weaker than the neophobia caused by not drinking any saccharin.

In any case, the present experiments show that the results of Capaldi and Myers (1982) and of LeMagnen (1957) can be obtained with nonnutritive as well as with nutritive satiation. On the other hand,

the present findings stand in contrast to the negative results obtained by Holman (1980) with a different method of nonnutritive satiation. Although this difference could be attributed to special properties of saccharin or to procedural differences between the experiments, a more interesting explanation is also possible. Saccharin consumption may reduce hunger, as Miller (1957) suggested, while satiation with one arbitrary flavor rather than another, as in the procedure of Holman (1980), has no differential effect on hunger. Thus, rats may associate flavors with their own state of hunger at the time the flavors are consumed, as well as with subsequent changes in the state of hunger, as suggested by Revusky (1967). To the extent that low levels of hunger are more pleasant than high levels of hunger, rats would learn to prefer a flavor consumed while they were satiated with either food or saccharin to a flavor consumed while they were not satiated.

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